Fruit and Vegetable Processing

Level II

Based on June 2021 Version 3 Occupational standards (OS)



Module Title: - Operating a Drying Process

LG Code: IND FVP2 M06 LO (1-3) LG (41-43)

TTLM Code: IND FVP2 TTLM 1223v1

December, 2023

Addis Ababa, Ethiopia

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Introduction to the Module

This module covers the knowledge, skills and attitude required to prepare the drying process for operation, operate and monitor the drying process and shut down the drying process.

LG #1	LO #1- Prepare the Drying Process for Operation

Instruction sheet
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Confirming available materials • Confirming services • Checking equipment performance • Setting drying methods for fruit and vegetables This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Confirm available materials • Confirm services • Check equipment performance • Set drying methods for fruit and vegetables
Learning Instructions:
1. Read the specific objectives of this Learning Guide. 2. Follow the instructions described below. 3. Read the information written in the information Sheets 4. Accomplish the Self-checks 5. Perform Operation Sheets 6. Do the “LAP test”

Information sheet 1

1.1 Confirming available materials to meet receipt requirements

1.1.1 Introduction

The drying process is the removal of water or other liquids from gases, liquids, or solids. Most commonly, the term “drying” refers to the removal of water or other volatile substances from additives by thermal methods. The aim of drying is to reduce the volume and the weight to facilitate transportation, to sterilize the products, and to produce materials that provide the desired conditions. In terms of energy saving, the major percentage of energy consumption in many industries is formed by the energy consumed for drying processes. With the usage of new technologies it is possible to save a considerable amount of energy. The main factor to be taken into consideration when selecting a drying process and a dryer is to use minimum energy and a maximum drying rate to obtain the product with the desired qualities Microwave drying is an alternative drying method that provides advantages such as high heat conduction to the inner parts of the dried material, cleaning, energy gain, easy. Air drying following osmotic dipping is commonly used in tropical countries for the production of so-called "semi-candied" dried fruits.

Drying is a crucial unit operation in various industries, including food processing, pharmaceutical manufacturing, and chemical production. It involves removing moisture or solvents from materials to achieve the desired moisture content. The specific drying method and parameters employed depend on the material being dried, the desired moisture content, and the operational constraints.

Drying is an excellent way to preserve fruits and vegetables, extending their shelf life and concentrating their flavor. However, it is important to prepare the fruits and vegetables properly before drying to ensure a safe and successful outcome.

Selecting fruits and vegetables for drying

- Choose fruits and vegetables that are ripe, firm, and free from blemishes or bruises.
- Avoid overripe or underripe fruits, as they will not dry properly.

Washing fruits and vegetables

- Wash all fruits and vegetables thoroughly under running water to remove any dirt, debris, or pesticides.
- Use a clean vegetable brush to scrub away any stubborn dirt.

Peeling and cutting fruits and vegetables

- Peel fruits and vegetables that have thick skins, such as apples, potatoes, and carrots.
- Cut fruits and vegetables into uniform pieces to ensure even drying.
- The size of the pieces will depend on the drying method used.

Pre-treating fruits and vegetables

Pre-treating fruits and vegetables helps to prevent browning, preserve color, and enhance flavor. Some common pre-treating methods include:

- Blanching: Blanching involves briefly immersing fruits and vegetables in boiling water and then immediately plunging them into ice water.
- Dipping in a citric acid solution: Citric acid solution helps to prevent browning in fruits and vegetables. To make a citric acid solution, combine 1 tablespoon of citric acid with 1 quart of water.
- Soaking in a sugar solution: Sugar solution helps to preserve the color and flavor of fruits. To make a sugar solution, combine 1 cup of sugar with 1 quart of water.

Drying methods

There are several different methods for drying fruits and vegetables. The most common methods are:

- Sun drying: Sun drying is the simplest and most traditional method of drying. However, it can be slow and is not always reliable, as it is dependent on the weather.
- Oven drying: Oven drying is a faster and more reliable method than sun drying. However, it is important to use a low oven temperature to prevent the fruits and vegetables from burning.
- Food dehydrator drying: Food dehydrators are designed specifically for drying fruits and vegetables. They provide even heat and airflow, resulting in consistent drying results.

Drying process operation

Once the fruits and vegetables have been prepared, they can be placed on drying trays and placed in the dryer. The drying time will vary depending on the type of fruit or vegetable, the size of the pieces, and the drying method used.

- Check the fruits and vegetables periodically during the drying process to ensure that they are drying evenly.
- The fruits and vegetables are dried when they are firm and pliable, with no moisture remaining.
- Once the fruits and vegetables are dry, they should be stored in an airtight container in a cool, dark place.

Fruit and vegetable drying additives and agents

Chemical food preservatives are those substances which are added in very low quantities (up to 0.2%) and which do not alter the organoleptic and physico-chemical properties of the foods at or only very little. Preservation of food products containing chemical food preservatives is usually based on the combined or synergistic activity of several additives, intrinsic product parameters (e.g. composition, acidity, water activity) and extrinsic factors (e.g. processing temperature, storage atmosphere and temperature)

This approach minimizes undesirable changes in product properties and reduces concentration of additives and extent of processing treatments. The concept of combinations of preservatives and treatments to preserve foods is frequently called the hurdle or barrier concept. Combinations of additives and preservatives systems provide unlimited preservation alternatives for applications in food products to meet consumer demands for healthy and safe foods.

Chemical food preservatives are applied to foods as direct additives during processing, or develop by themselves during processes such as fermentation. Certain preservatives have been used either accidentally or intentionally for centuries, and include sodium chloride (common salt), sugar, acids, alcohols and components of smoke. In addition to preservation, these compounds contribute to the quality and identity of the products, and are applied through processing procedures such as salting, curing, fermentation and smoking.

Traditional chemical food preservatives and their use in fruit and vegetable processing technologies could be summarized as follows:

- Common salt: brined vegetables;
- Sugars (sucrose, glucose, fructose and syrups):
- Foods preserved by high sugar concentrations: jellies, preserves, syrups, juice concentrates;
- Interaction of sugar with other ingredients or processes such as drying and heating;
- Indirect food preservation by sugar in products where fermentation is important (naturally acidified pickles and sauerkraut

Lactic acid: This acid is the main product of many food fermentations; it is formed by microbial degradation of sugars in products such as sauerkraut and pickles. The acid produced in such fermentations decreases the pH to levels unfavorable for growth of spoilage organisms such as putrefactive anaerobes and butyric-acid-producing bacteria. Yeasts and moulds that can grow at such pH levels can be controlled by the inclusion of other preservatives such as sorbet and benzoate.

Acetic acid: Acetic acid is a general preservative inhibiting many species of bacteria, yeasts and to a lesser extent moulds. It is also a product of the lactic-acid fermentation, and its preservative action even at identical pH levels is greater than that of lactic acid. The main applications of vinegar (acetic acid) includes products such as pickles, sauces and ketchup.

Benzoic acid: in the form of its sodium salt, constitutes one of the most common chemical food preservative. Sodium benzoate is a common preservative in acid or acidified foods such as fruit juices, syrups, jams and jellies, sauerkraut, pickles, preserves, fruit cocktails, etc. Yeasts are inhibited by benzoate to a greater extent than are moulds and bacteria.

Other acidulates:

- Citric acid: fruit juices; jams; other sugar preserves;
- Acetic acid: vegetable pickles; other vegetable products;
- Sodium benzoate: vegetable pickles; preserves; jams; jellies; semi-processed products;

- Sodium propionate: fruits; vegetables;
- Potassium sorbate: fruits; vegetables; pickled products; jams, jellies;
- Methyl paraben: fruit products; pickles; preserves;
- Sulphur dioxide: fruit juices; dried / dehydrated fruits and vegetables; semi-processed products.
- **Malic and tartaric** (tartric) acids is used in some countries mainly to acidify and preserve fruit sugar preserves, jams, jellies, etc.
- **Citric acid** is the main acid found naturally in citrus fruits; it is widely used (in carbonated beverages) and as an acidifying agent of foods because of its unique flavour properties. It has an unlimited acceptable daily intake and is highly soluble in water. It is a less effective antimicrobial agent than other acids.

Table 1.1: Fruit and vegetable to be dried

Fruits	**Preparation for Drying**
Apples	Pare, core and cut into ⅛-inch slices or rings. Pretreat dipping for 2 minutes.
Bananas	Peel, cut into ¼-inch slices. Dip in ½ cup pineapple juice mixed with ¼ cup honey.
Berries	Leave whole, except slice strawberries in half.
Cherries (any kind)	Remove stems and pits. If juicy, drain 1 hour.
Grapes	Leave whole, remove stems. Dip in boiling water to crack skins.
Peaches and apricots	Peel if desired, remove pits, slice. Pretreat dipping solution.
Pears	Pare and remove core and woody tissue. Cut into ¼-inch slices or rings, or into quarters or eighths. Pretreat dipping solution.
Pineapple	Peel, core and slice ½-inch thick.
Plums	Same as prunes. Use freestone varieties. Pretreat.
Prunes	Cut in halves and remove pits or leave whole. *Halves*: No

	pretreatment. *Whole*: To soften and crack skins and to help fruit dry better, hold in steam or boiling water for 2 minutes.
Beans, green and lima	Shell. Steam 15–20 minutes, or until tender but firm.
Beans, snap	Trim and slice lengthwise (or cut in 1-inch pieces). Steam about 3–5 minutes, or until tender but firm. Spread about ½-inch deep on trays.
Beets	Trim off all but 1 inch of tops and roots. Steam whole about 30–60 minutes, depending on size, or until cooked through. Cool and peel. Cut in ¼-inch cubes, or slice ⅛-inch thick. Spread not more than ¼-inch deep on trays.
Broccoli	Trim, slice lengthwise in ½-inch strips. Steam 10 minutes or until tender but firm.
Cabbage	Trim, cut into ⅛-inch thick strips. Steam 5–10 minutes, or until tender but firm. Spread evenly to a depth of not more than 1 inch. Pretreat with lemon juice.
Carrots	Scrape or peel. Slice crosswise ⅛-inch thick, or dice in ¼-inch cubes. Steam small pieces 3 minutes (or shred before steaming). Spread in thin layer on trays.
Celery	Remove leaves, cut stalks into ½-inch pieces. Water blanch 1 to 2 minutes or until tender. Stir occasionally during drying.
Corn	Husk and trim. Blanch whole ears 9 minutes. For medium or raw kernels, blanch 3–5 minutes. Cut corn from cob after blanching.
Eggplant	Peel and slice ⅛- to ¼-inch thick. Dip in lemon juice solution for 5 minutes or steam 5 minutes (or until tender).
Greens	Trim off tough stems. Steam 5 minutes or until tender. Spread leaves that mat, such as spinach, about ¼-inch deep.
Mushrooms	Peel the larger mushrooms. Dry whole or slice, depending on size. No precooking necessary. If stems are tender, slice for drying; if tough, discard. Spread on trays.
Onions	Peel, slice into ⅛-inch rings. Blanch 1 minute. If dried for seasoning, do not steam.
Peas, green	Steam shelled peas 3 minutes or until tender. Stir during drying.

Peppers (all kinds) and pimentos	Cut into ½-inch strips or rings. Remove seeds. Steam 10 minutes. Spread rings 2 layers deep; spread strips not more than ½-inch deep.
Pumpkin and winter squash	Quarter, remove seeds and pit, cut in 1-inch strips and peel. Slice strips crosswise ¼-inch thick. Bake at 300°F until soft. Place in dehydrator.
Soybeans, edible green	Blanch pods in steam 10–15 minutes, or until beans are tender but firm. Shell.
Squash, summer and zucchini	Trim, slice ¼-inch thick without peeling and steam 6 minutes or until just tender. Pretreat optional.

1.1.2. Confirming services and ready for operation

i. Water

Potable water is essential in all fruit and vegetable processing, as an ingredient in some products and for washing down equipment. An adequate supply of potable water should be available from taps in the processing room. If there is no mains supply, or if the mains supply is unreliable or contaminated, water from boreholes is likely to be relatively free from microorganisms, but it may be contaminated with sand. River water is likely to be contaminated and should only be used if no other source is available

If necessary, water should be treated to remove micro-organisms. There are four ways of treating water at a small scale: by filtration; by heating; by ultra-violet light and by chemical sterilants, such as hypochlorite (also known as 'chlorine solution' or 'bleach'). Domestic water filters are too slow for the large amounts of water required and other water treatment methods are likely to be too expensive for small-scale producers

ii. Steam

Steam also comes into contact with fruits and vegetables in some processing operations. These include some lye-peeling systems, steam-heated exhaust boxes, steam-flow closers, steam blanchers, and water blanchers which are heated by direct injection of steam. Quality control staff should determine that either the steam that comes into contact with the product is not contaminated

by boiler additives or that the additives are not harmful, or both. Quality control staff should also ensure that condensate and the products of corrosion that may accumulate in the pipework of the steam distribution system during shut-downs are removed by purging the system before food processing operations start. It is also important to determine that steam traps and strainers are maintained in good condition to help ensure that clean steam is delivered to processing points. Containers, labels and packaging materials

1.1.3. Check equipment performance

The apparatus for drying must operate continuously so as to provide sufficient capacity to handle daily, large quantities of the fruits or vegetables to be dried. Furthermore the drying operation must be so efficient in its removal of moisture from the fruits and vegetables as to prevent future decay or freezing in the packaging or storing of such foodstuffs.

Fruits and vegetables, such drying function being accomplished by the absorbent characteristic of the conveyer material in its contact with the fruits and vegetables that is supported and conveyed thereby. The drying process is the removal of water or other liquids from gases, liquids, or solids. Most commonly, the term “drying” refers to the removal of water or other volatile substances from additives by thermal methods. The aim of drying is to reduce the volume and the weight to facilitate transportation, to sterilize the products, and to produce materials that provide the desired conditions. In terms of energy saving, the major percentage of energy consumption in many industries is formed by the energy consumed for drying processes. With the usage of new technologies it is possible to save a considerable amount of energy. The main factor to be taken into consideration when selecting a drying process and a dryer is to use minimum energy and a maximum drying rate to obtain the product with the desired qualities [Microwaves are electromagnetic waves in the frequency range of 300 MHz to 300 GHz . The heating effect of the microwave can be explained as the ingestion of energy by a dielectric material and then an increase in the temperature as the result of the absorption of this material. There are two important mechanisms Ionic polarization and dipole rotation that explain the heat consumption in the microwave field. Microwave drying is an alternative drying method that provides advantages such

as high heat conduction to the inner parts of the dried material, cleaning, energy gain, easy. Process control and quick start and termination of the drying process.

The main cause of spray drying is to increase the shelf life and easy handling of juices. In the present paper, the studies carried out so far on spray drying of various fruits and vegetables are reported. The major fruit juices dried are mango, banana, orange, guava, bayberry, watermelon, pineapple, etc. However, study on vegetable juices is limited. In spray drying, the major optimized parameters are inlet air temperature, relative humidity of air, outlet air temperature, and atomizer speed that are given for a particular study. The juices in spray drying require addition of drying agents that include matlodextrin, liquid glucose, etc. The drying agents are added to increase the glass transition temperature.

1.1.4. Setting drying methods for fruit and vegetables

Drying is the oldest method of preserving food. Throughout history, the sun, the wind and a smoky fire were used to remove water from fruits, meats, grains and herbs. By definition, food dehydration is the process of removing water from food by circulating hot air through it, which prohibits the growth of enzymes and bacteria. Dried foods are tasty, nutritious, lightweight, easy to prepare and easy to store and use. The energy input is less than what is needed to freeze or can, and the storage space is minimal compared with that needed for canning jars and freezer containers.

Drying methods

Basically, drying can be done by two processes. natural drying and mechanical dehydration or artificial drying based on source of energy. Natural drying takes place under the influence of sunlight and wind and is of three types'. sun, solar and shade drying. In natural drying there is no control over temperature, air flow and humidity whereas in artificial drying, these conditions are well controlled.

i. **Solar drying** utilizes a collector, which traps heat and makes it possible to dry foods in any climate. The collector is a specially designed covered box that increases the drying temperature and maximizes air circulation. You can find online articles on solar food drying, including plans for building solar dryers at builditsolar.com.



Figure 1.1. Solar dryer

ii. **Oven drying** uses a conventional gas or electric oven. It is a good choice if you want to do occasional drying or are drying for the first time. Caution: the oven-drying method is not safe in a home with small children.



Figure 1.2. Oven dryer

iii. **An electric food-dehydrator** can consistently produce a quality product and is easier than other methods. You can purchase a basic model for as little as $50, which is a good choice for first-time users or those who want to dry foods occasionally or in small amounts.

iv. **Freezer Method** - Seal the food in freezer-type plastic bags. Place the bags in a freezer set at 0°F or below and leave them at least 48 hours. Freeze-drying process is carried out in a closed low temperature environment, completely separated from air dust bacteria and other pollution materials. There are almost no changes from raw materials to dried materials. The obvious advantages are:



Figure 1.3. Freezer dryer

v. Atomization

Atomization is the most important stage in spray-drying process, which converts the fluid feed into tiny droplets/particles. Due to the subsequent reduction in particle size and dispersion of the particles in the drying gas, the surface area of the particles increases exponentially. This increment in surface area of the particles helps to dry the feed in seconds.



Figure 1.4. Automatic drying solution for fruit and vegetable

(https://www.youtube.com/watch?v=IuF5P1WLURk, Accessed date: December 01, 20123)

With the small size of droplets and the even distribution of the fluid feed, the moisture removal occurs without disturbing the integrity of the material. The atomization is achieved by atomizers which are generally classified as rotary atomizers, pressure nozzles, pneumatic nozzles and sonic nozzles. Atomizers are selected based upon the feed which needs to be dried and targeted final properties of the dried product as well as the particle size.

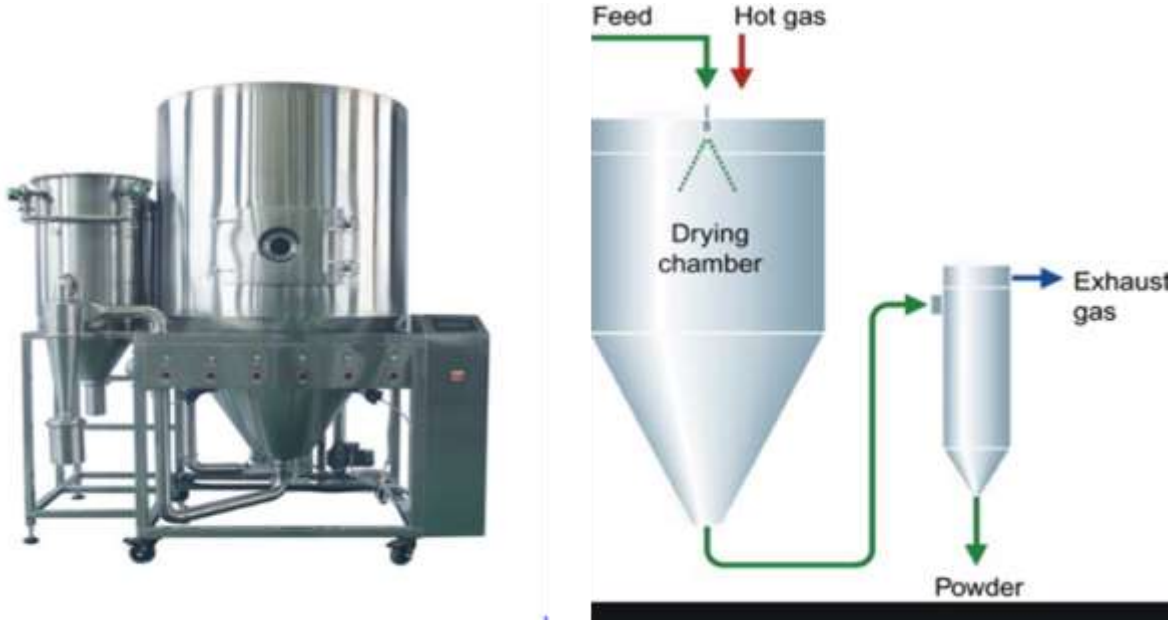


Figure 1.5. Atomization dryer

vi. Hot air drying

Atmospheric air is generally used as a drying medium in spray-drying process. During the spray-drying process, the atmospheric air is filtered through a filtering system and subsequently preheated according to the operating parameters. Sometimes, nitrogen or other inert gases are also used based upon the feed being dried and its instability, or sensitivity to oxygen .The drying of feed droplets after they come in contact with drying medium in a spray-drying process is a result of simultaneous heat and mass transfer. The heat from the drying medium is transferred to droplets by convection and then converted to latent heat during the evaporation of the droplet's moisture content. The rate of heat and mass transfer depends upon the droplet diameter and the relative velocity of the air and droplets. The initial drying period starts in spray-drying once the droplet comes in contact with the drying medium. This is followed by the falling rate period where the rate of drying begins to decrease, and the period ends once the droplets reach their critical moisture content.

Self-check 1	Written test

Name: _____ ID: _____ Date:_____

Directions: Answer all the questions listed below.

Test I: Short Answer questions

1 What is the difference between sun drying and oven drying?

2 What are the benefits of using a food dehydrator for drying fruits and vegetables?

3 How does blanching help to preserve fruits and vegetables?

4 What is the role of sugar in fruit and vegetable preservation?

5 What are some of the safety considerations when drying fruits and vegetables?

6 Write the fruit and vegetable drying additives and agents

7 List out fruit and vegetable to be dried

8 What are uses of steam in fruit and vegetable processing plant?

9 List out all services used for fruit and vegetable drying processing

10 What is the main performance of drying equipment?

11 The main factor to be taken into consideration when selecting a drying process and a dryer……?

12 What is atomization drying equipment operation?

13 The main dryer types for fruit and vegetable processing?

Test II: Choose the best answer for the following questions

1. Which of the following is the main goal of drying fruits and vegetables?
   A. To extend their shelf life
   B. To sterilize them
   C. To remove their flavor
   D. To make them easier to transport

2. What is the most common method for drying fruits and vegetables in tropical countries?
   A. Sun drying
   B. Oven drying

C. Food dehydrator drying
D. Microwave drying

3. Which of the following is a common pre-treating method for fruits and vegetables?
   A. Blanching
   B. Dipping in a citric acid solution
   C. Soaking in a sugar solution
   D. All of the above
4. What is the main factor to consider when selecting a drying process and a dryer?
   A. The type of fruit or vegetable
   B. The desired moisture content
   C. The operational constraints
   D. All of the above
5. Which of the following is a common chemical food preservative used in fruit and vegetable processing?
   A. Sodium chloride (common salt)
   B. Sugar
   C. Lactic acid
   D. All of the above
6. Which of the following is a natural drying method?
   A. Sun drying
   B. Oven drying
   C. Food dehydrator drying
   D. Freeze-drying
7. Which of the following is the fastest method of drying food?
   A. Sun drying
   B. Oven drying
   C. Food dehydrator drying
   D. Freeze-drying
8. Which of the following is the most energy-efficient method of drying food?
   A. Sun drying

B. Oven drying

C. Food dehydrator drying

D. Freeze-drying

9. Which of the following is a common application for spray drying?

A. Drying milk

B. Drying coffee

C. Drying pharmaceuticals

D. All of the above

10. What is the main advantage of atomization in spray drying?

A. It increases the surface area of the particles, which helps to dry the feed in seconds.

B. It prevents the feed from sticking to the walls of the drying chamber.

C. It helps to control the size of the dried particles.

D. All of the above

LG #2	LO #2- Operate and Monitor the Drying Process

Instruction sheet

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Starting up the drying process
- Monitoring control points
- Maintaining performance
- Drying product
- Monitoring drying equipment
- Identifying and reporting out-of-specification product and process equipment
- Monitoring and clearing waste

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Start up the drying process
- Monitor control points and drying equipment
- Maintain performance within specification
- Dry product
- Identify and report out-of-specification.
- Monitor and clear waste.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

Information sheet 2

2.1. Starting up the drying process

The drying process for fruits and vegetables involves several crucial steps to ensure a safe and effective outcome. Starting up the drying process correctly is essential to achieve the desired results. Here's a detailed guide to starting up the drying process for fruits and vegetables:

2.1.1. Preparation

i. **Selection**: Choose ripe, firm fruits and vegetables free from blemishes or bruises. Avoid overripe or underripe produce, as they may not dry properly.

ii. **Washing**: Wash all fruits and vegetables thoroughly under running water to remove dirt, debris, and pesticides. Use a clean vegetable brush to scrub away stubborn dirt.

iii. **Peeling and cutting**: Peel fruits and vegetables that have thick skins, such as apples, potatoes, and carrots. Cut fruits and vegetables into uniform pieces to ensure even drying.

iv. **Pre-treating (Optional):** Pre-treating fruits and vegetables helps to prevent browning, preserve color, and enhance flavor. Some common pre-treating methods include:

- Blanching: Briefly immerse fruits and vegetables in boiling water and then immediately plunge them into ice water.
- Dipping in a citric acid solution: Citric acid solution helps to prevent browning in fruits and vegetables. To make a citric acid solution, combine 1 tablespoon of citric acid with 1 quart of water.
- Soaking in a sugar solution: Sugar solution helps to preserve the color and flavor of fruits. To make a sugar solution, combine 1 cup of sugar with 1 quart of water.

2.1.2. Drying method selection

Choose the most suitable drying method based on the type of fruit or vegetable, the desired drying time, and available equipment. Common drying methods include:

- **Sun drying:** The simplest and most traditional method but can be slow and weather-dependent.
- **Oven drying:** Faster and more reliable than sun drying, but requires careful temperature control to prevent over drying.
- **Dehydrator drying:** Ideal for consistent and even drying, providing optimal control over temperature, airflow, and humidity.

2.1.3. Equipment preparation

Ensure the drying equipment is clean, sanitized, and in good working condition. Familiarize yourself with the equipment's controls and settings.

Initial drying:

- Arrange fruits and vegetables: Place prepared fruits and vegetables in a single layer on drying trays, ensuring adequate spacing between pieces to allow for airflow.
- Set drying temperature: Follow the recommended drying temperature for the specific fruit or vegetable. Start at a lower temperature and gradually increase if necessary.
- Initiate drying: Start the drying process according to the equipment's instructions. Monitor the drying progress periodically.

2.2. Monitoring and confirming control points for fruit and vegetable drying

Monitoring and confirming control points during the drying process are crucial for ensuring the safety and quality of the dried product. Control points are specific parameters that must be maintained within acceptable ranges to achieve the desired drying results.

2.2.1. Key control points for drying process

i. **Temperature**: Maintain the drying temperature within the recommended range to prevent overdrying or underdrying. Use a thermometer to monitor and adjust the temperature as needed.

ii. **Airflow**: Ensure adequate airflow around the drying trays to promote even drying and prevent moisture buildup. Check for blockages in the airflow system.

iii. **Moisture content:** Monitor the moisture content of the drying fruits and vegetables to determine when the drying process is complete. Use a moisture meter or test the texture of the product.

iv. **Appearance:** Observe the appearance of the drying fruits and vegetables. They should be evenly dried, with no signs of discoloration or spoilage.

Monitoring Frequency:

Monitor the control points regularly, especially during the initial stages of drying. The frequency of monitoring may decrease as the drying process progresses.

Recordkeeping:

Maintain records of the drying process, including temperature, airflow, moisture content, and appearance observations. This documentation can be helpful for future reference and troubleshooting.

Corrective Actions:

If any control points deviate from the acceptable ranges, take corrective actions promptly. Adjust the drying temperature, airflow, or drying time as needed to maintain optimal drying conditions.

2.2.2. Equipment needed for drying

To be certain of the final quality and consistent drying of foods, a dehydrator is recommended, especially with unpredictable Ohio weather. Sharp knives and a food processor or blender will also make the drying task easier.

Many guidelines call for blanching, steaming or pretreating foods. Equipment for these processes includes a deep kettle with a lid and a wire basket, a colander, or an open mesh cloth bag to hold produce. A nonmetal bowl is best for pretreating fruits and vegetables to prevent discoloring



Figure 2.1. Industrial freezer dryer.

2.2.3. Choice of drying materials

The materials used for the construction of the drier are easily maintained and repaired, and can be obtained locally at cheaper costs. The physical and chemical properties of the materials are strong enough to withstand heat, vibration, humid air, fatigue and stress without failure during operation. These include

Plywood: This was chosen for the body of the cabinet because it is a poor conductor of heat. Hence, heat loss from the cabinet will be greatly minimized.

Sheet metal (Aluminum): It was chosen because of its high resistance to corrosion. The inside of the cabinet is lined with the sheet in order to reflect heat back to the cabinet and also prevent decaying of the wood due to humid air.

Galvanized Sheet Metal: This was chosen because of its toughness and ability to conduct and radiate heat. It was used for fabricating the heat exchanger.

Mild Steel: It has great strength and can be easily welded. It was used for the frame. e) **Wire Mesh**: It was used for building the trays. This is due to its ability to resist corrosion and allow air to pass through it.

Burnt Bricks: This was chosen because it is a poor conductor of heat. It was used to build the wall of the heating unit



Figure 2.2. Industrial fruit dryer

2.2. Monitoring control points

2.2.1. Definitions

Monitoring is the process that the operator relies upon to maintain control at a Critical Control Points (CCP). Accurate monitoring indicates when there is a loss of control at a CCP and a deviation from a critical limit. When a critical limit is compromised, a corrective action is needed. The extent of the problem needing correction can be determined by reviewing the monitoring records and finding the last recorded value that meets the critical limit. Monitoring also provides a record that products were produced in compliance with the "Hazard Analysis Critical Control Point (HACCP) plan.

2.2.2. What will be monitored?

Monitoring may mean measuring a characteristic of the product or of the process to determine compliance with a critical limit. Monitoring may also involve observing if a control measure at a CCP is being performed.

- Measurement of cold-storage compartment temperature when critical for temperature-sensitive ingredients.
- Measurement of the pH of an acidifying ingredient when critical for the production of an acidified food.
- Measurement of line speed when critical to adequate cooking or chilling processes

2.2.3. How Critical limits and control measures will be monitored

Monitoring must be designed to provide rapid (real-time) results. There is no time for lengthy analytical testing because critical limit failures must be detected quickly and an appropriate corrective action instituted before distribution.

Physical and chemical measurements are preferred monitoring methods because testing can be done rapidly. Physical and chemical measurements (e.g., pH, time, temperature) can often be related to the microbiological control as illustrated by the fried-fish example in Principle 3. Examples of physical- and chemical-measurement monitoring at a CCP follow:

Objectives and principles of HACCP

HACCP is meant to assure the production and distribution of safe food by identifying and controlling process steps that are critical in elimination of food safety hazards or reducing the effect of these hazards to safe levels. HACCP applies a systematic approach in the identification, evaluation and determination of appropriate control measure in food manufacturing (NACMCF,

1998). Codex prescribes seven (7) principles in the implementation of HACCP. Thus unlike standards that promulgate requirements, HACCP is based on principles and therefore not prescriptive in its application and implementation. The seven principles are:

- Hazard analysis
- Identification of Critical Control Points (CCP)
- Establishment of critical limits
- Establishment of a monitoring procedure
- Establishment of corrective actions
- Establish a verification procedure
- Establish a record keeping and documentation system

Factors that influence drying

The efficiency and effectiveness of fruit drying is influenced or affected by three basic factors. They are:

- Temperature of the drying air
- Velocity of the drying air
- Thickness of fruit slices

The first two factors are dependent on the air and structural design and engineering of the dryer whilst the last has to do with the product.

i. Effect of temperature

The ideal temperature for fruit drying is between 50oC to 55^{0}C. It is further recommended that drying temperature for fruits should not exceed 60oC for two main reasons; loss of nutrients and case hardening. According to the author, most nutrients within fruits are destroyed at temperatures above 60 ^{0}C. It is therefore recommended that in order to preserve the nutrient value of the product, a temperature below 60 ^{0}C is ideal.

ii. Effect of air velocity

A good air current allows replacement of saturated air with unsaturated air on the surface of the product. This allows for continuous evaporation and hence satisfactory drying efficiency. In the absence of air current, an immobile saturated air forms a stagnant boundary layer. In practice therefore, the faster the air current, the better it is to prevent the formation of stagnant boundary layer and hence the better the efficiency of the drying process. An air speed of 0.2 to 0.5m/s is recommended.

iii. Effect of thickness of fruit slices

The thicknesses of the slice of fruits affect the rate of water movement from the core to the surface for evaporation. The thicker the slice, the longer it takes for water diffusion and hence the longer the drying time. It therefore, presumes that thinner fruits are preferred as drying time is the most important factor. However, it is worth noting that the quality of the dried fruits should meet the market expectation. In this regard, too thin slices may result in such unacceptable end products. These may even be blown within the chamber during the drying process

Table 2.1: Quality controlling characteristic of fruit and vegetable

System	Objective	Activities	Applicability
Inspection	Product conformance by screening out conforming products from nonconforming products	Visual checks/ measuring; then testing and reporting the results.	Generally, Production-related activities, such as checking incoming goods, in-process or final product,

			predispatch, etc
Quality control	Product Conformance by Eliminating causes of non-conforming products	Inspection followed by appraisal of results and feedback to the process being controlled	Generally, Production-related activities, such as checking incoming goods, in-process or final product, predispatch, etc
Quality assurance	Generating confidence in product conformance	Comprises all QC activities, plus documented quality systems and quality audits	All functions of the company from design to after-sales service

2.3. Maintaining performance within specification

Maintaining performance within specification is an essential aspect of ensuring the consistent quality and effectiveness of dried fruits and vegetables. By closely monitoring and controlling various factors throughout the drying process, the desired product characteristics can be consistently achieved.

Key Performance Indicators (KPIs) serve as crucial benchmarks for evaluating the performance of the drying process. These KPIs include:

- Moisture Content: Maintaining the moisture content within the specified range is paramount for ensuring proper preservation, extending shelf life, and preventing microbial growth.
- Temperature: Controlling the drying temperature within the recommended range is critical to prevent overdrying or underdrying. Overdrying can lead to nutrient loss and hardening, while underdrying can result in mold growth and spoilage.
- Airflow: Ensuring adequate airflow around the drying trays promotes even drying and prevents moisture buildup. Proper airflow also helps to maintain consistent drying rates.

- Appearance: Monitoring the appearance of the dried fruits and vegetables is essential to ensure they are evenly dried, free from blemishes, and have the desired color and texture.
- Sensory Characteristics: Evaluating the sensory characteristics of the dried products, including taste, aroma, and texture, is crucial to ensure they meet the desired sensory specifications.

To effectively maintain performance within specification, a comprehensive monitoring and control system must be implemented. This system should include:

- Regular monitoring: Regularly monitoring the KPIs during the drying process is key to identifying any deviations from specifications. This allows for timely corrective actions to be taken.
- Temperature control: Use thermometers to monitor and adjust the drying temperature as needed. This ensures that the temperature remains within the recommended range.
- Airflow management: Ensure adequate ventilation and check for blockages in the airflow system. Proper airflow management promotes even drying and prevents moisture buildup.
- Moisture monitoring: Use moisture meters or test samples to monitor moisture content and adjust drying time accordingly. This ensures that the moisture content of the dried products meets the desired specifications.
- Appearance inspection: Visually inspect the drying fruits and vegetables for any signs of uneven drying, discoloration, or spoilage. Regular inspection helps to identify and address potential quality issues early on.
- Sensory evaluation: Conduct sensory evaluations to assess taste, aroma, and texture and make adjustments to the drying process if necessary. Sensory evaluation ensures that the dried products meet the desired sensory specifications.

In addition to monitoring and control, comprehensive documentation and recordkeeping are essential for maintaining performance within specification. This documentation serves as evidence of adherence to specifications and facilitates troubleshooting when issues arise. Records should

include temperature, airflow, moisture content, appearance observations, and sensory evaluation results.

2.4.1 Monitoring the drying process

An overview is given regarding the most recent use of non-destructive techniques during drying used to monitor quality changes in fruits and vegetables. Quality changes were commonly investigated in order to improve the sensory properties (i.e., appearance, texture, flavor and aroma), nutritive values, chemical constituents and mechanical properties of drying products. The application of single-point spectroscopy coupled with drying was discussed by virtue of its potentiality to improve the overall efficiency of the process. With a similar purpose, the implementation of a machine vision (MV) system used to inspect foods during drying was investigated; MV, indeed, can easily monitor physical changes (e.g., color, size, texture and shape) in fruits and vegetables during the drying process.

Hyper spectral imaging spectroscopy is a sophisticated technology since it is able to combine the advantages of spectroscopy and machine vision. As a consequence, its application to drying of fruits and vegetables was reviewed. Finally, attention was focused on the implementation of sensors in an on-line process based on the technologies mentioned above. This is a necessary step in order to turn the conventional dryer into a smart dryer, which is a more sustainable way to produce high quality dried fruits and vegetables

- Operating parameters and air conditions highly influence the dryer performance and the energy required. Increase the air speed and/or temperature highly reduced the energy required and enhance the dryer efficiency. In other words, high reduction in the cost can be achieved.
- The quality of the fruit in terms of variation in moisture content is highly controlled by the dryer system temperature. However, high temperature could damage the fruit which worsens the quality. Therefore, the air temperature plays the main role in controlling the quality of the fruit. Control of the humidity in the dryer improved efficiency of the dryer by only venting the system as much as is required to maintain the conditions within the dryer.

- Controlling the humidity in the dryer reduces the cost of operation. Moreover, improving the efficiency in terms of energy and time reduces the costs of the process.
- Using the new model to simulate the drying system can lead to low energy consumption, high quality of products and low cost of the process. It is highly recommended to simulate the dryer before conducting laboratory experiments and/or commercializing the products.

The new model can be adopted with other dryer systems such as solar or hybrid drying systems. Major quality parameters associated with dried food products are the color, visual appeal, shape of product, flavor, microbial load, retention of nutrients, porosity bulk density, texture, rehydration properties, water activity and chemical stability, preservatives, and freedom from pests, insects and other contaminants, as well as freedom from taints and off-odors.. Therefore, quality of dried food products depends on many factors, such as raw materials, processing environment, packaging, microbial stability, use of additives, and temperature of storage.

2.4.2 Fruit dryer machine working principle

The working principle of heat pump drying machine: utilize refrigerant compression through the compressor to form the high temperature and high pressure gas. The gas went into the condenser to release heat, the heat will be sent into the chamber by the circulating fan, to heat the air in the chamber (The maximum air temperature up to 75 ℃). Then the air temperature rises, the moisture in the drying material will gradually evaporate, and then exhaust of the moisture by the fresh air dehumidification system, to achieve the drying effect.

2.4.3 Fruit dryer machine features:

The dryer machine can be used to dry variety of fruits such as mango, strawberry, pineapple, plum, apricot, apple, banana, etc.

- The drying parameters are easy to control and wide adjustable range, the temperature adjustment range is -20 to 100°C (with auxiliary heating device), and the relative humidity adjustment range is 15% to 80%.
- Easy to operation, the heat recovery efficiency is as high as 60% or more.
- Efficient heat recovery, the heat recovery efficiency is as high as 60% or more.

2.4. Drying product to meet specification

2.4.1. Introduction

Drying is one of the most energy-consuming, being nonlinear in the changes in water content, unit operations in postharvest processing, and it has been used since ancient times. Drying is a complex operation that involves removal of moisture.

During drying, two processes occur simultaneously.

- Transfer of energy, mostly as heat, generally from the surrounding environment and/or an energy source to the wet solid;
- Transfer of mass, as moisture, from inside of the solid to the surface and its subsequent evaporation due to the process described in Point 1.

The aim of food drying is the reduction of the amount of free-water to slow down deteriorative processes, which are principally caused by microbial growth, chemical reaction and/or enzymatic activity.

Fruits and vegetables are particularly susceptible to deteriorative processes, since their initial water content range is from 74–90%, and then, water activity allows microbial growth (>0.60). Drying, then, can positively affect fruits' and vegetables' shelf-life. Furthermore, it can reduce the cost of storage and transport, due to the loss of the original shape and weight. However, despite these advantages, the process may cause damage and severe changes in the physicochemical and organoleptic properties of the products. Indeed, there are changes in flavor, color, shrinkage and with no adequate control, oxidation of fat and degradation of nutritional compounds.

Producing dried fruits and vegetables that meet specifications requires a comprehensive approach that encompasses process control, quality assurance, and continuous improvement. By effectively managing these three critical elements, manufacturers can consistently deliver high-quality products that satisfy customer expectations and regulatory requirements.

Process control for fruits and vegetables drying

Process control involves establishing and maintaining standardized procedures for each stage of the drying process, ensuring consistent and repeatable outcomes. Key aspects of process control for fruits and vegetables drying include:

i. Standardized procedures: Develop and implement documented procedures for each step of the drying process, tailored to the specific characteristics of the fruits and vegetables being dried. These procedures should clearly outline the expected actions, responsibilities, and acceptable ranges for each parameter.

ii. Equipment calibration: Regularly calibrate all equipment used in the drying process, including temperature sensors, airflow meters, and moisture meters. Calibration ensures the accuracy of measurements, preventing deviations from specifications that could affect the quality of the dried products.

iii. Preventive maintenance: Implement a preventive maintenance schedule for drying equipment to minimize downtime, maintain optimal performance, and extend equipment lifespan. Regular maintenance also helps to identify and address potential issues before they escalate and impact product quality.

iv. Training and certification: Provide thorough training to all personnel involved in the drying process for fruits and vegetables. Ensure they understand the standardized procedures, equipment operation, quality control guidelines, and specific considerations for drying fruits and vegetables. Consider implementing certification programs to validate personnel competency.

2.4.2. Quality assurance for fruits and vegetables drying

Quality assurance focuses on evaluating and ensuring that the dried fruits and vegetables meet all specified requirements. This involves implementing rigorous inspection and testing procedures throughout the drying process and upon completion. Key aspects of quality assurance for fruits and vegetables drying include:

i. Incoming material inspection: Inspect incoming fruits and vegetables upon arrival to ensure they meet the specified quality standards for size, ripeness, freedom from defects, absence of contaminants, and suitability for drying. Reject any materials that do not meet the requirements.

ii. In-process monitoring: Continuously monitor the drying process for fruits and vegetables, including temperature, airflow, moisture content, and appearance, to identify potential issues early on. Implement control measures to maintain parameters within the specified ranges for the specific fruits and vegetables being dried.

iii. Random sampling: Conduct random sampling of dried fruits and vegetables throughout the drying process to assess moisture content, appearance, sensory characteristics, microbiological safety, and nutritional content. Analyze results to identify any deviations from specifications and address potential quality issues promptly.

iv. Finished product testing: Perform thorough testing of the finished dried fruits and vegetables to ensure they meet all specifications, including moisture content, appearance, sensory characteristics, microbiological safety, nutritional content, and adherence to labeling requirements. Document test results for traceability.

2.4.3. Fundamentals of food-drying

In the optimization of the drying process, many parameters are considered, in order to reach the following objectives: an increase of foodstuff stability, a reduction of storage and transport costs, energy savings and, of course, a high-quality product. The total cost of a drying process and the quality of the final foodstuff often are competing parameters, especially for low cost processed food. The main aspects in terms of energy and quality for fruits and vegetables are discussed below.

2.4.4. Quality aspect in drying

During drying of fruits and vegetables, many physicochemical changes occur, such as: changes in color due to enzymatic or non-enzymatic browning reactions, changes in texture and shrinkage and

loss and/or degradation of nutritional compounds (e.g., ascorbic acid, carotenoids, phenolic compounds and the like)

2.4.5. Nutritional quality changes

The nutritional quality of fruits and vegetables depends on their chemical composition, which shows a wide range of variation depending on the species, cultivar and maturity stage. Heat processing, moreover, leads to the degradation and/or isomerization of most of the chemical compounds. Due to the complexity of the matrices, some chemical compounds are chosen as markers of nutritional quality. For fruit and vegetables, ascorbic acid, carotenoids, vitamin E and phenolic content are generally used as markers.

2.4.6. Leathers from fresh fruit

Select ripe or slightly overripe fruit. Wash fresh fruit or berries in cool water. Remove peel, seeds and stem. Cut fruit into chunks. Use 2 cups of fruit for each 13-inch by 15-inch fruit leather. Puree fruit until smooth. To prevent darkening, add 2 teaspoons of lemon juice or ⅛ teaspoon ascorbic acid (375 milligrams) for each 2 cups of light-colored fruit.

If you choose to sweeten the leather, add corn syrup, honey or sugar. Corn syrup or honey is best for longer storage because they do not crystallize. Sugar is fine for immediate use or short-time storage. Use ¼ to ½ cup sugar, corn syrup or honey for each 2 cups of fruit. Saccharin-based sweeteners could also be used to reduce tartness without adding calories. Aspartame sweeteners might lose sweetness during drying

Pouring the leather

Fruit leathers can be poured into a single large sheet (13-inch by 15-inch) or into several smaller size pieces. Spread purée evenly, about ⅛-inch thick, onto drying tray. Avoid pouring purée too close to the edge of the cookie sheet. Larger fruit leathers take longer to dry. Approximate drying times are 6 to 8 hours in a dehydrator or up to 18 hours in an oven.

Drying the leather

Dry fruit leathers at 140°F. Leather dries from the outside edge toward the center. Test for dryness by touching center of leather; no indention should be evident. While warm, peel leather from plastic and roll. Then, allow the leather to cool and rewrap the roll in plastic. Chances are, the fruit leather won't last long enough for storage. If it does, it will keep up to 1 month at room temperature.

Test for dryness

Dried fruits are generally done when they reach about 20 percent moisture content. Because fruit will be more pliable when warm, cool several pieces and test by folding the fruit upon itself; it should not stick together. Berries should rattle when stored in a container. When drying is complete, cool the fruit before storing, but don't leave out to gather additional moisture from the air. The product is then ready to be conditioned.

Dried vegetables should be crisp when dried and should "snap" when broken in two. At this stage of moisture, no conditioning is needed.



Figure 2.3. Moisture analyzer meter

Procedure: - **moisture analyzer meter**

i. Set test parameters in accordance with instruction below and the displayed prompts.
ii. Enter adjustment menu and start procedure.
iii. Enter: - testing temperature - permissible error - serial number of the temperature adjustment set
iv. Upon confirmation of serial number start message is displayed. Press key to confirm. The drying process starts and continues until specified temperature is reached. Time and sensor temperature information is displayed
v. The temperature is maintained for 8 minutes (like for temperature adjustment procedure). After 8 minutes you shall see a window for entering temperature read from the installed adjustment set. Press to confirm.

Determination of moisture content.

Principle Heating and drying of a test portion of dried fruit at a temperature of 70 ºC ± 1 ºC under a pressure not exceeding 13 kPa (100 mm Hg).

Apparatus: Usual laboratory equipment and, in particular, the following:

- Electric oven: Capable of being maintained at 70 ºC ± 1 ºC at a pressure of 13 kPa (100 mm/Hg)
- Dish: of corrosion-resistant metal, of diameter about 8.5 cm, with tight-fitting lid.
- Fruit Chopper: made of a material which does not absorb moisture.
- Desiccator: containing an effective desiccant.
- Steam bath
- Sand (fruit powder)
- Analytical Balance: capable of an accuracy of ± 0.01 g.

Preparation of test sample

Take approximately 50 g of dried mango and pass it through the fruit chopper three times, mixing thoroughly after each grinding. Keep it in a completely filled, airtight, closed container to prevent absorption of water.

Procedure: If it is required to check whether the repeatability requirement is met, carry out two determinations in accordance with to under repeatability conditions.

Step 1: Preparation of dish and lid .Add about 2 g of the sand to the dish and dry, with the lid, for 2 h in the oven set at 70 ºC. Leave to cool to room temperature in the desiccator and weigh to the nearest 0.01 g. Repeat the same drying procedure until a constant weight is achieved.

Step 2. Test portion. Weigh, to the nearest 0.02 g, about 5 g of the test sample and spread this test portion as evenly as possible over the bottom of the dish containing the sand.

Step 3: Determination. Moisten the portion and the sand thoroughly with a few milliliters of hot water. Mix the test portion and sand with a spatula. Wash the sample residue on the spatula into the dish with the minimum volume of hot water. Heat the open dish on the steam bath to evaporate the water to dryness. Then put the dish, with the lid alongside, in the oven set at 70 ºC and continue drying for 6 h under a pressure not exceeding 13 kPa (100 mm/Hg). Do not open the oven during this period. During drying, admit to the oven a slow current of air (about 2 bubbles per second) dried by passing through sulphuric acid. The metal dish shall be placed in direct contact with the metal shelf of the oven. After drying, remove the dish, cover it immediately with its lid and place it in the desiccator. After cooling to room temperature, weigh it, still covered, to the nearest 0.02 g.

Step 4: Calculation

The moisture content, expressed as a percentage by mass, of the test portion is equal to

$$\%\ \boldsymbol{moisture\ content} = \frac{(\boldsymbol{m1} - \boldsymbol{m2})}{\boldsymbol{mo} - \boldsymbol{m2}} \boldsymbol{x100}$$

Where:

mo. = the mass, in g, of the dish with its lid and the sand;

m1 = the mass, in g, of the dish with its lid and the sand with the test portion before moistening and oven-drying;

m2 = the mass, in g, of the dish with its lid and the sand with the test portion after oven drying. Give the result to one decimal place

2.5. Monitoring drying equipment

2.5.1. Principles of monitoring drying equipment's

i. **Removal of standing water**. The most efficient way to remove water in a building is to physically vacuum it. This is normally accomplished by using a powerful carpet cleaning machine. If carpet and pad are involved, there are several devices that are available that will utilize the weight of the technician to compress the pad to allow for the maximum removal of water.

ii. **Evaporation through air movement**. After a water loss, drywall, wood framing and subfloors are typically saturated with water. This water can only be removed through evaporation. This is normally accomplished using industrial air movers that move thousands of cubic feet of air per minute. (The Walmart box fan does not begin to be able to accomplish this task.) A 10' x 10' room that has been completely affected by a water loss will normally require 4 industrial air movers to adequately dry the room.

iii. **Dehumidification.** is extraordinarily difficult to evaporate water when the air is already full of water. Dehumidifiers pull moisture out of the air, put it in a liquid state and remove it from your structure.

iv. **Temperature Control**. This is the most complex of the drying principles. All drying equipment works best at specific temperatures. Most dehumidifiers work best between 80 and 90 degrees. Some materials will dry more quickly when the surface temperature is 90 degrees or higher.

2.5.2. Function checking

The particular function for which a piece of equipment is intended largely determines the general type of equipment employed. For example:

- Material handling equipment includes conveyors and tube systems
- Preparation equipment includes sterilizers or wash systems

- Heat processing equipment includes ovens and fryers
- Preservation equipment includes freezers and dehydrators
- Product distribution equipment includes wrapping and palletizing systems

A novel dynamic pressure rise method is developed as a remote sensing procedure for determining at different times during the primary drying stage of the freeze drying process

- The temperature of the moving interface between the dried and frozen layers of the product,
- temperature close to the upper surface of the dried layer of the product,
- The temperature of the bottom surface of the frozen layer of the product, and
- The temperature profile of the frozen layer of the product. Furthermore, by knowing the temperature of the heating plate and determining the value of the temperature of the moving interface from the dynamic pressure rise method, the value of the position of the moving interface could be determined by an expression presented in this work

A systematic approach is developed for investigation of spray drying processes for chemical and biological systems. The approach involves an in-depth study of atomizer performance, spray dryer parametric sensitivity, spray-dried powder properties, thermal inactivation and post-drying properties. The approach helps considerably in rational design of spray drying experiments and in investigation and optimization of various process aspects of spray drying of chemical and biological systems, leading to large savings in labor, cost and time.

Spray drying technique has been widely used for drying heat-sensitive foods, pharmaceuticals, and other substances, because of the solvent rapid evaporation from the droplets, although most often considered a dehydration process, spray drying can also be used as an encapsulation method when it entraps ‘active’ material within a protective matrix, which is essentially inert to the material being encapsulated. Compared to the other conventional microencapsulation techniques, it offers the attractive advantage of producing microcapsules in a relatively simple continuous processing operation.

2.5.3. Identify and report out-of-specification

The term out of specifications, are defined as those results of in process or finished product testing, which falling out of specified limits. The out of specifications (OOS), may arise due to deviations in product manufacturing process, errors in testing procedure, or due to malfunctioning of analytical equipment. When an out of specifications (OOS) has arrived, a root cause analysis has to be performed to investigate the cause for OOS. The reasons for OOS can be classified as assignable and non-assignable.

When the limits are not in specified point called out of specifications. That is temperatures, moisture content, air flow, time/speed and Pressure/vacuum. When OOS has occurred, the analyst should inform to quality control (QC) manager. Each out of specification will be identified with a unique identification number. Quality control professionals typically classify quality defects into three main categories: minor, major and critical. The nature and severity of a defect determines in which of the three categories it belongs.

Minor defects are usually small, insignificant issues that don't affect the function or form of the item. In most cases, the customer wouldn't even notice a minor defect on a product. And the customer wouldn't likely return an item due to a minor defect alone

Major defects are more serious than minor defects. A product with a major defect departs significantly from the buyer's product specifications. Major defects are those which could adversely affect the function, performance or appearance of a product.

Critical defects are the most serious of the three defect types. Critical defects render an item completely unusable and/or could cause harm to the user or someone in the vicinity of the product. Tell your inspector if they've classified a defect in a different category than you consider appropriate.

2.6. Monitoring and clearing waste

2.6.1. Introduction

The fruit and vegetable industry typically generates large volumes of effluents and solid waste. The effluents contain high organic loads, cleansing and blanching agents, salt, and suspended solids such as fibers and soil particles. They may also contain pesticide residues washed from the raw materials. The main solid wastes are organic materials, including discarded fruits and vegetables. Odor problems can occur with poor management of solid wastes and effluents; when onions are processed; and when ready-to-serve meals are prepared.

2.6.2. Washing and sanitizing drying trays and equipment

Used to prevent food borne illness by ensuring that all trays used for drying are properly cleaned and sanitized.

Scope: This procedure applies to employees involved in production, packaging, as well as those responsible for cleaning, washing and sanitizing drying trays and equipment.

Instructions:

- Train production, packaging and other employees on using the procedures in this SOP.
- Follow manufacturer's instructions regarding the use and maintenance of equipment and use of detergents for cleaning and sanitizing drying trays and equipment.
- Wash, rinse, and sanitize trays: After each use
- Any time contamination occurs or is suspected

Wash, rinse, and sanitize drying trays using the following procedure:

- Wash with soapy water and designated sponge.
- Use designated sponge to wash off any fruit particles stuck to the tray.
- Do not scratch tray with knife or any sharp object
- Rinse with clean water till no trace of soap/detergent is present.
- Clean and sanitize dryers:
- Use designated napkins in cleaning dryers
- Clean all inside surfaces of dryer

- Ensure that dried fruit particles are completely removed. Do not scratch with knife or any sharp object.
- Clean outer surface of dryer with napkin and clean water

2.6.3. Work areas housekeeping

Ensure that equipment and materials are placed carefully to avoid causing a fall or "striking against" accident. Clean up after every job. All spilt oil, grease or liquid must be cleaned up immediately. The closure of individual Work Permits must check for cleanliness and equipment/lose items removing. Keep all machine motors and exhausts unobstructed. Do not allow buildup of dusts and sand on structures, cable trays, shelves, ledges, or lockers. Ensure that any place in lay down is safe and healthy and its surface shall be even and smooth and free from obstacle. Proper and easy means of access and egress shall be provided due to reach the good housekeeping state in lay down. A land of lay down that equipment's place there, shall be had good conditions concerning firmly and be in stable manner. Keep the lay down area safe and clean and place compatible equipment's together. Adequate tools for handling of equipment's and stacking shall be provided until employees able to arrange any equipment safely and correctly. Equipment's shall be placed with proper horizontal distance in proper height. Regard to special housekeeping and cleanup of spillages in lay down is necessary for preventing from falling equipment's causing an accident. Ensure that all employees who perform any handling and maintenance activity have proper personal protective equipment's

2.6.4. Workshop housekeeping

Workshop should be kept neat and tidy. Good housekeeping can significantly reduce the risk of an accident and injury, failure to maintain a clean and tidy Workshop can result in accident and injury. Work areas and equipment are to be thoroughly cleaned after use. Benches are to be kept clean and free from chemicals and apparatus that are not being used. Aisles and exits are to be kept free from obstructions. All walkways, work stations, access to emergency equipment and exits shall be free from obstruction at all times. Liquid spills shall be cleaned up immediately. Heaps or stacks of equipment shall be stable and shall not obstruct lines of view necessary for

supervision of shop users. Wood and metal dusts shall be collected at the end of each operation. Dry sweeping is not recommended and the use of air hoses is not permitted. Flammable and combustible materials shall not be allowed to accumulate in open areas of the workshop.

2.6.5. Material storage

Remove empty cartons, wrappings and other flammable waste as soon as possible. In the same storage area do not store substances which may react with each other to produce heat or an explosion. Make sure gas cylinders and containers cannot fall. Ensure boxes, sacks, barrels, or other objects are stacked correctly, using chocks and lashings where necessary. Do not store in access ways. Do not manually lift heavy items above chest level.

Reductions in wastewater volumes of up to 95% have been reported through implementation of good practices. Where possible, measures such as the following should be adopted:

- Procure clean raw fruit and vegetables, thus reducing the concentration of dirt and organics (including pesticides) in the effluent.
- Use dry methods such as vibration or air jets to clean raw fruit and vegetables. Dry peeling methods reduce the effluent volume (by up to 35%) and pollutant concentration (organic load reduced by up to 25%).
- Separate and recirculate process wastewaters.
- Use countercurrent systems where washing is necessary.
- Use steam instead of hot water to reduce the quantity of wastewater going for treatment (taking into consideration, however, the tradeoff with increased use of energy).
- Minimize the use of water for cleaning floors and machines.
- Remove solid wastes without the use of water.
- Reuse concentrated wastewaters and solid wastes for production of by-products.

Self-check 2	Written test

Name: _____ ID: _____ Date: _____

Directions: Answer all the questions listed below.

Test I: Short Answer Questions

1. What is the purpose of pre-treating fruits and vegetables before drying?
2. What are the three factors that influence the efficiency and effectiveness of fruit drying?
3. What are the five KPIs for evaluating the performance of the drying process?
4. What are the four essential elements of a comprehensive monitoring and control system for the drying process?
5. What are the five main physicochemical changes that occur during drying of fruits and vegetables?

Test II: Choose the best answer for the questions

1. Which of the following is NOT a recommended way to pre-treat fruits and vegetables before drying?
   A. Blanching
   B. Dipping in a citric acid solution
   C. Soaking in a sugar solution
   D. Frying

2. Which of the following is NOT a key control point for the drying process?
   A. Temperature
   B. Airflow
   C. Humidity
   D. Appearance

3. Which of the following is NOT a desirable characteristic of dried fruits and vegetables?

A. Low moisture content
B. Even drying
C. Overdrying
D. Free from blemishes

4. Which of the following is NOT a step in maintaining performance within specifications for drying fruits and vegetables?
   A. Regular monitoring
   B. Temperature control
   C. Airflow management
   D. Appearance inspection
5. Which of the following is NOT a quality aspect of dried fruits and vegetables?
   A. Moisture content
   B. Appearance
   C. Flavor
   D. Nutritional content

Operation sheet 2

2.1. Drying leather fresh fruit product

A. Tools and equipment's

A. Tea-spoons
B. Personal protective equipment
C. Knife

B. Procedures

Step 1- wears personal protective equipment

Step 2- Select ripe or slightly overripe fruit.

Step 3- Wash fresh fruit or berries in cool water.

Step 4- Remove peel, seeds and stem.

Step 5- Cut fruit into chunks.

Step 6-Use 2 cups of fruit for each 13" x 15" inch fruit leather.

Step 7- Purée fruit until smooth.

Step 8- Add 2 teaspoons of lemon juice or 1/8 teaspoon ascorbic acid (375 mg) for each 2 cups of light colored fruit to prevent darkening.

Step 9- To sweeten, add corn syrup, honey or sugar. Corn syrup or honey is best for longer storage because it prevents crystals. Sugar is fine for immediate use or short storage. Use 1⁄4 to 1⁄2 cup sugar, corn syrup or honey for each 2 cups of fruit.

Step 10- Dry fruit leather at 140° F

.

2.2. Drying vegetables

A. Tools and equipment's

- Teaspoons
- Personal protective equipment
- Knife

B. Procedures

Step 1- Wears personal protective equipment

Step 2- Wash vegetables. Remove mouldy, rotten, and badly damaged part

Step 3-. Cut in serving-size pieces and steam-blanch.

Step 4- Spread on towel-lined trays to remove excess moisture.

Step 5- Preheats an oven or food dehydrator to 130°f to 140°f.

Step 6- Place vegetables on drying trays.

Step 7- Dries until vegetables are shriveled and leathery, or brittle for longer storage.

Step 8- Cool 30 minutes, or until no longer warm and remove from drying trays.

Step 9- Store in an airtight container in a cool, dry place.

2.3. **Testing and determination of moisture content**

A. Tools and equipment's

- Electric Oven, dicing machine, Thermometer.
- Dish -diameter about 8.5 cm, with tight-fitting lid.
- Fruit Chopper/ cutter, slicer, Sand.
- Desiccator, Steam Bath
- Analytical Balance accuracy of ± 0.01

B. Procedures/Steps/Techniques

Step 1- Wears personal protective equipment

Step 2- Prepare Dish and Lid for test

Step 3- Add about 2 g of the sand to the dish and dry, with the lid, for 2 h in the oven set at 70 ºC.

Step 4- Leave to cool to room temperature in the desiccator.

Step 5- Prepare test portion; weigh, to the nearest 0.02 g, about 5 g of the test sample and spread this test portion as evenly as possible over the bottom of the dish containing the sand .

Step 4- Determine and calculate the moisture content in percent

2.4. Monitoring and clearing waste

A. Tools and equipment's

- Personal protective equipment

B. Procedures/Steps/Techniques

Step 1- Wears personal protective equipment

Step 2- Wash with soapy water and designated sponge.

Step 3- Use designated sponge to wash off any fruit particles stuck to the tray.

Step 4- Do not scratches tray with knife or any sharp object

Step 5- Rinse with clean water till no trace of soap/detergent is present.

Step 6- Store in designated area till next use.

Step 7- Clean and sanitize dryers

Step 8- Clean all inside surfaces of dryer

Step 9- Ensure those dried fruit particles are completely removed. Do not scratch with knife or any sharp object

Step 10- Clean outer surface of dryer with napkin and clean water

LAP test 2	Performance Test

Name: _____ ID: _____Date: _____

Time started: _____ Time finished: _____

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **10** hour. The project is expected from each student to do it.

Task-1 Apply monitoring and clearing waste

Task-2 Perform testing and determination of moisture content

Task-3 Perform drying vegetables

Task-4 Operate drying leather fresh fruit product

LG #3	LO #3- Shut down the Drying Process

Instruction sheet
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Shutting down drying process • Collecting, treating and disposing or recycling waste • Recording workplace information ` This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Shut down drying process. • Collect, treat and dispose or recycle waste. • Record workplace information
Learning Instructions:
1. Read the specific objectives of this Learning Guide. 2. Follow the instructions described below. 3. Read the information written in the information Sheets 4. Accomplish the Self-checks 5. Perform Operation Sheets 6. Do the “LAP test”

Information sheet 3

3.1.Shutting down drying process

The Standard Operating Procedures for each type of equipment must be adhered to when shutting a unit down.

- Scheduled shutdown
- Maintenance shutdown
- Emergency shutdown
- Shutting down to a standby condition.

3.1.1. Emergency shutdown

An emergency shutdown is initiated in the event of a fire, major spill, instrument failure, power failure, or total loss of control of chemical or physical processes. Emergency shutdown procedures must be followed during a shutdown sequence. Shutdown of a unit can be initiated by the automatic shutdown system. The systems may be shut down automatically because of temperatures, fluid levels, pressures or flows that are above or below trip points.

Typical shutdowns initiated by trips may include:

- Low liquid level in a vessel
- High liquid level in a storage tank
- High viscosity causing increased load on pumping or mixing equipment
- Mixer failure
- Pressure to high
- Temperature to high
- Low feed flows

3.1.2. Maintenance shutdown

When maintenance to the unit equipment is required, the equipment may need to be entered so that work can take place.

The shutdown should be a scheduled or planned shutdown as per Standard Operating Procedures where equipment is:

- Isolated (process, mechanical and electrical)
- Cooled and depressurized
- Purged and gas freed
- Cleaned
- Gas tested on a continuous basis prior to and during entry.

3.1.3. Scheduled shutdown

A scheduled shutdown is initiated by the operator during normal operation of the unit when:

- Maintenance is required
- Feed supply is low or exhausted.

The shutdown procedure will depend on the type of equipment and the process chemistry.

- Some steps taken in a unit shutdown may include:
- Shutting off the feeds to stop processes and heat generation particularly if processes are exothermic (produce heat)
- Recirculating feeds from supply tanks so they do not enter the unit
- Shutting off heating or cooling to the unit or feed preheat system
- Shutting off mixing and other mechanical operations
- Cooling and flushing materials from the unit

3.1.4. Shutting down to a standby condition

When a unit is to be shut down for a short period of time for maintenance on auxiliary equipment, the unit is shut down to a standby condition.

A standby shutdown allows a quick startup of the unit after maintenance is completed in order to minimize lost production time and off spec material.

A typical standby condition may include:

- Recirculating material upstream and downstream
- Reduced heating or cooling (sufficient to maintain a safe process condition)
- Slow-rolling compressors

- Venting process gases to flare
- Diverting process streams to temporary storage.

3.1.5. Shut down drying process procedures

- Turning off the liquid feed.
- Running some water through the nozzle to clean it out.
- Turning off the water feed, and then the air feed.
- Shutting down the burner and close the main gas shut-off valve.
- Allowing the electric blower to run until the equipment has cooled off.
- Turning of the electric blower and open the drying chamber door to inspect. If the chamber requires cleaning turn on the electric blower and brush material into the chamber outlet. If the chamber requires washing, clean with water and open the liquid drain valve to evacuate the water.

3.2. Collecting, treating and disposing or recycling waste

3.2.1. Fruit waste management

The aim of waste management is to achieve rational management of resources and minimize the amount of waste disposed into the environment. The main areas of waste management include prevention and decrease of waste formation, reutilization, recovery, waste selection, waste handling, waste transformation or destruction, waste placement, and storage.

3.2.2. Procedures for the management of fruit processing waste

Slurry treatment has two aims, decreasing the amount of slurry and slurry processing to develop the structure and composition that is suitable for placement. This latter can be performed by stabilization and disinfection. The decrease of slurry quantity practically means water removal, which is carried out by mechanical procedures or heat treatment or by the combination of both. Taking the general composition of slurry into consideration, it can be seen that 90% of the water content, which is pure water and capillary water, can be removed by thermal separation procedures.

The main steps of slurry treatment and placement are as follows:

- Slurry concentration;
- Slurry conditioning;
- Disinfection;
- Water removal;
- Aerobic stabilization;
- Anaerobic stabilization;
- Combustion;
- Final placement and waste deposition.

The goal of slurry concentration is the decrease of easily removable water content and thus the decrease of slurry quantity. The most frequently applied procedures are gravitational and flotation-based slurry condensation devices, slurry centrifuges, and membrane separation techniques. Depending on the construction, the following dry matter levels can be achieved by different water

removing procedures: gravitational condensation 4–5%, centrifuges 10–20%, and membrane separation 30–40%.

The aim of slurry conditioning is to decrease the water content, stabilize organic substances, and reduce the number of microorganisms. Physical conditioning can be performed by pasteurization, thermal conditioning, and washing. Washing means the elimination of colloid organic contaminants from the slurry, which are then driven back for biological cleaning.

There are seven commonly used methods of managing fruit and vegetable waste

- Storing the culled fruit and vegetables on-site in a pile or bermed area for a limited time
- Returning fruit and vegetable waste to the field on which it was grown
- Feeding fruit and vegetable waste to livestock
- Giving the fruit and vegetable culls to local food banks
- Composting fruit and vegetable culls
- Processing fruit and vegetable culls to separate juice from pulp
- Disposing of fruit and vegetable waste in a local Sub-Title D landfill.

The method of separating the fruit and vegetable culls into juice and pulp is accomplished by using a press. Typical systems are screw presses that can effectively separate the juice from the pulp. After separation, each fraction has its benefits for different reasons and purposes. If the culls are of good food quality they can be used as juices in food applications based on available markets. The pulp can also potentially be used as a component of foods. For those culls that are not of human food quality, the separated pulp can be used as one component of compost or animal food. (If the pulp is used for animal feed, check with an animal scientist or veterinarian prior to feeding.)The pulp can also be used as a soil amendment or as one component of a composting process. The juice can also be used as a feedstock for ethanol production or anaerobic digestion processes. For either process, there should be a market for the final products, ethanol or methane. A few pros and cons of separating juice from pulp are:

Advantages:

- Low disposal cost
- Potential on-site processing
- Low transportation cost to processing site
- Fruit and vegetable juice will evaporate quicker if separated from pulp
- Pulp can be used in composting
- Less composting filler materials will be needed
- Pulp can be fed to animals
- Fruit and vegetable juice will be easier to transport and apply to the receiving field/pasture
- Fruit and vegetable juice can be a feedstock for ethanol or anaerobic digestion processes
- Fruit and vegetable juice is easier to store than whole fruit and vegetables.

Disadvantage:

- A method of separating fruit and vegetable juice and pulp has to be in place
- Fruit and vegetable juice storage has to be in place
- A composting site and procedures have to be ready
- A tank is necessary for storing and transferring fruit and vegetable juice to the location to be used for the production of ethanol or anaerobic digestion.

3.3. Recording workplace information

Work place information related to maintaining food quality may include

- Standard Operating Procedures (SOPs),
- Specifications and production
- Quality specification
- Log sheets
- Basic data
- Standard forms
- Written and verbal instruction

Production records. Recipes Raw materials and ingredients received and suppliers Wastage % at different stages of the process Stock levels for each ingredient Production volumes and measurements Maintenance programs and schedules

Quality assurance records. Target amounts of ingredients and any changes made to recipe Measurements made at process control points Batch numbers and product code numbers Cleaning procedures and schedules

Standard Operating Procedures (SOP) are also documents, and contain written step-by step instructions that laboratory staff should meticulously follow when performing a procedure. A laboratory will have many SOPs, one for each procedure conducted in the laboratory. It is a good idea to standardize the formats of SOPs so staff can easily recognize the flow of the information.

Self-check 3	Written test

Name: _____ ID: _____ Date: _____

Directions: Answer all the questions listed below.

Test I: Short Answer Questions

1. What are the four main steps of slurry treatment and placement?
2. What are the three main areas of waste management?
3. What are the seven commonly used methods of managing fruit and vegetable waste?
4. What are the two main aims of emergency shutdown procedures?
5. What are the five main types of workplace information related to maintaining food quality?

Test II: Choose the best answer for the questions

1. Which of the following is the MAIN purpose of a scheduled shutdown?
   A. To perform maintenance on the unit equipment
   B. To minimize lost production time and off spec material
   C. To allow a quick startup of the unit after maintenance is completed
   D. All of the above
2. What is the goal of slurry concentration?
   A. To decrease the amount of easily removable water content
   B. To stabilize organic substances
   C. To reduce the number of microorganisms
   D. All of the above
3. What are the two main aims of slurry treatment?
   A. Decreasing the amount of slurry and slurry processing
   B. Developing the structure and composition that is suitable for placement
   C. Stabilization and disinfection

D. All of the above

4. What is the purpose of turning off the liquid feed when shutting down a drying process?
   A. To stop processes and heat generation
   B. To prevent recirculating feeds from entering the unit
   C. To cool and depressurize the unit
   D. To purge and gas free the unit
5. Which of the following is NOT a disadvantage of separating fruit and vegetable juice from pulp?
   A. A method of separating fruit and vegetable juice and pulp has to be in place
   B. Fruit and vegetable juice storage has to be in place
   C. Fruit and vegetable juice is easier to transport and apply to the receiving field/pasture
   D. Pulp can be used in composting

Operation sheet 3

3.1 Procedures for Shutting down drying process

A. Tools and equipments

- Personal protective equipment

B. Procedures

Step 1- Wears personal protective equipment

Step 2- Turn off the liquid feed.

Step 3- Run some water through the nozzle to clean it out.

Step 4- Turn off the water feed, and then the air feed.

Step 5- Shut down the burner and close the main gas shut-off valve.

Step 6-Allow the electric blower to run until the equipment has cooled off.

Step 7- Turn of the electric blower and open the drying chamber door to inspect. If the chamber requires cleaning turn on the electric blower and brush material into the chamber outlet. If the chamber requires washing,

Step 8- clean with water and open the liquid drain valve to evacuate the water.

LAP test 3	Performance Test

Name: _____ ID: _____Date: _____

Time started: _____ Time finished: _____

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **1** hour. The project is expected from each student to do it.

Task-1 – **Apply shut down drying process**

Reference Materials

Books and articles:

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AKNOWLEDGEMENT

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVET instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

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