Horticultural Chain Management for Eastern and Southern Africa

A practical manual

Horticultural Chain Management for East and Southern Africa

A TRAINING PACKAGE

PRACTICAL MANUAL

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FOREWORD

In November 2005, the Rural Infrastructure and Agro-industries Division of the United Nations Food and Agriculture Organization (FAO) and the Special Advisory Services Division of the Commonwealth Secretariat agreed to work together to help strengthen human capacities in horticultural chain management in East and Southern Africa in response to needs expressed by member countries of that region. Formal agreements were established with the University of Pretoria, South Africa, for the development and implementation of a 'Train the Trainers' programme. The core curriculum of the programme focused on practical approaches to assuring the safety and quality of horticultural produce and on efficient organisation of the supply chain in order to improve the competitiveness of small and medium-sized enterprises (SMEs) and farmers in domestic and regional markets. The training programme was held at the University of Pretoria, South Africa, in June 2006 and drew participant trainers from nine countries in the East and Southern African region. This training package has been produced as a direct result of that programme.

The training package consists of a theoretical manual and a practical manual. The practical manual is designed to complement the theoretical manual and to provide the trainer with simple practical tasks that reinforce and enhance comprehension of theoretical training. The whole package is structured to provide the trainer with sufficient technical background and reference materials to allow him/her to customise training in accordance with the needs of the target group to be trained.

It is hoped that this training package will stimulate improvements in fresh produce supply chains across the region, leading to safer produce of higher quality and to better economic returns for SMEs and small-scale producers.

FAO and the Commonwealth Secretariat welcome feedback from the users of this training package. Comments and critiques, as well as contributions on the contents, will help to improve future editions. Comments should be e-mailed to rosa.rolle@fao.org and t.williams@commonwealth.int.

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Horticultural Chain Management

Practical Manual

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I. INTRODUCTION TO THE PRACTICAL MANUAL

This practical manual is designed to complement the theoretical manual and to provide the trainer with simple practical tasks that reinforce and enhance comprehension of theoretical training on horticultural chain management. The trainer may in turn use this guide for the development of context-appropriate hands-on training packages for small-scale farmer-learner programmes.

The manual includes demonstrations, hands-on activities, tasks (such as the development of questionnaires and the conduct of interviews), problem-solving challenges and field visits with a focus on observation and recording. The following approaches have been selected for inclusion in this manual:

- **Experiments with demonstrations**: These include introductory presentations followed by practical demonstrations and a hands-on 'do-it-yourself' exercise. Each individual must take notes, make daily observations and record results. A report, which includes data analysis, discussions and conclusions, is required at the end of the training programme with verbal feedback of results and a group discussion on the effectiveness of the practical exercise. Practical exercises are designed to be very basic and inexpensive, with minimal requirements for equipment and/or chemicals, such that they can be easily duplicated under field conditions.
- **Tasks**: Tasks have been selected to provide the participant with a basic understanding of the issues at stake. The discussion sessions emanating from each task provide an opportunity for participants to contribute their experiences and to contextualise the theoretical work.
- **Problem solving**: This approach refers to brief discussions of classic case studies, which allows trainees to apply lesson concepts as they work through each problem.
- **Field visits**: The guide to field visits provides some basic background information on the site to be visited and highlights key points that should be observed during the site visit.

II. MEETING THE CONSUMER

1. Meeting the consumer and observing consumer behaviour

Purpose:

- To apply the principles of consumer behaviour to real-life food product examples in a supermarket
- To observe practices in the supermarket retail of fresh fruits and vegetables

Procedure

Trainers will visit two retailers. During these visits, trainers will observe consumer behaviour and compare the two retailers in that regard. The feedback session will be in the form of an informal discussion.

Activities during the visit:

- Observe the general appearance of the store
- Observe location of produce in the store
- Observe produce display in the store
- Observe produce packaging
- Observe produce quality
- Observe consumer behaviour

Tasks following the visit:

- Write a summary of critical observations
- Discuss observations following on lecture sessions

Discussions and feedback:

- Present brief (three-minute) feedback on key observations at the store

III. FIELD VISITS

1. Visit to a fresh produce market

Purpose:

- To visit a fresh produce market and to observe first-hand the flow of products, management of produce flow, cash flow and transactions, stakeholder interaction, hygiene, waste and quality management systems
- To understand how all elements of supply chains are integrated so as to assure safety and quality

Field site protocol

Visiting a fresh produce market is interesting, but it can also be risky if certain protocols are not followed. Trainers are requested to observe these protocols to ensure that maximum benefit can be derived from the visit. Fresh produce markets are extremely busy during trading hours and participants are requested not to interfere with the normal flow of goods or with the work of traders and other workers. Trainers should at all times remain in a close circle with the group and ensure that no one falls behind; the group should remain at the sides of the halls to avoid injuries caused by fast moving forklifts and trucks.

Activities during the visit:

- Make a note of critical questions and observations for further discussion
- Collect rotten fruit samples in labelled plastic bags for microbiological testing
- Note strengths and weaknesses of the marketing system

Tasks following the visit:

- Draw the supply chain for a selected fresh produce item, charting the different types of activities and links in the chain, and distinguishing between those that involve physical transformation and those that reflect service inputs
- Write a one-page summary of critical observations of systems, failures and strengths of the market and relate it to the situation in your respective country
- Complete this assignment and report on it on the final day of the programme

Discussions and feedback:

- Present brief (three-minute) feedback on key observations at the market
- Present feedback on the supply chain for the selected produce item
- Write a brief summary of key discussion points that could be of practical value to your respective country

2. Visit to an orchard

Purpose:

- To visit an orchard in order to observe the implementation of general principles of Good Agricultural Practices (GAP) as well as harvesting operations

Field visit protocol:

- When visiting an orchard, adherence to strict codes of conduct must be observed in order to derive maximum benefit from the visit
- Participants should remain with the group at all times
- A limited number of questions may be asked during the visit, but the tour guide should also be given ample time to explain the system

Code of conduct for visit:

- Dress appropriately (wear closed shoes, for example)
- Do not smoke, do not litter and be attentive to moving vehicles
- Refrain from touching fruit in the orchard
- Do not eat or drink while on the tour
- Be respectful and friendly to all staff and workers

Activities during the visit:

- Make a note of critical questions and observations for discussion after the visit
- Note strengths, weaknesses and non-conformances for later documentation in your field report
- Observe the general sanitation of the orchard
- Observe harvesting operations and the use of specialised tools during such operations
- Observe harvesting containers
- Observe temporary storage procedures
- Observe systems for identifying orchard blocks to facilitate traceability of produce
- Observe produce quality

Discussions and feedback

- Present a brief (three-minute) feedback on key observations in the field during group discussions
- Write a brief summary of key discussion points that could be of practical value to your respective country

3. Visit to a pack house

Purpose:

- To visit a pack house in order to observe process flow, pack line operations, hygiene, waste disposal systems and quality management

Field site protocol:

- When visiting a pack house, a strict code of conduct must be observed if maximum benefit is to be derived from the visit
- Participants should remain with the group at all times
- Participants should be aware of fast moving forklifts and other vehicles
- A limited number of questions may be asked during the visit, but the quality manager should also be given ample time to explain the system

Code of conduct for the visit:

- If you have any septic wounds or are feeling sick do not enter the facility with the group (wait at the office)
- Dress appropriately (wear, for example, closed shoes, hair tied back, a warm jacket for visits to cool storage)
- Remove jewellery prior to entering the plant
- Wash hands thoroughly prior to entering the plant
- Wear protective clothing as provided; this may include hair or beard nets, clean coats, boots or shoe coverings
- Do not smoke, do not litter and be attentive to overhead structures and forklifts
- Refrain from touching equipment and/or products
- Do not eat or drink while on the tour
- Be respectful and friendly to all staff and workers

Activities during the visit:

- Make notes of critical questions and observations for discussion after the visit
- Note strengths and weaknesses of operations and any non-conformances for later documentation in your field report
- Observe the lay-out of the pack house
- Observe the surroundings of the pack house
- Observe how hygienic conditions are in the pack house
- Observe washing operations
- Observe pack line operations
- Observe packing operations
- Observe pre-cooling, storage and any specialised operations

Discussions and feedback:

- Present a brief (three-minute) feedback on key observations in the field
- Write a brief summary of key discussion points that could be of practical value to your respective country

IV. MICROBIOLOGY

1. Introduction to micro-organisms

'Micro-organisms are small organisms that can only be observed through a microscope. Many of these organisms consist of a single cell. They can be found everywhere in the environment. Some have the ability to take up nutrients and metabolise them into a large number of end products. Micro-organisms often have the ability to react to changes in their environment and some have been known to adapt to new environments.

Many micro-organisms are beneficial to humans. Some are involved in the production of fermented foods such as bread, cheese, wine, beer and sauerkraut. Others are used by industry in the production of products such as enzymes, antibiotics and glycerol. Additional microbial functions such as degradation of organic matter and enrichment of soils also benefit mankind. Pathogenic micro-organisms, however, have the potential of causing food-borne illnesses.

Pathogenic micro-organisms can contaminate fruits and vegetables through contact with the soil and dust, as well as through poor production and handling practices such as the application of untreated manure during production, the use of contaminated irrigation water or unsanitary handling practices.

Micro-organisms can also cause fresh fruit and vegetable to decay, thus reducing their shelf-life and marketability, resulting in heavy losses to farmers'[1].

2. Setting up a basic microbiology laboratory

Infrastructural requirements

In order to set up a basic microbiology laboratory, the following will be required:

- A small room with washable surfaces (walls, floor and ceiling);
- One or two tables with washable surfaces;
- A shelf or two and a cupboard (or storage cabinet); and
- A basin with running tap water or a portable bowl.

The room must be washed and disinfected prior to commencing microbiological work. A commercial disinfectant such as Dettol or household bleach can be used as a disinfectant.

Purpose

The purpose here is to demonstrate that a microbiology laboratory can be set up with minimum equipment requirements and at minimal cost.

Equipment and supplies

Commercial equipment can be purchased from a company that supplies laboratory equipment. An 'alternative' level of equipment could also be sourced from a hardware store (see below).

[1] University of Maryland, 2002.

Materials

Commercial	***Alternative***
Autoclave	Pressure cooker
Analytical top pan balance	Digital kitchen balance, battery operated
Hot plate/magnetic stirrer	Gas stove/electrical hot plate
Water bath	Large cooking pot

Instruments

Commercial	***Alternative***
Bunsen burner with LP[2] gas/ethanol burner	Candle
Inoculation holder with loop	Wooden rod and thin wire
Tweezers	Fine pair of pliers
Spatula	Spoon
Scalpel with blade	Sharp knife
Weighing boats	Foil/plastic lids
70 per cent ethanol	Surgical spirit/methylated spirit
Spreading rod – plastic (sterile)	Spreading rod made of wire
Sterile swabs	Cotton ear buds
Distilled water	Bottled water/untreated, clear water, boiled

Other

Thermometer
Scissors
Foil
Masking tape
Permanent marking pen
Matches and/or gas lighter or cigarette lighter
Oven gloves

Description of items of equipment and supplies

a. Equipment

- An autoclave (pressure cooker) is used to sterilise items or culture media for microbiological use
- A balance is used to weigh out chemicals or culture media according to a prescribed recipe, or to weigh fruit or vegetables to be studied
- A cooking pot is used to heat water on the gas stove/hot plate to create a water bath
- A thermometer is used to measure the temperature of the water and the settings of the stove/hot plate, in order to control the temperature of the water bath. A water bath, kept at 50°C, is used to keep agar molten until it can be poured

b. Instruments

- A Bunsen burner/ethanol burner/candle is used during aseptic work to create a sterile environment and to sterilise instruments prior to use

[2] Liquefied petroleum gas (LPG).

- An inoculation holder with loop is used to transfer bacterial cultures
- Tweezers are used to transfer fungal cultures and to pick up and transfer plant material
- A spatula/spoon, as well as the weighing boats/foil, are used to weigh out chemicals
- A scalpel/knife is used to aseptically cut, either fungal cultures or fruit pieces
- A spreading rod is used to spread a sample over the surface of an agar plate
- Swabs are used to collect samples from surfaces
- Ethanol (70 per cent)/surgical/methylated spirit is used to disinfect working surfaces, as well as instruments before use
- Distilled water is essential in the preparation of culture media, as chlorine in treated water will inhibit the growth of microbes; a water purifier would be ideal

c. Chemicals and culture media

Chemicals and culture media are commercially available from companies that supply laboratory chemicals. Some chemicals can be substituted by home-grown vegetables. Potatoes can, for example, serve as a substitute for potato dextrose agar.

d. Glass ware and Plastic ware

These can also be obtained from companies that supply laboratory ware. A simple laboratory will require a few Erlenmeyer flasks (conical) or screw-cap bottles (Schott bottles) ranging from 250 to 1000ml, a few beakers, ranging from 100 to 1000ml, some test tubes and test tube racks, disposable sterile Petri dishes (90mm in diameter), and measuring cylinders 250, 500 and 1000ml.

3. Demonstrating the omnipresence of micro-organisms

Introduction

Micro-organisms can be found in every habitat on earth. They are found in the air, sea, rivers and soil, on plants and in fish and humans. They can even be found in extreme habitats such as Antarctica and in hot springs.

Purpose

The purpose of this task is to demonstrate that micro-organisms are everywhere.

Materials

- Contact plates with nutrient agar
- Petri dishes with nutrient agar

Procedure

This task can be carried out as a group exercise, with different groups investigating different surfaces.

Surface sampling

- Choose a surface for investigation
- Label the base of the contact plate with your name and the identity of the surface you have chosen to investigate
- Remove the lid of the contact plate and press it for 30 seconds against the selected surface
- Incubate the plate for 24-48 hours at room temperature

Air sampling

- Identify a sampling point
- Label the base of the contact plate with your name and the location of the sampling point you have chosen to investigate
- Place an open nutrient agar plate at the selected sampling point and leave it open at this point for 30-60 minutes
- Note the time for which the plate was exposed
- Replace the lid
- Incubate the plate for 24-48 hours at room temperature

Results

Surface/sampling point investigated	**Total number of colonies**	**Number of fungal colonies**	**Number of bacterial colonies**

Questions and discussion issues

- Which sampling point had the least number of colonies?
- Which sampling point had the largest number of colonies?
- Can you explain the difference?

V. DETECTION OF POST-HARVEST PATHOGENS

Introduction

Post-harvest pathogens are saprophytes[3] and infect fruit and vegetables through natural and artificial openings (wounds). As they grow they break down the cells of the fruits or vegetables, causing them to become limp or water-soaked. This creates the opportunity for other saprophytes to invade and grow on the nutritious plant sap/juices.

The isolation of a specific post-harvest pathogen from very rotten fruit is challenging, given the possibility of isolating a number of other saprophytes in the process. The surface of the produce should be disinfected prior to attempting to isolate any organisms. If, however, the produce is beyond recognition, the disinfectant will negatively impact on post-harvest pathogens in the fruit or vegetable.

Purpose

The purpose of this task is to isolate post harvest pathogens from fruit.

Materials

Materials for the task should comprise:

- Malt extract agar in Petri dishes;
- A scalpel;
- Ethanol;
- A burner; and
- Decaying fruit

1. Detection of yeasts and moulds

- Mark the bottom of the plate with the sample to be investigated and the date of the experiment
- Sterilise the scalpel by dipping it in ethanol before setting it alight with a match
- Cut a small square from the edge of the fungal growth on the fruit and place it on the surface of a malt extract agar plate; if the fruit is too rotten, press the surface of the malt extract agar plate against the aerial fungal growth on the fruit
- Incubate for two to three days at room temperature

2. Detection of fungi

- Mark the bottom of the plate to be investigated with the term '*Penicillium*'
- Press the fungal-infected surface of a *Penicillium*-infected citrus fruit on to the surface of a malt extract agar plate
- Cover the plate and incubate for 48-72 hours at room temperature

Question and discussion issues

- Describe the colonies observed on each plate

[3] A micro-organism, plant or fungus that lives on decaying matter.

VI. MONITORING SOURCES OF CONTAMINATION DURING POST-HARVEST OPERATIONS

1. Water as a source of produce contamination

Introduction

Water is used for irrigation as well as for washing fresh produce after harvesting. Water is also a carrier of food-borne pathogens, especially when it is contaminated with sewage and manure. Although the outer surface of fresh produce may appear to be intact to the naked eye, all plants and fruits have respiratory openings such as lenticels and stomata through which water can enter.

Purpose

The purpose of this task is to demonstrate how food-borne pathogens in water used for washing can penetrate/infect fruits and vegetables.

Materials

Materials for the task should include:

- Fresh produce (apples, pears, tomato, sweet potato etc.);
- A scalpel/knife;
- A beaker/bowl;
- 1 litre of water;
- Blue food colouring;
- Tongs to remove produce from water; and
- A drying rack.

Procedure

This task can be carried out as a group exercise, with different groups investigating different fruits and/or vegetables.

- Place water in a bowl and add 10 drops of food colouring; mix
- Submerge produce samples in the water for 10 minutes
- Remove samples from water with tongs and drain for 10 minutes
- Observe the amount of dyed water on the surface of the produce
- Remove a 2cm-slice from the stem end of the produce; observe and record the amount of dye penetration
- Clean the knife and cut the produce in half
- Observe

Results

Evaluate the dye penetration using the following scale:

- 4 = lots of dye
- 3 = moderate amounts of dye
- 2 = some dye
- 1 = slight amounts of dye
- 0 = no dye

Produce item	Outer surface	Stem end	Cut surface	Damaged area

Question and discussion issues

- How much dye was present on the surface of the produce?
- How much dye was present in the interior?
- What kinds of barriers prevented the dye from penetrating throughout the product?
- What effect did damage to the surface of the produce have on colour penetration?
- Suppose the dye represents micro-organisms in the water. What conclusions can be drawn in terms of damage to produce as a means of facilitating these organisms in contaminating produce?

2. Monitoring the hygiene of surfaces

Introduction

Surfaces collect dust and liquids such as fruit juice, dirty wash water etc. Surfaces are also frequently touched by people. In order to minimise contamination of fruits and vegetables, all surfaces, including those of baskets, crates etc. that are used to contain or transport fresh produce, must be kept clean at all times.

Purpose

The purpose of this task is to demonstrate the microbial contamination of surfaces.

Materials

Materials for this task should include:

- Sterile swabs;
- Sterile water;
- Nutrient agar in Petri dishes;
- A spreading rod;
- A burner;
- Ethanol; and
- A micropipette with tips.

Procedure

This task can be carried out as a group exercise, with different groups investigating different sampling points.

Swab sampling of a 5 x 5cm surface

- Slightly moisten the swab with sterile water
- Press the swab firmly on to the selected surface and sample as shown in figure 1

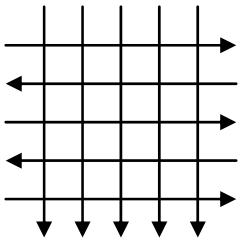


Figure 1. The swab sampling technique[4]

- Transfer the swab back into a sterile tube
- Send the swab to a certified laboratory for determination of total viable count (TVC) or for the determination of the presence of a specific food-borne pathogen or faecal contamination indicator

Determination of total viable count (TVC)

- Place the swab into 9ml of sterile water; mix well
- Prepare a dilution series and plate out onto nutrient agar plates
- Incubate at room temperature for 24-48 hours
- Count the number of colonies between 30 and 300 per plate
- Calculate the number of cells per $5cm^2$

Results

Sample point	Total viable count (TVC)

Questions and discussion issues

- Discuss the microbial counts obtained at the various sampling points

3. Demonstrating the importance of effective hand washing

Introduction

Hands are the main source of contamination with food-borne pathogens since they are the tools with which humans handle everything. The human skin is also the natural habitat of *Staphylococcus* species, including *S. aureus*. These microbes live and hide in the small crevices of the skin. Ordinary hand washing will not remove all microbes from the skin. Correct hand washing, however, cleans the hands adequately to allow for proper handling of fresh produce.

A correct hand washing procedure should remove transient bacteria, skin cells, sebaceous secretions, sweat and other organic material picked up during daily activities. During hand washing, all areas of the hands, including fingertips and thumbs should be thoroughly washed.

[4] Redmond, 2006.

Hand drying is as important as hand washing in preventing cross-contamination and the transfer of micro-organisms, since wet hands can transmit up to 500 times more bacteria than dry hands.

Purpose

The purpose of this task is to demonstrate the effect of hand washing on the microflora of the skin.

Materials

Materials for the task should include:

- Soap;
- Warm water;
- Paper towels; and
- Nutrient agar in Petri dishes.

Procedure

- Press the three middle fingers of the left hand onto the surface of a nutrient agar plate for 30 seconds
- Close the lid and mark on the back of the plate 'not washed'
- Wash your hands with warm water and soap* and dry thoroughly with paper towels
- Repeat the first step and mark the plate 'washed'
- Incubate the plates at room temperature for 48 hours

**Correct hand washing and drying procedure*

- Adjust water to a comfortable temperature and wet hands; dispense a small amount of soap into the palms of the hands creating a lather
- Using as much friction as needed, thoroughly clean all surfaces of hands including between the fingers
- Pay attention to the nails and nail beds by rubbing the nails of one hand across the palm of the other, creating enough friction to clean underneath the nails
- Rinse the hands under running water, being sure to hold the hands in a downward position
- Use paper towels or a warm air blower to dry the hands thoroughly
- Using the same paper towel, turn off the water supply

Questions and discussion issues

- On which plate were the most colonies observed?
- How many types of colonies were present on each plate?
- Did you succeed in removing all the micro-organisms from your hands?

Note:

Food handlers must wash their hands after:

- Handling money
- Using the toilet facility
- Touching face or hair
- Blowing the nose
- Handling raw meat/poultry
- Handling trash
- Eating or drinking
- Doing any other activity that may contaminate their hands

VII. ASSESSMENT OF FRESH PRODUCE QUALITY

Introduction

Fruit and vegetable consumption is growing globally. At the same time, consumers are becoming increasingly conscious of the quality of the fruits and vegetables that they consume. Satisfying consumer demand and assuring the markets for fresh fruits and vegetables therefore necessitates that produce is of optimum quality in terms of the state of ripeness, organoleptic quality and variety.

Quality is made up of many attributes, both intrinsic and extrinsic (Jongen, 2000). Intrinsic features of a fresh produce item include key external attributes such as colour, shape, size and freedom from defects, as well as internal attributes such as texture, sweetness, acidity, aroma, flavour, shelf-life and nutritional value (Hewett, 2006). Intrinsic components are the most important components of the subjective approach used by the consumer in deciding what to purchase. Extrinsic factors on the other hand, refer to production and distribution systems.

1. Measurement of quality

Determination of total soluble solids (TSS) using a refractometer

Introduction

During fruit development, nutrients are deposited as starch. As fruit ripen, these starch deposits are converted to sugar, leading to increasing sugar levels, which correspond to the 'taste' of the fruit. The measurement of total soluble solids (TSS) is therefore a suitable index for assessing the degree of ripeness of fruit of significant sugar content.

TSS is measured as °Brix using a refractometer. Some refractometers compensate for temperature change, while others may be calibrated for accurate measurement at 20°C.

Purpose

The purpose of this task is to determine the total soluble solids content of fruits using a refractometer.

Materials

The materials required are:

- A refractometer; and
- Fruit.

Procedure

Sampling fruit

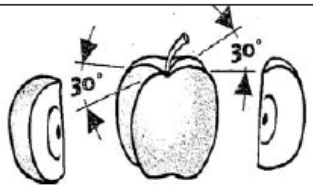
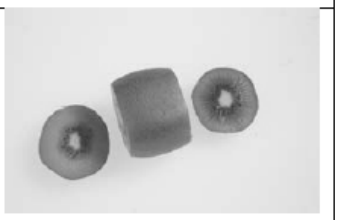
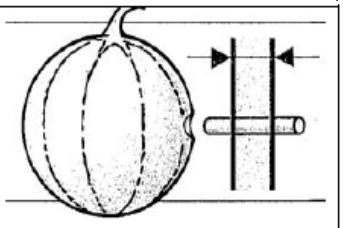
In order to evaluate a lot selected for inspection, a sample of at least ten fruits must be selected at random from the batch. In case of small fruits such as lychee, strawberries or cherries, ten sales packages must be withdrawn and at least five fruits must be sampled from each package. In situations where the fruit are bulk packaged, ten primary samples of fruit must be withdrawn. The fruits must be free from defects such as sun scorch as well as pests and diseases.

Sample preparation

Different sample preparation techniques apply to different commodities, as shown in figure 2.

Extraction of the juice sample for measuring soluble solids must take into account natural differences in the distribution of soluble solids within the fruit, for the species concerned. Although it is not possible to lay down precise sampling preparation guidelines for all produce, the overriding criterion is that the juice sample is, as far as possible, representative of the whole fruit.

Figure 2. Recommended juice extraction procedures for obtaining a representative sample of juice

Apples, Pears, Peaches and Nectarines	From each fruit two longitudinal slices (from stem end to calyx-end) are taken, one from the most coloured side and one from the opposite. The core is removed. The slice is squeezed longitudinally to get a mixture of juice from all regions.	
Apricots, Plums	Cut the fruit in half. Each half is measured to get a mixture of juice from all regions.	
Kiwifruit	Cut the stem and blossom ends at a distance of 15 mm from each end of the fruit and squeeze the two slices separately.	
Melons	Using a small diameter metal borer (1 – 4 mm) a core of melon should be extracted from the equatorial axis area. Each end of the core should be discarded i.e. the skin and the flesh area immediately beneath it and also the soft pulpy seed area. The remaining flesh should be used to extract the juice for testing.	

Melons – Two longitudinal slices are cut from the stem end to calyx-end: one from the side that touched the ground during growth and one from the opposite side. A sample of fruit flesh is cut off from the middle of each longitudinal slice, with the core and peel removed. This sample is squeezed to extract the juice for testing (see figure 3, below).

Figure 3 Sampling of fruit flesh from a melon

Table grapes and small fruits such as cherries, litchis, strawberries – At least five berries are taken from each bunch or sales package at different locations within the package. The berries can either be squeezed and tested individually or can be squeezed together for testing.

Citrus fruit – Each fruit must be cut in half, crosswise, and squeezed to extract all of the juice.

Tomatoes – Two slices must be cut longitudinally from the stem end to the calyx-end of the fruit. The slices must be squeezed longitudinally to yield a mixture of juices.

*Measurement of soluble solids content using a hand-held refractometer**:***

- Place an equal number of drops from the prepared fruit juice or the prepared fruit on to the refractometer prism plate
- Close the prism lid and turn the instrument towards the light
- If necessary, the eyepiece is focused until a clear image appears; the position at which the demarcation line between the light and dark regions crosses the vertical scale gives the percentage of soluble solids
- The reading on the prism scale is noted to one decimal place. After each test, the plate must be cleaned with distilled water, wiped with soft tissue and calibrated to 0.0

Measurement of soluble solids content using a digital refractometer

- Calibrate the refractometer:
    - Place several drops of distilled water on to the prism surface; this should give a reading of zero
    - Readjust the meter to zero if the reading is not zero
    - Wipe the prism dry using lint-free cloth
    - Place several drops of a 6 per cent sucrose solution on the prism – the reading should be 6 per cent; if not, the refractometer must be recalibrated by the supplier
- Place several drops of fruit juice on the prism
- Press the 'read' button to obtain a digital value

Recording the results

- Record the reading to one decimal place as well as the details of the cultivar, stage of maturity and ripeness
- Each reading for individual fruit bunches and sales packages must be noted; the sum total of all readings is averaged and rounded to one decimal place to give a meaningful figure
- If the juice is taken from two different parts of the fruit, the final reported reading is the average of that for the individual fruit
- If the average readings for all fruit are equal to or greater than the limit specified by standards, the lot has reached the minimum maturity level
- If the average readings for three or more of the ten fruits, bunches or sale packages are at least 10 per cent below the limit specified in the standard, a second sample must be taken

2. Measurement of fruit firmness using a penetrometer

Introduction

The firmness of a fruit is linked to the state of maturity and ripeness. Firmness may be influenced by fruit variety, as well as the region of production and growing conditions. This exercise describes an objective test to determine the firmness of fruit with the use of a penetrometer. A penetrometer is used by producers, packers and distributors for determining the stage of ripeness of a fruit, as well as by the retail trade to determine palatability and shelf life.

Firmness measurements are based on the pressure required to push a plunger of specified dimensions into the pulp of the fruit up to a specific depth. Penetrometers are calibrated in both metric (kg) and imperial (lbs) units and can cover different pressure ranges in accordance with the variety and stage of ripeness of the produce to be tested.

A plunger having a diameter of 8mm is generally suited to testing softer produce (e.g. peaches, nectarines, plums etc.), while one that is 11mm in diameter is generally used for testing firmer varieties of produce (e.g. apples and pears). A pointed plunger is used in the case of avocados.

The penetrometer must be bench-mounted on a fixed rigid drill stand to ensure that pressure is applied at a steady controlled rate and at a constant angle to the fruit. This is more difficult when using a hand held penetrometer.

Purpose

The purpose of this exercise is to determine the ripeness of fruit using a penetrometer.

Materials

The materials required comprise:

- Fruit; and
- A penetrometer.

Procedure

Sampling

Take a random sample of at least ten fruits when evaluating a lot for inspection. These fruit must be free from defects.

Sample preparation

- Remove an area of peel (only skin depth) of up to 2cm^2 from two opposite sides of the equatorial area of the fruit
- When the fruit has a peel of mixed colours, e.g. apples, the tests should be carried out where possible between the highest and lowest coloured portion of the surface

Measurement

- Hold the fruit firmly with one hand and rest it on a rigid surface
- The choice of plunger size and scale range used will depend on the type and the variety of the produce being tested and its stage of maturity and ripeness
- Adjust the penetrometer reading to zero and place the head of the plunger against the flesh in the peeled area of the fruit
- Apply steady downward pressure until the plunger has penetrated the flesh of the fruit up to the depth mark (half way up) on the plunger; slow, steady pressure is essential as sharp uneven movements may give unreliable results

- Remove the plunger and note the reading on the penetrometer dial to one decimal place
- Repeat the process on the opposite side of the same fruit after adjusting the penetrometer reading to zero
- All tests must be conducted as uniformly and carefully as possible in order to allow an accurate comparison of results
- Record the reading to one decimal place, as well all the details such as the maximum puncture force in Newtons, plunger size, cultivar or variety and stage of maturity tested

Calculations

- Average the readings for each individual fruit, then obtain an average of the sum total of all average readings to one decimal place
- If the average readings of three or more of the ten fruits are at least 10 per cent below the limit specified in the standard, the lot has reached the minimum maturity level
- If the average readings of three or more of the fruits are at least 10 per cent below the limit specified in the standard, a second sample needs to be taken and analysed with other fruits of the reduced sample or from a new sample. If the average of the two samples is below the limit specified in the standard, the lot fails the minimum maturity level and must be rejected

3. Measurement of pH

Introduction

The taste and flavour of fruits is greatly influenced by pH. Fruits in general have a pH of around 4.5. However, the pH of the fruit varies in accordance with cultural practices (fertiliser application), handling (microbial decay could result in a pH change), conditions of storage and transport and the storage environment of the produce.

Purpose

The purpose of this task is to determine the pH (acidity) of the fruit juice.

Materials

The materials required are:

- A pH meter; and
- Fruit.

Procedure

Sample preparation

- Three replicate samples, each replicate containing ten fruits, must be selected from the packaging or at the sampling point if the fruit size is small
- Depending on the type of produce, either cut the fruit in half and squeeze out the juice with an extractor or a juice-press – with citrus fruits, for example – or homogenise the flesh into a pulp
- Combine all of the juice extracts/homogenates collected from each fruit variety, and filter through muslin cloth to remove solids and peel
- Using a clean, dry 20ml pipette withdraw 20 ml of each sample in triplicate and transfer to a 50ml beaker.

Measurement of pH

- Follow the manufactures instructions
- Allow the pH meter to warm up for at least 30 minutes
- Remove the electrode from the cap containing potassium chloride (KCl) solution and rinse with distilled water in a cleaned beaker
- After drying, place the electrode in a pH7 buffer solution and calibrate the instrument. Later on, after rinsing the electrode with distilled water, calibrate with the second buffer pH4. Calibration must be done at 25°C
- During calibration or taking the readings make sure that the electrode does not touch the sides or bottom of the beaker
- Measure the pH of the fruit juice; record the reading to the first decimal point
- Remove the electrode and rinse it again in distilled water; dry and place the electrode tip back into the cap containing KCl solution

Recording results

- Readings must be taken for each of three samples; the final pH will be reported as the average of these three readings
- In situations where the final pH reading deviates from the standard value, the sampling process must be repeated.

4. Measurement of fruit acids by titration and calculation of the total soluble solids (TSS) to acid ratio

Introduction

The sugar to acid ratio is used a quality index for many fruits. This ratio is generally used to determine the maturity at harvest, on the packing line or at the point of export. This ratio has a significant influence on the taste and the flavour of the fruit and provides an indication of its commercial and organoleptic ripeness. At the beginning of the ripening process, the sugar to acid ratio is low, owing to the low sugar and high acid content of the fruit. During ripening, fruit acids are degraded, the sugar content increases and the sugar to acid ratio increases. Over- mature fruits have very low levels of fruit acids and lack characteristic fruit flavour.

Fruit acids are determined by measuring titratable acidity.

Purpose

The purpose of this exercise is to determine the maturity of fruit using the ratio of sugar to acid.

Materials

The materials required for the task comprise:

- A laboratory burette of 25 or 50ml capacity; alternatively an automatic burette can be used;
- A 10ml pipette, a beaker (250ml), a filter (muslin cloth) and an extractor or homogeniser;
- A bottle of distilled water;
- Sodium hydroxide (NaOH) – a standard solution of freshly made sodium hydroxide solution (either 0.1 M or 0.5 M) must be used. A 0.1M solution of NaOH solution can

be prepared by dissolving 0.4 g NaOH in 100 ml of distilled water); a 0.5M NaOH solution can be prepared by dissolving 2 g NaOH in 100 ml of distilled water) NaOH;
- Phenolphthalein – a 1 per cent solution of phenolphthalein is prepared by dissolving 1 gram of phenolphthalein in 100 ml of a 95 per cent v/v solution of ethanol. A 95 per cent v/v solution of ethanol is prepared by measuring 95 ml of 100 % ethanol into a 100ml volumetric flask and adding distilled water up to the 100 ml mark; and
- A pH meter – as mentioned above.

Procedure

Sampling
To evaluate the lot selected for inspection, take a sample of at least ten fruits of each size at random from the sampling points. Select fruits without defects.

Sample preparation
- Record details of the fruit cultivar, level of maturity and ripening stage
- Prepare samples as described above in the section on pH measurement

Titration
- Transfer 10 ml of juice to a beaker, using a pipette
- Add three drops of phenolphthalein indicator to the juice using a dropping pipette
- Fill the burette with 0.1M NaOH solution to reach the zero mark
- Slowly titrate the NaOH into the juice; care must be taken to ensure that the NaOH is dropped directly into the solution and does not adhere to the glass, otherwise the reading may be incorrect
- During the titration, continuously swirl the flask and observe closely. Phenolphthalein indicator changes very rapidly from colourless to a pink end point, which can be easily missed. It is therefore recommended that NaOH be added one drop at a time and the solution is thoroughly mixed by swirling after the addition of each drop closer to the end point of the titration
- The indicator is stable for a brief period of 30 seconds and is light pink in colour when viewed against a white background. The shade of the indicator can, however, vary according to the nature of the juice product being tested. If the point of neutrality is missed, i.e. the colour of the indicator is too dark; the test must be repeated. An indicator strip should be used to avoid the end point of pH 8.1
- The volume of NaOH used (titre) on the burette must be recorded
- Three titrations must be performed for each juice sample

Calculation of the TSS to acid ratio
Brix (TSS) values must be recorded prior to the titration. Calculations for determining the ratio of TSS to acid for all types of produce are similar. Different fruits, however, contain different concentrations of acids in different proportions. A multiplication factor (acid factor) specific to the predominant acid is, therefore, used.

Factors for common fruit acids:	
Citric acid:	0.0064 (citrus, lychee)
Malic acid:	0.0067 (apple, pineapple, mango)
Tartaric acid:	0.0075 (grapes)

Using citric acid as an example:
1ml of 0.1M NaOH is equivalent to 0.0064g citric acid.

Results expressed as percentage acid:

$$\text{Percentage acid} = \frac{\text{Titre x acid factor x 100}}{\text{10ml juice}}$$

$$\text{The TSS/acid ratio} = \frac{\text{TSS}}{\text{\% acid}}.$$

For example, the results can be expressed as:

Percentage citric acid

$$\text{Percentage citric acid} = \frac{\text{Titre x 0.0064 x 100}}{\text{10ml juice}}$$

Formula is simplified to:
Percentage citric acid = titre x 0.064

$$\text{TSS/acid ratio} = \frac{\text{TSS}}{\text{Percentage acid}}.$$

Reporting the results

- Results must be reported to one decimal place. If the TSS/acid ratio reaches the limit specified in the standard, then the lot has reached its minimum maturity
- If the observation is at least 10 per cent below or above the limit specified in the standard, a second sample test must be carried out. If the average of two samples is below or above the limit specified in the standard, the lot fails the minimum maturity level and must be rejected

5. Impact of handling

Purpose

The purpose of this task is to demonstrate the importance of packing and packaging of different commodities.

Materials

The materials required are:

- Fresh fruit; and
- Packaging material.

Procedure
This task can be carried out as a group exercise, with different groups packaging different fruits for different target markets.

- Identify a fruit or vegetable
- Identify a target market for the fruit
- Select appropriate packaging materials
- Pack the fruits

Discussion issues
- Who is the target market?
- Why was this type of packaging selected?
- What were the main considerations in selecting the packing configuration chosen?

6. Impact of ineffective cold chain management

Purpose
The purpose of this task is to demonstrate the impact of ineffective cold chain management.

Materials
Fresh fruit is the only material required.

Procedure
- Store different commodities at two different temperatures: optimum storage temperature and in a hot environment

Evaluate the quality parameters of the products using any of the above tests

Discussion issues
- Note the quality differences between the fruit

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