Food and Agriculture Organization of the United Nations

Food loss analysis: causes and solutions

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2018

ISBN 978-92-5-130637-6

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Abbreviations and acronyms

ADB	Agricultural Development Bank
ADP	Agricultural Export Diversification Project
CABA	Caribbean Agribusiness Association
CARICOM	Caribbean Community
CARIRI	Caribbean Industrial Research Institute
CARDI	Caribbean Agricultural Research and Development Institute
CAREC	Caribbean Epidemiology Centre
CLP	Critical Loss Point
FAO	Food and Agricultural Organization of the United Nations
FSC	Food Supply Chain
GDP	Gross Domestic Product
GORTT	Government of the Republic of Trinidad and Tobago
HCN	Hydrogen cyanide
IDB	International Development Bank
IFAD	International Fund for Agricultural Development
IICA	Inter-American Institute for Cooperation on Agriculture
ICTA	Imperial College of Tropical Agriculture
ILO	International Labour Organization
ISHS	International Society of Horticultural Science
LAC	Latin America and Caribbean
LLPB	Livestock and Livestock Products Board
LRTS	Low Temperature Research Station
MFPLMA	Ministry of Food Production Land and Marine Affairs (Trinidad and Tobago)
NAMDEVCO	National Agricultural Marketing and Development Corporation (Trinidad and Tobago)
NAMISTT	National Agricultural Market Information System (Trinidad and Tobago)
NAREI	National Agricultural Research and Extension Institute (Guyana)
NARI	National Agricultural Research Institute
NGMC	New Guyana Marketing Corporation
PHL	Post-harvest loss
RH	Relative humidity
SMCL	Sugar Manufacturing Company Limited (Trinidad)
THA	Tobago House of Assembly
TT	Trinidad and Tobago
TTD	Trinidad and Tobago Dollar
TTABA	Trinidad and Tobago Agribusiness Association
USAID	United States Agency for International Development
UWI	University of the West Indies
VS	Vascular Streaking

Acknowledgements

Authors of this study are Majeed Mohammed and Kelvin Craig. The study was edited by Joseph Mpagalile, FAO and Vyjayanthi Lopez, FAO.

The authors wish to acknowledge the support received from the Representatives of the Food and Agriculture Organization of the United Nations (FAO) in Trinidad and Tobago. Also acknowledged is the tremendous dedicated support of Ms Celest Butters, Agricultural Assistant 3, Mr Alimuden Juman, Agricultural Assistant 2, Mr Jason Ramsaran, Agricultural Officer 1, County St George, Mr Kadeem Mohammed, Entomologist of CARDI, Dr Janet Lawrence, Field Officer 2 of National Agricultural Marketing and Development Corporation (NAMDEVCO), Mr Abdullah Ali Baksh.

The support of Mr Nizam Hassan, Director Research, Ministry of Food Production Land and Marine Affairs (MFPLMA), Evans Ramkelawan, Technical Advisor, Tobago House of Assembly (THA), Dr Pathleen Titus, Senior Lecturer and Researcher, University of the West Indies (UWI), Dr Lynda Wickam,

Chief Executive Officer, NAMDEVCO, Mr Ganesh Gangerpersad and Packinghouse Manager, NAMDEVCO, Mrs Nirmala Persad.

Special gratitude and acknowledgement go to Dr Vyjayanthi Lopez from the FAO Subregional Office for the Caribbean and Dr Joseph Mpagalile at FAO Headquarters in Rome for their support and guidance.

Support from a number of Extension Staff is highly appreciated in Counties St George, Caroni, St Patrick and St David in Trinidad and Tobago; other staff from agencies such as THA, NAMDEVCO and UWI; industry experts; several farmers and farmers' groups; a number of retailers, intermediaries, wholesalers, exporters, processors, input suppliers, supermarkets and produce associations.

Executive Summary

Cassava (*Manihot esculenta* Crantz) is a woody perennial shrub of the Euphorbiaceae family. In view of its favourable agronomic traits, tolerance to abiotic stresses and adverse environments, the crop is produced by small farmers in marginal agricultural areas in the Caribbean as well as other parts of the world. In recent years in African, Caribbean and Latin American countries, cassava production has grown and is projected to increase further because of its demand as food and its value as raw material for industrial use. Cassava cultivars are classified into two groups based on the amounts of hydrogen cyanide (HCN) present. Sweet types contain less than 50 mg kg-1 (fresh weight) and are generally sold as fresh roots, whereas bitter types have a larger amount of HCN, but have higher yields and starch content.

Fresh cassava roots are highly perishable under ambient conditions, becoming unmarketable in 3 days or less. With proper post-harvest handling and management practices fresh roots can be stored up to 30 days. In recognition of the importance of cassava as a source of carbohydrates and the potential for further development of a diverse range of value-added products, FAO in collaboration with CARICOM initiated a project entitled *Reduction of post-harvest losses along the food chain in the CARICOM subregion* and identified cassava as one of the three commodities for post-harvest loss measurement.

The main objectives of the investigation included an in-depth analysis of post-harvest handling practices of cassava producers, retailers (roadside and mobile market vendors, municipal markets, supermarkets), wholesalers, exporters, processors for development of value-added products and consumers, to obtain a more complete understanding of the system-wide nature of quality deterioration and subsequent losses in order to formulate appropriate solutions for quality management and loss reduction strategies; analysis of the cassava value chain as items for food consumption, with quality attributes, which must be protected and enhanced in various marketing channels; the examination of the significance of losses of both technological and socio-economic origins; examination of links between growers and provisions for transferring relevant research information on identified problems to producers, traders and processors; the design and evaluation of improved operations throughout the system and alternative post-harvest handling systems; and the description of key factors affecting the logistics performance in the CARICOM Region with particular emphasis on logistics that affect produce losses in the supply chain.

Post-harvest losses of cassava were measured at three critical loss points (CLPs) after screening the value chains. The critical loss points were at harvest (CLP#1), packinghouse operations (CLP#2) and at retail markets (CLP#3).

At CLP#1 total losses averaged 6.5 percent mainly because of physical damage and pathological and entomological damage being 3 and 3.5 percent respectively. No physiological losses were measured at CLP#1 and 2 and total losses at CLP#1 were at least three times higher than CLP#2. Losses were cumulative and injuries to roots at CLP#1 created avenues for further quality degradation as the commodity was moved along the value chain to CLP#3. Nevertheless, while the nature of all types of damage was almost the same (3.5 percent) after 6 days of retail marketing, the limit to marketability based on qualitative ratings was only up to day 2.

Strategies to reduce post-harvest losses include the use of appropriate harvesting tools such as the hand lifter to minimize breakage; removal of roots within 2 to 4 hours after harvest and providing protection against sunlight to minimize the desiccation of roots; washing of roots to remove dirt and dipping in a fungicide such as immazalil to limit microbial contamination; storing treated roots in polyethylene bags at a safe low temperature and high relative humidity 85-90 percent; inducing curing treatment to heal superficial wounds by keeping roots at 28-30 °C and 85-90 percent relative humidity; and application of wax treatment at 55-65 °C for a few seconds after treatment with a fungicide.

Chapter 1
Introduction

Background information

A high incidence of post-harvest losses exacerbates the problems of low agricultural productivity and food security in countries of the Caribbean Community (CARICOM). Post-harvest losses cause the quality and quantity of food to be severely reduced, thereby affecting incomes and impacting on the rural poor in the region. The Food and Agriculture Organization of the United Nations (FAO, 2011) indicated that post-harvest losses are highest in developing countries. Fonseca and Vergara (2014) reported that in the Latin America and Caribbean (LAC) Region 50 percent of the fruits and vegetables and 37 percent of roots and tubers are lost before they reach consumers. They further stated that improving logistics systems and management would be an efficient approach to reducing losses across the supply chain. They found that failure in logistics operations including product handling, precooling, packaging, storage, transportation, and inappropriate infrastructure, are among the most common reasons for the high quantities of food losses. These estimates do not include loss of quality, nutritional value and the health burden associated with consuming contaminated food products.

Several factors contribute to post-harvest losses along the supply chain such as preharvest factors, environmental hazards (inadequate temperature and relative humidity control) pests and diseases and senescence. Reducing the incidence of post-harvest losses along the food chain in the CARICOM subregion will contribute to improving food availability to address food insecurity, enhance food quality through better packaging, handling and storage, increase economic access to food through job creation and income-generation, and create efficient logistics systems to improve market access by delivering the right product at the right time.

Efforts to combat this situation in the past were unsuccessful partly because countries lack the required and up-to-date information about the scale of the problem that could help them develop programmes to address the problem. This lack of reliable and up-to-date information has continuously prevented governments, the private sector and other key stakeholders from implementing workable solutions. While there is increasing acknowledgement among governments in the CARICOM Region and the international community that post-harvest loss (PHL) reduction is one of the key elements required to reduce food insecurity, the use of inappropriate and out-dated approaches is limiting current interventions. This rapidly changing context, resulting from urbanization and globalization, means that interventions that were once regarded as successful may no longer be so, which is causing governments to improperly handle the challenges facing the post-harvest sector.

Given the need to better understand the strengths and weaknesses of the post-harvest handling systems in the CARICOM and to identify, plan and implement interventions policies and practices, FAO identified two countries, Guyana and Trinidad and Tobago to conduct detailed value chain analyses pertaining to cassava, tomato and mango.

Study objective

The main objective of this study was to conduct an in-depth analysis of post-harvest handling practices of cassava producers, marketers, processors and consumers, to obtain a more complete understanding of the system-wide nature of quality deterioration and subsequent losses so as to formulate appropriate solutions for quality management and loss reduction strategies. Furthermore, the assessment sought to identify the critical loss points and causes of losses at these points by using PHL assessment methodologies and tools. In addition, desk research was conducted to identify cost effective, environmentally friendly and gender appropriate solutions to reduce post-harvest losses, drawing on an inventory of past and current technologies and practices both within the region and outside.

Chapter 2
Methodological approach

Selection of countries and subsectors

CARICOM Member Countries Guyana and Trinidad and Tobago were selected for this study based on the importance of the targeted subsectors: cassava, mango and tomato. In addition, the assessment was conducted in Saint Lucia, which is not only a CARICOM Member Country but also a member of the Organization of Eastern Caribbean States (OECS). The study in Saint Lucia was undertaken to compare and verify the results obtained in Guyana and Trinidad and Tobago.

Selection of food supply chains

Three subsectors that are important in the CARICOM region were identified during a preceding study. The identification of these priority crops followed an in-depth desk study to review available information on production, post-harvest handling including processing, marketing, export, etc. for the major food crops in the CARICOM Region. Reports from previous studies conducted by the FAO, CARICOM, regional institutions and other national and international organizations were analysed. Several crops were identified that are important in the agricultural systems in the region. However, cassava, tomato and mango emerged as important food value chains and were therefore recommended as the priority crops for the project on the reduction of food loss and waste in the CARICOM Region.

Selection of stakeholders

The cassava value chain includes a highly diverse and complex number of producers (farmers) and traders (market types: farmers' or public municipal, roadside, mobile, supermarkets, processors) characterized by widely scattered production areas and fragmented marketing facilities. This structural variety, coupled with widely differing post-harvest practices among participants, posed considerable challenges to this investigation, which attempted to understand the entire value chain and its operations. Field observations and interviews were of paramount importance in discovering the differences in post-harvest operations among the diverse range of producers and marketers, as well as those linked to cultural methods in different locations of the study.

In Trinidad, farmer's market retailers and wholesalers were randomly selected from the updated and revised list compiled by the National Agricultural Marketing and Development Corporation (NAMDEVCO), while all wholesalers interviewed were from the Macoya and the Debe wholesale markets. The selected retail markets were Tunapuna, Chaguanas, Sangre Grande and Marabella.

Only supermarkets were chosen that had been in operation for the past 3 years, in possession of refrigerated displays and having a minimum output of 12 to 15 kg of cassava. At each market outlet, every stage where there was the potential for reduction of marketable quality and eventual manifestation of post-harvest losses, from the field in the case of a producer, or from procurement in the case of a trader to the point of consumer purchase was selected for in-depth analysis. This approach is referred to as the 'systems approach'.

Methodology and data collection

The methodology used for this study involved a literature review; collection and analysis of documentation and technical information on cassava; selection of the specific supply chains for the study and justification for this choice. Identification of 3 to 4 stages in the food chain where the losses are higher or have the greatest impact and selection of 1 to 2 for detailed analysis and participation and contribution to the development of a comprehensive approach, including appropriate tools for data collection and analysis to identify the scope and limitations of the study as well as gaps, to ensure that all marketing aspects, including handling and shipping were included. The implementation strategy for this study embraced the FAO recommended Food Loss Assessments methodology, which was adapted to the Caribbean situation when required.

Study approach

The study had four main components:

Literature review and search of previous studies documented by regional institutions such as the FAO, the Caribbean Agricultural Research and Development Institute (CARDI), the Inter-American Institute for Cooperation on Agriculture (IICA), the University of the West Indies, the University of Guyana, the University of Trinidad and Tobago and other national institutions such as the respective Ministries of Agriculture, Central Marketing Agencies and stakeholders such as the Agricultural Society of Trinidad and Tobago, the National Food Crops Farmers Association and the Trinidad and Tobago Agribusiness Association was undertaken to identify ongoing work in the field of food losses and examine the completeness and gaps.

Selection of the specific supply chains and the geographical area (countries) of the study and justify the reasons for this choice – The main actors in the supply chain of each commodity included farmers, processors, retailers, wholesalers, supermarkets and associations. Selection was based on production and marketing volumes from data obtained from the national marketing institutions in both countries. Processing companies or cottage industries involved in development of major value-added products from each commodity in each country were also included.

Conducting and managing field interviews – Approximately 2.5 months were spent in the field to conduct interviews and collect data. In an effort to catalogue all the standard operating practices in the cassava value chain, a set of themes of inquiry was developed to guide the interview process and to compile a questionnaire. Preliminary interviews identified the themes to be included in the questionnaire. All interviewees cooperated, many enthusiastically, when the interview was conducted within their own work environment in a two-way fashion, that is, employing the 'mirror image technique' (Ref).

The main elements of the mirror image technique involve dynamic, face to face interviews revealing an interpersonal process with key decision-makers associated with production, post-production, processing into value-added products, distribution and marketing functions; the consultants establish a rapport with interviewees while marshalling an extensive complex of variables in an intensive environment; the consultants have the flexibility to switch from a non-directive role, during the early stages of the interview, to a more directive one afterwards; examining post-harvest practices with respect to each theme of inquiry; perceptions among cassava farmers of the possible nature of post-harvest problems in terms of changes in quality and losses were examined; automatic checks were set up by tracing and tracking the original causal factor so as to avoid data collection errors arising from interviewees' bias, lack of knowledge of the correct answer or deliberate falsification of data.

Management of the interviews varied from farmer to trader to processor. While some were located with the assistance of the Agricultural Assistants in the county extension offices of NAMDEVCO in Trinidad and Tobago, others were located using their addresses as they appeared in the list of registered farmers and processors. On several occasions, cassava farmers were met while attending Agricultural District Meetings. A combination of methods was used with supermarket retailers being informed by telephone to alert them of the existence of the survey, potential objectives and uses. Interviews with wholesalers, public markets, mobile market and roadside market vendors were conducted at the actual location, mostly without previous arrangement. Interviews almost always took place in the midst of the activity characteristic of post-harvest operations. As such the consultants were able to pose questions in the work environment and, in many cases, to actually witness the traders' decision-making where and when it occurred.

The great advantage of being able to observe and record manifest behaviour pertinent to systematic processes needed to be tempered by strict attention to methodology. It was imperative that the consultants, stayed in an observational role, and did not introduce themselves into the process to the extent that they became a variable thereby altering, even imperceptibility, the actual decision-making environment. The consultants and technicians recognized their presence could encourage a typical response. These effects were believed to have been minimized after thoroughly crosschecking responses with a wide variety of outlets.

Identification of 3-4 stages of the food chain(s) where the losses are higher or have the greatest impact and detailed analysis of 1-2 – The critical loss points (CLPs) were identified by observation, the literature review, interviewing of experts, marketing quality assurance officers and field officers in each country. For each commodity supply chain one value-added product was followed at the particular processing facility either a village industry or larger-scale processing company. For each commodity a flow diagram was prepared to pinpoint the location of the CLPs and this was investigated in detail to identify causes and potential solutions. At least two stages were identified for detailed analysis during systematic evaluation of losses of the entire post-harvest handling system of each commodity and where there was potential for post-harvest losses to dominate.

Description of the key activities of the study

The flow of cassava from the point of harvest to consumption for producers and traders was documented by observing and recording the duration of each component of the system, the time taken for the cassava to move from one component to the next, including delays as well as measurable characteristics of the environment, i.e. temperature, relative humidity and time of day. In addition, hands-on familiarization with the cassava handling operations provided the framework for examining typical patterns of decision-making and actions taken by participants within the cassava value chain. This also provided information on the dynamics of the cassava value chain and permitted for its comprehensive mapping. By inserting the stages of the post-harvest handling system for cassava within the value chain also provided the template for tracking and tracing and, more importantly, identification of the CLPs. The key activities carried out during the study are summarized below.

Screening was conducted to identify the additional information or new information, survey and analysis to be provided on food losses in the cassava subsector. Flow charts were used to show the various stages in moving cassava from the farmer or producer level to various market outlets, namely, farmer's, mobile retail, wholesale, supermarkets, roadside and export, and processing plants for development of value-added products. The range of post-harvest losses at each stage along the commodity handling system was

FIGURE 1
Analysis of the cassava value chain

Pre-production ↓ **Production** ↓ **Postproduction** ↓ **Sales**

Pre-production

Crop attributes and inputs
- Favourable agronomic traits
- Tolerance to abiotic stress and adverse environment
- Drought resistance
- Early water stress and poor soil fertility limit production
- Breeding improvements targets nutritional content, disease resistance and yield

Production

Pre-harvest production
- Labour constraints
- Virus disease limitations
- Early planting spacing, monocropping, weeding and delayed harvesting can increase yield
- Varietal selection prolongs harvest with fewer physiological disorders
- Global production projected to increase by 2030

Postproduction

Post-harvest storage and transportation
- Fresh roots deteriorate after 2 to 3days
- Bulky and heavy to transport
- Low cost storage technology can increase shelf life to 2 weeks
- Value-added processing
- Processing reduces cyanide content, reduces weight and increase consumption
- Reduces post-harvest losses and increases marketing period
- Provide ingredients (starch, purees, flour) for tertiary products in baked products

Sales

Commercialization
- Limited international trading
- Limited industrial uses in the Caribbean
- There is potential for regional and internal trade in cassava flour, chips, starch, frozen logs and purees.

analysed based on available studies and reports. Frequent meetings, short questionnaires using electronic process and face-to-face or telephone interviews and or actual visits to sites to enable the action plan. Figure 1 provides a general view of the various activities screened by the consultants on preproduction, production, postproduction and sales characterizing the cassava value chain.

Survey – This involved mapping the current state of knowledge of the selected commodity and how it is handled in the wet and dry season in the particular market. Field data were collected from the point of harvest to the point of retail. Close attention was placed on the implications of indigenous handling practices on post-harvest losses and identification of best post-harvest practices to eliminate or reduce such losses. The methodology employed the proposed 4-S (Screening, Sampling and Survey, and Synthesis) approach for loss assessment based on the Food Loss Assessments methodology recommended by FAO as well as the diverse lessons learned by FAO's Rural Infrastructure and Agro-Industries Division.

Sampling was used in tracking and tracing the dynamic nature of the commodity handling system based on cultivar, season and market type, documentation of harvesting methods, harvesting techniques, maturity indices used, precooling practices, transport links to packinghouses, packinghouse design and process flow patterns. Thus all the steps indicated above covered environmental conditions, atmospheric composition, management practices to assist in determining the actual causes for quality deterioration at each step and the possible implication for cumulative losses. The questionnaire and site visits identified critical areas where there were post-harvest losses. By recording the above, then at harvest, the relationships between harvesting practices and post-harvest losses were assessed; identification of alternative methods for improving harvesting practices were determined as well as whether negative or positive effects could be determined from the resulting harvesting tools.

Cassava samples were purchased at each CLP and at the exact location where the activity of that particular stage was observed. Each sampling consisted of three replications of 12 to 15 kg of randomly selected cassava, which was representative of a market load. Simulated post-harvest storage trials of cassava samples were conducted in the laboratory at the UWI and evaluated after 2, 4, and 6 days similar to marketing conditions observed and recorded during field and market visits.

Each cassava sample was examined for marketable quality on a scale of 1 to 9 based on a method developed by Sherman *et al.* (1982) with 1 = unusable, 3 = unsalable, 5 = fair (limit to marketability), 7 = good and 9 = excellent. Each cassava sample was examined for damage and classified into two broad categories: marketable and unmarketable, based on the severity of the damage. The unmarketable cassava samples were designated as the post-harvest loss, weighed and the percentage loss calculated against the original weight. To determine the nature of the damage in the unmarketable category, cassava samples were further subdivided into three categories according to the nature of the apparent damage at that location, that is, physical, physiological and pathological and entomological.

Physical damage included cuts, bruises, punctures, scratches, splits, crushes, abrasions and cracks. Physiological damage included vascular streaking 1 and 11 (VS-1, VS-11), moisture loss (wilting, shrinkage), chilling injury. Pathological and entomological damage included that caused by fungi, bacteria, and insects. The weights in each category of damage were recorded and the percentage of post-harvest losses calculated for each category. Total post-harvest losses were obtained by summing the losses recorded at each CLP (Figure 1). Cassava samples were also taken to the University of West Indies and the National Agricultural Research and Extension Post-harvest laboratories to collect data on root dimensions, firmness and total soluble solids.

Synthesis involved visiting centres or institutions such as the respective Ministries of Agriculture, marketing and research agencies for production and marketing data and farms to observe cropping practices. In addition, the type of data and analytical procedures that are necessary to guide policy-makers when engaging in strategic interventions to improve the post-harvest handling system for the selected commodity were determined. Policy options concerning key logistics to reduce post-harvest losses through application of simple inexpensive post-harvest innovative methods that would strengthen the post-harvest knowledge system were analysed and recorded. The marketing channels of each priority crop in each country were appropriately defined based on observations, analysis and feedback. Costs were calculated for the respective volumes of produce associated with each value chain as well as for post-harvest losses as determined by the surveys.

Chapter 3
Situation analysis

RELEVANT INSTITUTIONS

Ministry of Food Production Land and Marine Affairs (MFPLMA) is a Biochemistry Laboratory Unit, which was established in Trinidad in 1983 at the Central Experimental Station, Centeno, where post-harvest research is conducted on a wide-range of tropical fruits, vegetables and root crops. The findings of this research are fed into other divisions of the Station and to the extension arm of the MFPLMA. There is also a farmer training centre at the MFPLMA Station where several post-harvest short courses and workshops are held throughout the year to educate farmers, extension field officers, marketers, exporters on essential post-harvest operations from field harvest to produce display and consumption. Training is also focussed on strategies to optimize quality and reduce post-harvest losses.

University of West Indies is another key institute in the region. Post-harvest studies are currently being pursued in both faculties on innovative methods to reduce losses of tropical commodities and to enhance value-added products. The UWI has also conducted several workshops throughout the Caribbean. The Third International Conference on Post-harvest and Quality Management of Horticultural Products of Interest to the Tropical Region was held by UWI in July 2013 in Trinidad under the auspices of the International Society of Horticultural Science (ISHS). The theme was 'Post-harvest technological initiatives to improve food security and market access'. A follow-up workshop entitled 'Post-harvest management strategies to reduce losses of perishable crops' was held in Trinidad from 24–25 February 2014 by UWI/CTA/NAMDEVCO to train certified farmers, exporters and field officers.

Trinidad and Tobago Agri-business Association (TTABA) is a 'For Development Company' established in May 2006 by private sector agribusiness stakeholders with government support to accelerate national economic and social development through the sustainable expansion of the agribusiness sector. As a 'for development not for profit company' TTABA is not owned by private shareholders but by its current 33 member associations drawn from every level of the agribusiness sector. The company cannot disburse dividends or profits to individual members but must reinvest its profits to further its objective of actively leading the development and expansion of the agribusiness sector in Trinidad and Tobago.

National Agricultural Marketing and Development Corporation (NAMDEVCO) is a statutory body created by Act of Parliament No. 16 of 1991 to replace the Central Marketing Agency. NAMBEVCO is mandated *"to create, facilitate and maintain an environment conducive to the efficient marketing of agricultural produce and food products through the provision of marketing services and the stimulation of business investment in the agro-industrial sector of Trinidad and Tobago"*. NAMDEVCO's Market Information System is now on-line. This process resulted in an improved system of collection, compilation and dissemination of market information and intelligence. In addition, NAMDEVCO monitors the activities of certified farms in order to forecast the availability of produce.

In 2003 NAMDEVCO established a Packinghouse Facility at Piarco, which was driven by the need for exporters of fresh agricultural products to access the higher end markets in developed countries, particularly supermarket chains. The Packinghouse offers any exporter or private sector the opportunity to receive, temporarily store, process, package, and ship produce bought from certified farms; thereby ensuring the quality of products necessary to make exporting fresh agricultural produce a profitable enterprise.

Users of the facility who wish to fill container loads of produce for ocean-freight can access a

FIGURE 2
Post-harvest handling activities at a packinghouse facility at Piarco, Trinidad and Tobago

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power supply and adequate turn-around space for their articulated vehicles. Storage capacity includes three (3) chilled compartments, which can accommodate approximately 60 tonnes of products at any time, and a frozen compartment, which holds about 30 tonnes of products. Recently a Blast Freezer with approximately 1 000 kg per 12 hour cycle was installed. Close proximity to the airport and its good road linkage with the major seaports makes the location of this facility particularly attractive to exporters.

DESCRIPTION OF SUBSECTOR SUPPLY CHAIN WITH GENDER DISAGGREGATED DATA

The distribution of the population in Trinidad and Tobago by administrative divisions and gender, the 2000 Population and Housing Census indicates that of 1 262 336 people resided in Trinidad and Tobago in 2000, most of the population, 95.7 percent, lived on the island of Trinidad, while 4.3 percent lived on Tobago. In absolute and percentage terms, Tunapuna/Piarco accounts for the largest share (16.2 percent) of the national population, followed by Couva/Tabaquite/Talparo (12.9 percent) and San Juan/Laventile (12.5 percent)[1].

The gender distribution of the population by administrative division was similar to the national pattern; however, with slightly more females than males in the cities of Port of Spain and San Fernando. Women also outnumbered men in the highly urbanized Municipal Corporations of Diego Martin and San Juan/Laventile. Men slightly outnumbered women in the remaining administrative divisions.

The 2000 Trinidad census also indicated that the agricultural sector, comprising commercial and subsistence agriculture workers provided 6.3 percent of the total employment in 2000 (NCR, 2009). The important commercial crop was sugarcane, which accounted for 29.2 percent of the total employment in the agricultural sector, but engaged only 1.9 percent of the employed work force in 2000. Other agricultural commodities produced in Trinidad and Tobago include, rice, cacao, coconuts, citrus fruit, flowers, vegetables and livestock and poultry (NCR, 2009).

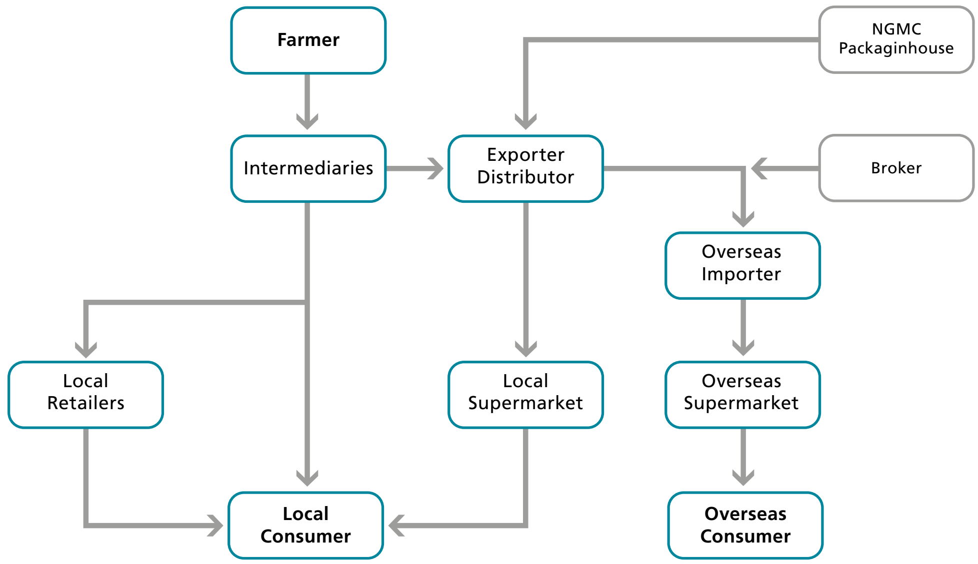
It should be noted that the Trinidad and Tobago 2000 census observed that the high proportion of women, in what would be called non-economic activity (unpaid) is generally misleading, as many women, who report being engaged in 'home duties', are usually involved in some small activity, e.g. making sugar-cakes, mitai, etc. or tend a garden to supplement family income or have a small income of their own. Further, some other non-economic activities performed by women such as cooking or caring for the family are usually chores that are normally paid for where women work and should be valued as a contribution to the household budget.

IDENTIFICATION OF ONGOING WORK ON REDUCTION OF POST-HARVEST LOSSES

There is no evidence of ongoing work on post-harvest losses for any commodities in Trinidad and Tobago. During the time period of the present survey the Ministry of Agriculture was engaged in a cassava cost of production survey in Trinidad and Tobago and conducting a face-to-face survey using a structured questionnaire, which asked a few questions about cassava defects after harvest but

[1] CARICOM Statistics. (Available at: http://www.caricomstats.org/Files/ Publications/ NCR%20Reports/ Trinidad%20and%20Tobago.pdf).

FIGURE 3
Current non-traditional agriculture value chain



Note: Some farmers also act as intermediaries.

did not focus on an estimation of cassava losses. The major gaps are: systematic measurement of post-harvest losses at each step of the system was not determined and the nature of losses based on type of damage, market type, season, cultivars were not determined.

DESCRIPTION OF THE EXISTING MARKETING SYSTEMS

In Trinidad and Tobago cassava is grown throughout the island in a wide-range of soil types. The areas with the highest production include Bejucal, Brasso, Caparo, Rio Claro and Freeport. In Tobago cassava is grown in every village but is more concentrated in Les Coteaux, Glamorgan and Belle Garden.

In Trinidad cassava is eaten boiled, fried, as the dominant starch food component in main dishes with meat and fish. Cassava is also processed into frozen cassava logs, purees for the baking industry, cubes, pone mix, patties, fries, flour and bread.

In Tobago a more diversified and innovative range of cassava value-added products are produced. These include cassola, fruitcake, punch, colada, khurma, callaloo, quiche, coocoo, granola, farine, wine, pizza, bread, ice cream, animal feed, pone puff and pastelles. These products are manufactured by Tobago Cassava Products Ltd, a company that operates under the auspices of the Tobago House of Assembly (THA), which was established in 2009. A market survey conducted by Mary King and Associates in 2008, commissioned by the Division of Finance and Enterprise Development (THA), indicated that cassava is the most viable crop for agroprocessing in Tobago. Products identified were farine, frozen cassava and cassava flour. Some of these products can be seen in the photographs (Figure 4).

The main varieties that are grown traditionally in Trinidad and Tobago include Maracas Black Stick. Butter Stick and MCOL. These varieties are no longer popular, compared to the cultivar MMEX, which is favoured by farmers in Trinidad because it can be harvested and marketed over a longer period from 7 to 15 months. The others, if harvested after 7 to 8 months, tend to get bitter, fibrous and woody.

FIGURE 4
Different cassava products being marketed in Guyana

(a) Cassava for sale at roadside vendor

(b) Farine at GMC's Guyana Shop

(c) Mini cassava bread

(d) Cassava bread squares

(e) Cassareep for sale at Guyana Shop

FIGURE 5
Different cassava products being marketed in Tobago

Cassava farine

Cassava bread

FIGURE 5
(Continued)

Cassava fruitcake

Cassava khurma

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FIGURE 6
Cassava beverages sold at Tobago Cassava Shop

Cassava punch (small size portion)

Cassava cola

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FIGURE 7
Other value-added cassava products sold at The Tobago Cassava Shop

Cassava value-added products

Cooking cassava farine in Tobago

Tobago Cassava Shop

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Chapter 4
Study findings

SECONDARY DATA AND KEY-INFORMANT (EXPERT) INTERVIEWS

Literature review

Production and postproduction research and outreach activities on cassava in Trinidad and Tobago have been documented in several bulletins, factsheets, international conferences and workshops. The Faculty of Chemical Engineering and Faculty of Agriculture at the University of the West Indies (UWI) Saint Augustine Campus, have spearheaded these research and outreach activities. Professor L.A. Wilson, Dr L.D. Wickham, Dr T. Ferguson, Dr G, Sirju-Charran and Dr L. Roberts-Nkrumah are leaders in tropical root crops. Also, bulletins on cassava production have been written by W. Charles and a factsheet on cassava production was written by F. Chandler, who are both from CARDI.

UWI in collaboration with TTABA, NAMDEVCO and MFPLMA have investigated cassava processing into various products including flour, chips, purees. The THA in Tobago has also conducted market studies for these value-added products. More recently an FAO, UWI regional meeting on the cassava value chain was held in Barbados and a presentation was made by Dr M. Mohammed and Mr K. Craig on post-harvest losses of cassava and quality management along the value chain. Presentations were also made by Dr J. Lawrence of CARDI, Mr Vassel Stewart of Caribbean Agribusiness Association (CABA), and Ms P. Titus of THA.

TTABA has also produced a working document on cassava best practices including information on quality requirements for fresh and processing for contract farmers in Trinidad and Tobago. Dr Wickham continues to publish and supervise students at undergraduate and postgraduate levels in post-harvest physiology and the biochemistry of various cassava cultivars during storage. She is currently engaged in product development studies on cassava and other root crops. As Deputy Dean, Outreach, she has also focused on developing techpaks for other countries in the Caribbean.

Review of the production and value of the produced cassava

Data are not available on the area of cassava planted and the volume of processed cassava products produced such as cassava casareep, cassava chips, cassava bread and egg ball, which is a boiled egg fried in a thick batter of previously boiled cassava. These are all made by small, primarily home-based cottage industries that fall outside the normal monitoring system and are difficult to monitor in every respect.

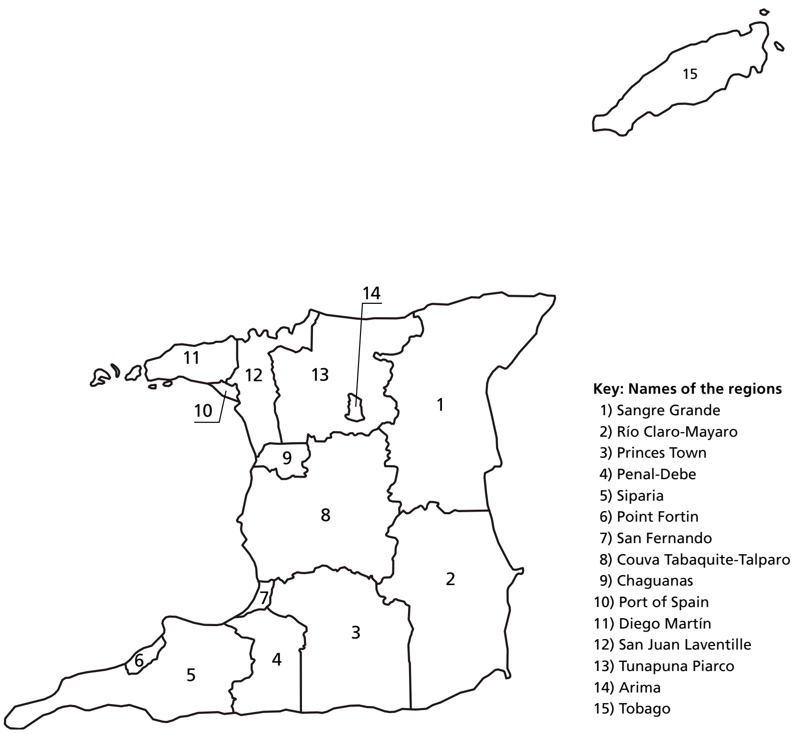
The consultants are not aware that there is any gender disaggregated data related to the cassava value chain, however, it is common knowledge that cassava production is also exclusively a male dominated activity. Men and women farmers are directly engaged in wholesaling and retailing, which is the same for wholesaling and retailing by intermediaries. However, the intermediary function of purchasing cassava at the farmgate seemed to be mostly by men; while retailing at the various municipal and other markets was almost exclusively by women. Further to the above, in the

TABLE 4.1
Volume of fresh cassava tubers produced in 2007–2012

Year	2007	2008	2009	2010	2011	2012
Volume	1 200	1 350	1 400	1 794	1 950	2 000

Source: NAMDEVCO

FIGURE 8
Map of Trinidad and Tobago showing the administrative regions



Source: http://d-maps.com/pays.php?num_pay=159&lang=en

coastal regions, the manufacture of products such as cassava pone, cassava chips, cassava bread and egg ball were almost exclusively by women.

The volume of cassava tubers produced in Trinidad and Tobago between 2007 and 2012 increased steadily from 1 200 tonnes in 2007 to 2 000 tonnes (Table 4.1). The main production areas were Tunapuna/Macoya, Caparo and Rio Clara (Figure 8).

Table 4.2 shows that during the 2006–2013 period the wholesale prices for fresh cassava tubers at the Macoya market ranged from TTD 3.46/kg in 2007 to TTD 8.48/kg in 2013. Wholesale prices in 2012–2013 were essentially double the prices in 2006–2007. At the Macoya market, 70 percent of people engaged in wholesaling activities and interviewed were men and 30 percent were women. Observations at this market suggested that men and women were engaged in wholesaling activities in a 70 (men):30 (women) ratio. The reverse ratio was found for retailing activities at Macoya. Retailing was conducted at the Chaguanas municipal market by approximately 65 percent women and 35 percent men.

Pre-packaged frozen cassava products were easily found in the main supermarkets in Trinidad. As shown in Table 4.3, they included frozen cassava logs, cassava cubes, grated cassava and cassava dumpling. The most popular sizes were 500 g and 1 000 g. Prices varied slightly between brands. Frozen logs were on average TTD 16/500 g – obviously this is expensive, particularly when compared to frozen potato fries. However it is available for those who can

TABLE 4.2
Average prices at Norris Deonarine northern wholesale market, 2006-2013

Crops	Unit	2006	2007	2008	2009	2010	2011	2012	2013
Cassava	kg	3.96	3.46	3.84	4.63	4.64	4.33	7.85	8.48

USD 1=TTD 6.40 (approx.)
Source: NAMDEVCO

TABLE 4.3
Summary of retail price ranges for pre-packaged major frozen cassava products sold at the main supermarkets

Product	Average price (TTD)	Weight
Frozen cassava	15.99	500 g
	15.58	500 g
	30.24	1 000 g
Cassava logs	15.99	500 g
	24.43	900 g
	22.99	1 000 g
Cassava cubes	9.79	500 g
	21.49	908 g
Grated cassava	25.49	900 g
Cassava dumpling	26.60	700 g

USD 1 = TTD6.40 (approx.))
Source: NAMDEVCO

afford to purchase and is an important step in the development of the industry.

Principle cassava supply chains

The main cassava supply chain in Trinidad is in the Cunupia/Caparo area of Central Trinidad even though the Tunapuna/Macoya area of North Trinidad and the Rio Claro area of South Trinidad are also cassava producing areas (Table 4.4).

Table 4.4 shows the six stages of the FSC against a number of parameters, associated with the FSC in Trinidad and Tobago. These include location, months of the year available, product(s), nature of project support, facilities and equipment, duration and distance and inputs and services. The tables also show how each FSC ranks in terms of economic importance, job creation, and its contribution to income-generation, foreign exchange and food security. The cost of production and the value of products at each stage are also shown where the information is available.

The Central Trinidad FSC is considered to be economically important and contributes to employment-generation and some poverty reduction. It could not be ascertained to what extent, if at all that cassava production and trade is contributing to increased foreign exchange but it is certainly contributing to foreign exchange savings at the national level through the sale of frozen cassava logs and cubes that are substituting frozen potato fries.

The major final product in Central Trinidad is frozen cassava logs, which are available at major supermarkets. In addition, boiled and fried cassava and cassava pone are eaten throughout Trinidad and Tobago. Boiled and fried cassava is available in public, mobile and roadside markets and at various food courts. On the other hand, cassava pone, which was traditionally made at home, can now be purchased from bakeries and eaten as a dessert or a snack between meals.

Figures on the volume of cassava produced by each supply chain are not available but NAMDEVCO data indicate that there are 10 cassava producers in North Trinidad, 3 in Central Trinidad and 5 in South Trinidad. Over the years, TTABA, NAMDECO, UWI, CARDI and MFPLMA have all provided support to cassava production, processing and marketing.

HISTORY OF GOVERNMENT AND PRIVATE SECTOR INVOLVEMENT IN THE SUBSECTOR

The economy of Trinidad and Tobago (TT) is dominated by the petroleum industry and is therefore very susceptible to external shocks induced by movements in energy prices. This reality has signified the need for economic diversification hence the national economic policy and strategy place great emphasis on growth of non-oil foreign exchange earnings and relatively labour-intensive sectors of the economy, such as tourism, agriculture, agro-processing, and financial services.

Primary agriculture is an economically small but socially important sector and accounts for 16.7 percent of the land area. Agriculture contributes minimally to GDP (1.02 percent in 2004),

TABLE 4.4
Detailed description of the cassava supply chain of Caparo

Stage in food supply chain	Location	Months of the year	Number of actors	Products	Volume (Tonnes)	Facilities/ Equipment	Duration/ Distance	Inputs and Services	Cost of production (TTD)	Value of products TTD
Primary production	Caparo	January-December	35	Cassava tubers	400	Tractors and ploughs for land preparation; cutlass for cutting planting material	Year-round	Planting material, fertilizer, labour for cleaning, weed control and drain maintenance	175 000/ha	
Harvest	Caparo	January-December	35	Cassava tubers	400	Forks, bags, wheel barrow	Year-round	Labour to harvest, bag and load roots into pickups	40 000/ha	4/kg
	Chaguanas		35	Cassava tubers			8-12 km to Chaguanas municipal market, about 25-30 minutes; 4-6 km to Couva municipal market, 20-25 minutes;	Labour for loading, transportation and packaging		
Storage	From farm to wholesale or retail markets and to packinghouse	January-December	35		316	Store at ambient temperature 28-32 °C; RH 75-80 %	12-15 km to Chaguanas municipal market, about 30-35 minutes	Labour for sorting, grading, packaging	500/tonne	10/kg
Transportation	From farm to Macoya wholesale market; from farm to supermarket; from farm to packinghouse	January-December	35	Cassava tubers	310	Pickups, trucks, vans		Driver, labour for loading and unloading	1 500/tonne	11/kg
Retail market sales	Several municipal markets including Chaguanas, Tunapuna, Macoya; roadside, mobile markets and supermarkets		30	Cassava tubers	307	Covered and open air markets; trays of pickups	Year-round	Driver, labour for loading and unloading, selling	1 200/tonne	7.00/kg

TABLE 4.4
(Continued)

Stage in food supply chain	Location	Months of the year	Number of actors	Products	Volume (Tonnes)	Facilities/ Equipment	Duration/ Distance	Inputs and Services	Cost of production (TTD)	Value of products TTD
Packinghouse	NAMDEVCO Packinghouse at Piarco	January - December	5	Cassava tubers	3		Year-round			
Processing	NAMDEVCO Packinghouse at Piarco	January - December	5	Cassava tubers	1.8	Washing equipment including power washer, washing / soaking / storage bins; work tables; refrigeration room, cutting devices, trolleys, sanitizers	Year-round	Labour to receive and record, wash, peel, cut, treat, pack, weigh, label, store, dispatch, record	180/tonne (subsidized by NAMDEVCO as an incentive)	
Storage	NAMDEVCO Packinghouse at Piarco	January - December	5	Frozen cassava logs	1.8		Overnight soaking at the packinghouse – ambient temperature 28-32 °C; After vacuum packing storage in freezers at (minus) -18 °C			
Transportation	From packinghouse to supermarkets markets in TT	January - December	5	Frozen cassava logs	1.8	Pickups, trucks, vans	10-25 km to supermarkets, about 25-35 minutes		560/tonne	
Wholesale	Major supermarkets and hotels in TT	January - December	5	Frozen cassava logs	1.8	Freezers	Year-round	Driver, labour to load and unload, sell		
Retail	Major supermarkets in TT	January - December	5	Frozen cassava logs	1.8	Open front freezers or freezing cabinets	Year-round			23-30/kg

but is a significant employer (5 percent of those employed) and important to the rural socio-economy. Agro-industries (food, beverage and tobacco) are a significant segment of national GDP (3.1 percent in 2004) and manufacturing GDP (45.2 percent). The country is a net importer of food but a net exporter of beverages and tobacco products.

Other noteworthy characteristics of the agricultural sector are that most holdings are small – nationally 87.1 percent of holdings were less than 5 ha with 22 percent being smaller than 0.5 ha; in Tobago 45.8 percent of holdings were under 0.5 ha. Many private farmers, 76.5 percent, listed farming as their only or main occupation and 55.3 percent received in excess of half of their income from farming. 14.7 percent of farmers were women; 3.7 percent of farmers had no formal education, while 60.2 percent had primary and 27.9 percent had secondary. The age profile of farmers is skewed towards the elderly; 35.4 percent of farmers were over 55 years with 15.4 percent over age 65. Nationally, 11.3 percent of agricultural land was irrigated and 33.6 percent subject to flooding. 82.9 percent of the land area (representing 69.3 percent of parcels) is owned/rented/leased and 8.4 percent (representing 17.2 percent of parcels) is held by squatters. Chronic labour shortages are a feature of agricultural endeavours. This may be partly because the sector provides the lowest returns and wages in the country.

The agriculture sector in Trinidad and Tobago has been in relative decline for several decades and declined in absolute (real) terms in 2003 and 2004. The decline has been attributed to external factors identified as economic structural transformation and changes in the global trading environment, while domestic constraints have been identified as weak research, extension and marketing systems, inadequate area under irrigation, flooding and praedial larceny.

INVENTORY OF ACTIVITIES AND LESSONS LEARNED FROM PAST AND ONGOING INTERVENTIONS

The Government of Trinidad and Tobago's goal for the agricultural sector is to create a secure nation and this concept is well-articulated in the Ministry of Food Production Land and Marine Affairs (MFPLMA) Action Plan for 2012–2015. Food security is defined by FAO (1996) as existing "*when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life*".

In Trinidad and Tobago, the MFPLMA Action Plan recognizes that the concept of food security is linked to health, sustainable economic development, environment and trade. To achieve this, it is imperative that a higher level of food production and effective utilization of fisheries resources is needed in a sustainable manner to strengthen the agricultural sector. The MFPLMA has therefore focussed on the development of six commodity groups namely staples (rice, dasheen, cassava, eddoes, sweet potatoes, breadfruit), vegetables (pumpkin, dasheen bush, ochro, tomato, hot pepper, cucumber), fruits (citrus, Sucrier banana, pineapple, mango, dwarf pommecythere, papaya, avocado, watermelon, banana/plantain, coconut), pulses (pigeon peas, bodi), livestock (sheep and goats for meat, dairy goats and cattle for milk, rabbits for meat, buffalypso/buffalo for meat and milk), aquaculture (frozen tilapia), strategic commodities (cocoa, honey).

For each commodity group emphasis was placed on increasing production and postproduction capacities to ultimately attain a greater degree of self-sufficiency, promotion of food security as well as development of export markets for these commodities. The main elements of the plan of action for each commodity group included development of technology and infrastructure for post-harvest storage and handling to alleviate problems of inconsistent supply and quality. In this context additional packinghouses (Trinidad 4, Tobago 1) would be constructed at strategic locations. Packinghouses equipped with modern packing-line facilities including washing, drying, precooling, sorting, grading, hot water treatments, waxing and other hormonal, fungicidal and bactericidal treatments, packaging, storage and post-storage logistics management so that post-harvest losses could be reduced. Development and commercialization of a range of value-added products such as bakery items, fries, snacks and breakfast cereals within the scope of postproduction strategies to reduce food waste were noted as well.

The MFPLMA Action Plan for agriculture contains strategies for development of the sector through the creation of an enabling environment framework, which includes:

- **Policy revision** (Livestock Policy, Fisheries Policy, implementation of revised agricultural incentive programme, agriculture trade policy, land use policy, integrated coastal zone management policy, national agricultural health and food safety authority).
- **Legislation** to review archaic legislative acts

such as the Land Adjudication Act, The Plant Protection Act, Animal Health Act, Fisheries Management Bill, Cocoa and Coffee Industry Board Act, Land Surveyors Act, Praedial Larceny Bill, State Land Bill.

- **Post-harvest technologies** to further develop post-harvest management to improve quality, shelf-life and the food safety of fresh crop and livestock products in order to increase returns to farmers, reduce post-harvest losses and ensure safer fresh produce for consumers.
- **Post-harvest logistics management** through an infrastructural development programme for improved agricultural access roads to reduce physical damage during transportation from field to packinghouse facilities and market distribution channels, water management and flood control to reduce production losses, training of young professionals in post-harvest technology to reduce losses, internships, conferences, workshops at farmer training centres, universities and community institutions, marketing infrastructures, research and development, information and communication technology, development of tech-packs, innovative harvesting , loading devices to reduce physical damages.

CURRENT POLICY FRAMEWORK ON SUBSECTOR FOOD LOSSES

The Government of Trinidad and Tobago is taking steps to redevelop the sector and has proposed interventions within the framework of the National 20/20 Vision Plan. The core implementation strategy emphasizes the need to increase productivity, profitability and competitiveness through adoption of improved technologies, varieties and new commodities; improving efficiency and effectiveness of marketing and agricultural health and food safety systems, and linkages with agro-industry. The core strategy is complemented by efforts to reduce constraints of infrastructure, land tenure, credit and production risk.

The programmed interventions for addressing the above constraints are contained within the 5-year National Medium Term Investment Plan with overall objectives to increasing farm profitability and international competitiveness, expansion of the irrigated area under cultivation, strengthening of the marketing system and links to demand centres, improving effectiveness, efficiency and productivity of the infrastructure and systems for research, extension, training, and agricultural health and food safety, support to agricultural planning and developing alternative strategies for productive and profitable use of agricultural land including a specific focus on unused sugar land, reducing the risk of praedial larceny and encouraging more effective participation of industry and farmer organizations.

The sector has access to a range of services to further the process of agricultural and rural development. The Ministry of Food Production, Land and Marine Affairs and the Tobago House of Assembly are both involved in providing research, extension, regulatory and administrative services to the agricultural sector. There are a number of public agencies whose mandates address specific areas of intervention. These are the National Agricultural Marketing and Development and the Marketing Division of the THA for Marketing; the Agricultural Development Bank for agricultural finance; the Cocoa and Coffee Industry Board to develop the cocoa and coffee industries; the Sugar Manufacturing Company covering the manufacture and export of sugar; and the Livestock and Livestock Products Board to ensure the effective management and development of that subsector. Moreover, there are a number of farmer and industry organizations that include the Agricultural Society, which is a broad umbrella organization for all farmers and industry organizations such as the Poultry Association.

Moreover, Trinidad and Tobago hosts a number of regional and international organizations. These include: the University of the West Indies (Faculty of Food and Agriculture and Faculty of Engineering); the Caribbean Agricultural Research and Development Institute; the Caribbean Epidemiology Centre (CAREC); the Caribbean Industrial Research Institute; Centre for Agriculture and Biosciences International works in the area of biological control of insect pests; and the internationally recognized Cocoa Research Unit based at the University of the West Indies, Saint Augustine Campus. Trinidad and Tobago also hosts the offices of the Inter-American Institute for Cooperation on Agriculture and the FAO.

At the regional level, the Jagdeo Initiative 3, which was endorsed by the Government of the Republic of Trinidad and Tobago (GORTT), provides a framework and strategy for regional agricultural development. Spearheaded by President Bharrat Jagdeo of Guyana, which encompasses the entire CARICOM agrifood/product system. The aim is for "*the creation of an enabling economic and business environment* *for competitive and sustainable agricultural and rural development*". The main critical constraints affecting agriculture in the region were identified, and strategies developed to overcome these constraints within the context of improved international competitiveness.

The strategies identified: creating an enabling environment for business and private sector enterprise, including farmers; improving supply capacity and competitiveness; establishing and strengthening of private sector organizations; and refining the resource management capabilities for business and trade efficiency.

The actions outlined in Trinidad and Tobago's Medium Term Investment Priority Framework are designed to complement this regional initiative while making the requisite domestic adjustments to address challenges and to exploit the many opportunities.

PRELIMINARY ANALYSIS OF POST-HARVEST LOSSES (SCREENING)

Cassava post-harvest handling system

Figure 4 highlights the cassava post-harvest handling system and value-added products based on information obtained from previous studies, and

FIGURE 9
Cassava post-harvest handling system and value-added products

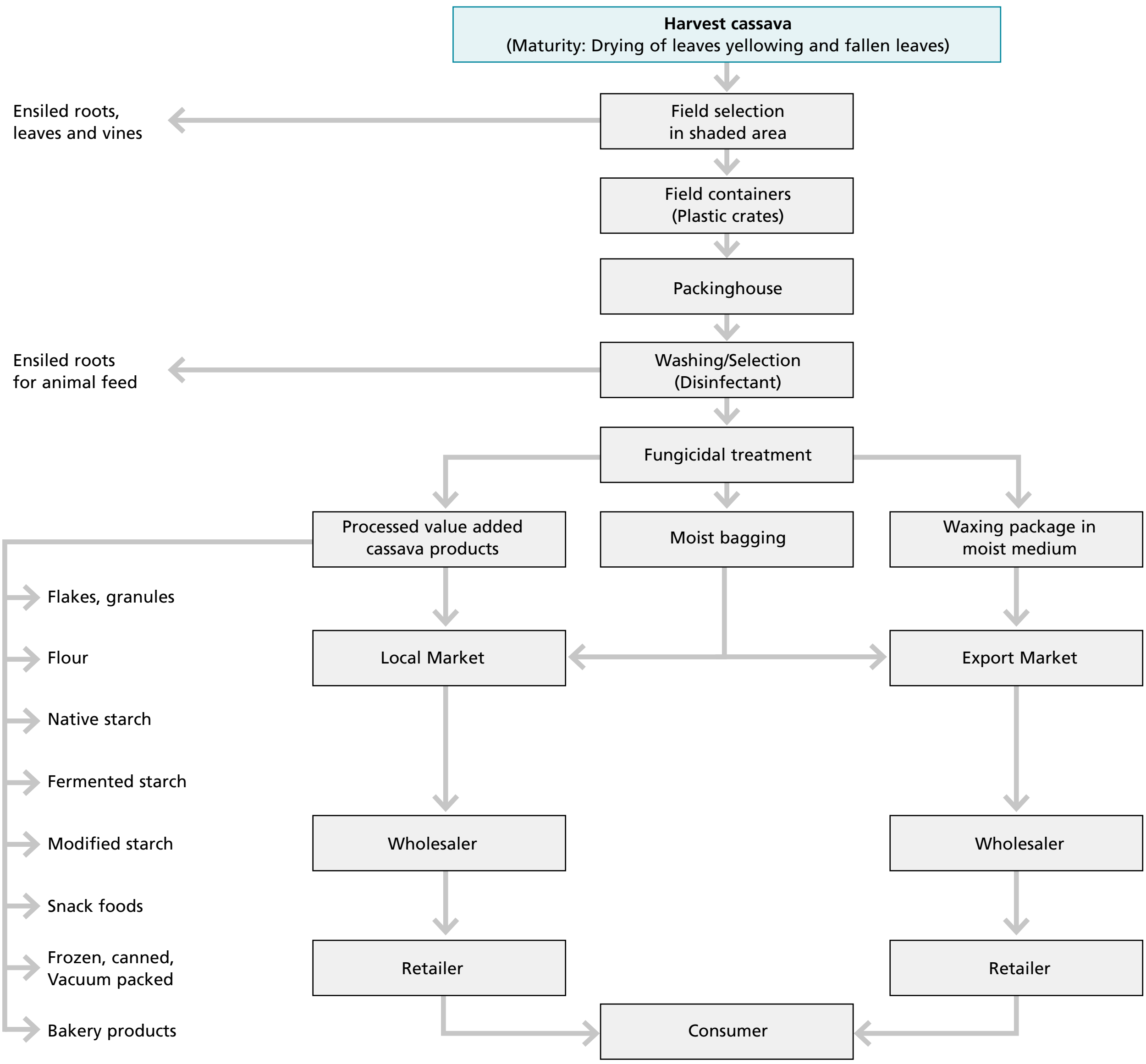
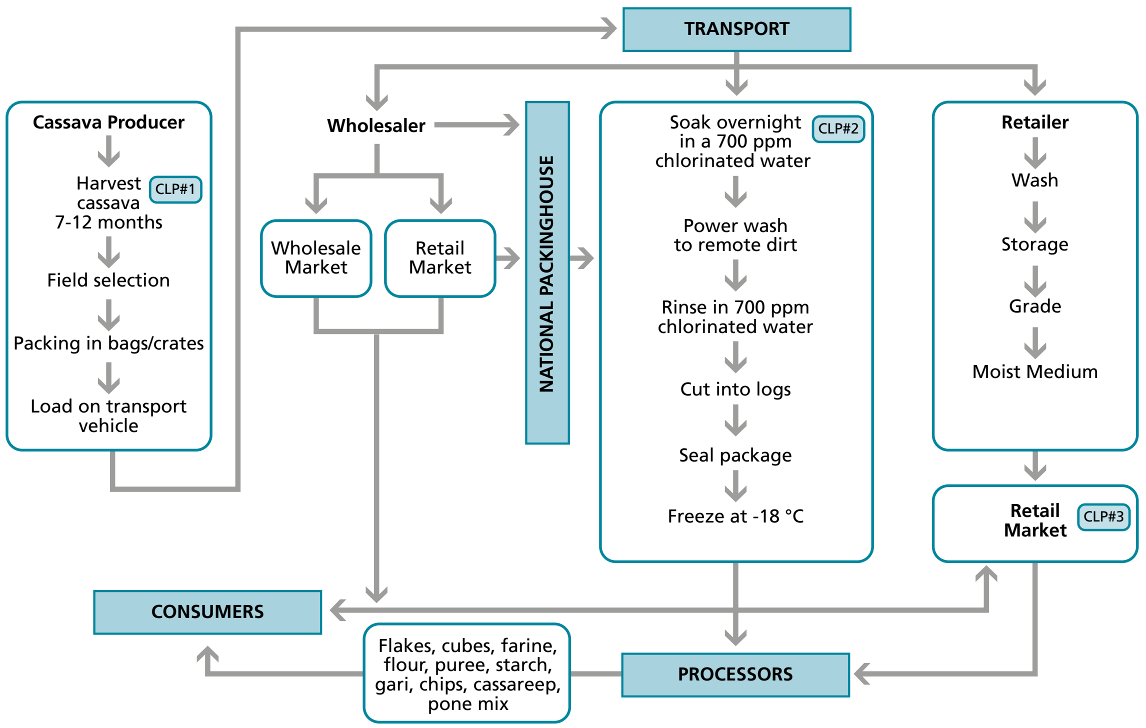


FIGURE 10
Cassava value chain in Trinidad and Tobago



from discussions with several experts working in root crops postproduction technology. The major actors involved in the cassava value chain included farmers who sell to wholesalers and processors, farmers who retail at farmer's markets, roadside markets and mobile markets. There are also wholesalers who source from several producers and processors and process the product into frozen cassava logs, frozen grated cassava and cassava pone mix.

Brief description of the cassava value chain

The cassava value chain includes a highly diverse and complex number of producers (farmers) and traders (market types: farmer' or public municipal, roadside, mobile, supermarkets, processors) characterized by widely-scattered production areas and fragmented marketing facilities. The flow of cassava from the point of harvest to consumption, for producers and traders, was documented after observing and recording the duration of each component in the system, the time taken for the cassava to move from one component to the next, including delays as well as measurable characteristics of the environment, i.e. temperature, relative humidity and time of day.

In addition, hands-on familiarization with the cassava handling operations provided the framework for examining typical patterns of decision-making and action taken by participants within the cassava value chain. This also provided information on the dynamics of the cassava value chain and allowed for comprehensive mapping of the cassava value chain (Figure 10).

By inserting the stages of the post-harvest handling system for cassava within the value chain provided the template for tracking and tracing and, more importantly, identification of the critical loss points (CLPs). As shown in Figure 10, the following components were identified as the CLPs for cassava (CLP#1 harvesting, CLP #2 packinghouse operations, CLP #3 retail display), where qualitative and quantitative losses were measured.

Chapter 5
Food losses

CRITICAL LOSS POINTS – TYPE AND LEVEL OF FOOD LOSSES

The types of losses associated with cassava in Trinidad and Tobago were both quantitative and qualitative with critical loss points occurring at field harvest (CLP#1), packinghouse (CLP#2) and retail marketing (CLP#3). The qualitative and quantitative losses are presented in Table 5.1 and Table 5.2 .

SAMPLE ANALYSIS

The average of three replicates, with each replicate comprising five cassava root samples, were analysed for fresh weight, length, width and total soluble solids as shown in Table 5.3. Data were also taken on prevailing environmental conditions at the critical loss points in the cassava value chain (Table 5.3).

CAUSES OF LOSSES

Quality losses of cassava roots initiate in the field and are primarily associated with the manual method of uprooting plants using a fork to loosen the soil from the roots and a cutlass to separate roots from the mother plant. The resultant physical damage were punctures and abrasions when incisions were made by the fork on the peel and flesh as well as breakage at the primordial and distal ends caused by the manual force exerted when the root was extracted from the soil and with the subsequent separation of the soil from the roots. Quality losses varied around 30 percent in Trinidad and Tobago, and were not only related to the equipment and method of harvest but to the soil type as well.

Most times separate field labourers were engaged in the actual uprooting of the plants from

TABLE 5.1
Qualitative losses occurring in the cassava value chain

Stage in food supply chain	Quality reduction (%)
Harvesting method	4
Bagging and loading	2
Transportation and unloading	5
Packing houses	10
Wholesale market	2
Retailing	7 (after 3 days)

TABLE 5.2
Quantitative losses occurring in the cassava value chain

Critical loss points	Quality reduction (%)
Harvesting	6.5
Packinghouse	2.0
Retailing	14.5
Supermarkets	1.5
Wholesale markets	0.5
Total	**20**

TABLE 5.3

Quality attributes of cassava and environmental conditions at the three critical loss points

Parameter	Quality attributes		
	Trinidad and Tobago		
Fresh weight (kg)	0.28 - 0.48		
Length (mm)	208.60 - 265.10		
Width (mm)	42.80 - 57.60		
Total soluble solids	3.20 - 3.50		
Environmental conditions			
	Skin temperature °C	**Pulp temperature °C**	**Relative humidity (%)**
CLP# 1	30 - 32	34 – 36	60 – 65
CLP# 2	27 - 29	29 – 30	55 – 65
CLP# 3	31 - 33	35 – 37	55 – 65

TABLE 5.4

Types of post-harvest losses of cassava at critical loss points

Critical loss points (CLPs)	Types of post-harvest losses (%) unweighted				
	Physical	Physiological		Pathological and Entomological	Losses (%)
		VS-1	VS-11		
Field harvest CLP#1	1.5cd	0.0a	0.0a	2.0de	3.5g
Packinghouse CLP#2	1.0bc	0.0a	1.0bc	1.5cd	3.5g
Retail marketing CLP#3:					
Day 2	0.5ab	1.0bc	0.0a	0.5ab	2.0de
Day 4	1.0bc	1.0bc	1.0bc	2.0de	5.0i
Day 6	1.0bc	1.5cd	2.5ef	1.0bc	6.0j
Supermarket	0.5ab	2.5ef	4.5hj	0.0a	7.5k
Losses	5.5i	6.0j	9.0l	7.0k	27.5m

Data taken on three replications of (12-15 kg) cassava x 10 times at different locations
Ambient conditions: 28-32 °C and 65-75 percent RH. VS: Vascular Streaking.

the soil, while others were employed to place the harvested roots in polypropylene bags. This often created major logistical impediments that impacted negatively as they accelerated quality losses in the field. Harvested roots with physical damage created avenues for contamination from adhering soil, damage from insect infestation, water loss, secondary pathological infection as roots were left exposed to prevailing high temperatures and low relative humidity, as shown in Table 5.3 for periods ranging from 4 to 6 hours.

Quantitative losses

Post-harvest losses of cassava in Trinidad and Tobago were 27.5 percent for farmers who retailed at the public, roadside or mobile markets. At CLP#1 post-harvest losses averaged 3.5 percent similar to that measured from samples measured at CLP#2. At CLP#3, where roots were displayed for sale under ambient conditions, post-harvest losses were 13 percent by day 6. Degradation of root quality progressed further at CLP#3 than CLP#1 and CLP#2 respectively, thereby confirming the cumulative nature of posthavest losses (Table 5.4).

The data in Table 5.4 show there are significant differences in the nature of losses at the CLPs. At

FIGURE 11a and 11b
Manual harvesting of cassava late (left), showing physical damage to cassava (right)

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FIGURE 12a and 12b
Pith breakdown resulting from waterlogging

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CLP#1 total losses averaged 6.5 percent mainly as a result of physical damage and pathological and entomological damage was 3 percent and 3.5 percent respectively. No physiological losses were measured at CLP#1 and 2, and total losses at CLP#1 were at least three times higher than for CLP#2. Losses were cumulative and the injuries to roots at CLP#1 created avenues for further quality degradation as the commodity moved along the value chain to CLP#3. Nevertheless, while the nature of all types of damage was almost the same (3.5 percent) after 6 days of retail marketing, the limit to marketability, based on qualitative ratings, was only up to day 2.

Physical damage included splits, lateral cracks and skin abrasions, wounding from harvesting equipment (forks and cutlasses mainly used), skin abrasions, skin and flesh bruises, punctures and stem and distal end breakages (Figure 11a and 11b). Damage was caused by inappropriate harvesting tools, over packing in polypropylene bags, abusive drop heights during loading and unloading in the field onto transport vehicles. Transportation from field to packinghouses over rough, narrow roads with cassava bags stacked 3–4 layers high without any buffer to cushion overhead weights resulted in the multiple physical injuries described above.

Physiological disorders were not detected at CLP#1 but cassava roots had visible evidence of moisture stress. At CLP#1, however, pathological and entomological losses accounted for 2 percent of post-harvest losses as waterlogged soils persisted because of the unusual high rainfall in the last 2 months of 2013, which continued into January 2014 when data were being collected.

FIGURE 13
Cassava brown streak caused by *Botryodiplodia theobromae*

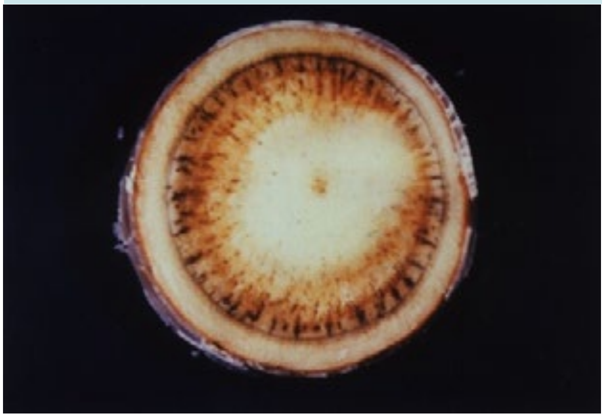
Cassava brown streak
Botryodiplodia theobromae
Root rot disease emergence is often favoured by waterlogged, poorly-draining soils

Rotting tubers cut open to reveal discoloration

Discoloration on tubers surface caused by root rot

SOURCE: J. ARACENA, 1993

FIGURE 14
Vascular streaking of cassava roots due to severe physical damage followed by secondary microbial development



SOURCE: J. ARACENA, 1993

These conditions ultimately promoted microbial decay, causing pith breakdown near the peduncle more so on farms where cassava samples were cultivated in low lying areas such Caroni, Felicity, Cunupia, despite having cambered beds (Figure 12). Entomological damage was associated with insect damage causing cassava brown streak to develop, which is also related to waterlogged soils (Figure 13) (Tables 5.4. and 5.5).

Post-harvest losses of cassava at CLP#2 amounted to 3.5 percent , while losses caused by physical damage was 1 percent. Likewise, physiological disorders such as vascular streaking (VS-11), identified as dark bluish or brownish radial veins or streaks near xylem vessels of the root pith (1 percent) and pathological and entomological was 1.5 percent, (Tables 5.4). The incidence of VS-11 was directly related to environmental field conditions, where temperatures were above 30-32 °C for over 6 hours, impacted negatively on damaged root skin and flesh, which eventually became invaded by soil-borne pathogens (Figure 14).

At CLP#3 cassava roots had the highest levels of losses as duration of retailing increased from 2 to 4 to 6 days. Cassava is usually retailed under ambient conditions (Table 5.3). Thus initiation of physical damage, resulting from wounding at harvest, was aggravated by multiple handling during loading, reloading, handling by consumers on the display as well as breakage from over-packing in polystyrene bags and emptying from variable drop heights onto relatively hard surfaces, factored significantly in the severity of the damage thereby conferring higher incidences of VS-1 and VS-11 as retailing time increased (Tables 5.4 and 5.5). The higher incidence of VS-11, which was indicative of moderate to severe physical damage leading to a blue-black pigmentation of vessels, which commonly appeared on or adjacent to microbial infected areas of the root (Figure 14) was slightly higher for cassava samples examined in Trinidad and Tobago than for Guyana.

Vascular streaking (VS1 and VSII) was a major post-harvest problem of cassava displayed for sale in supermarkets. Prevalence of low relative humidity (45-55 percent) within air-conditioned rooms having a temperature of 23 °C promoted moisture loss, particularly where roots had been broken. Extensive desiccation accounted for poor overall appearance. The 7.5 percent losses incurred were not absorbed by supermarkets but were actually sustained by the suppliers. A mutually agreed contact between suppliers and supermarket

FIGURE 15
Packinghouse operations for frozen cassava logs at NAMDEVCO facility


Soaked overnight


Power washed


Sanitized roots


Cutting and peeling


Peeled logs

Frozen logs

produce managers mandated that the supplier had to reclaim all cassava roots that had been classified as unmarketable.

The most popular cv. MMEX grown in Trinidad and Tobago has a longer harvesting interval that allows for staggered harvesting from 7 to 15 months and they do not become bitter; although some of the roots become fibrous after 13 months.

TRACING AND TRACKING

Several value-added cassava products are sold in supermarkets including frozen cassava logs, frozen grated cassava, cassava pone mix and cassava bread. Frozen cassava logs were selected to trace and track the quality of cassava at the point of reception and to review and monitor quality changes and losses through the various processing steps, whereby the fresh cassava roots were transformed into a tertiary product such as frozen cassava logs. Meanwhile discussions with six supermarket produce managers revealed they do not experience any losses from frozen cassava logs. The supplier was identified and a traceability study was undertaken.

The national marketing agency in Trinidad and Tobago NAMDEVCO gave the supplier a written contract at a highly subsidized fee to conduct all the processing steps including washing, soaking of roots in chlorinated water (700 ppm sodium hypochlorite) overnight, power washing to remove adhering dirt, second dipping of roots under the same level of a sanitizing agent for 1 hour, chopping of roots 6.35-7.62 cm (2.5 to 3 inches) long, skin removal, third dip in 700 ppm sodium hypochlorite for 1.5 hours, seal packaging in high-density polyethylene bags followed by blast freezing at -18 °C (Figure 15). The supplier then distributed the packaged frozen cassava logs to selected supermarkets.

When the various steps were traced, from the supplier to the finished product, post-harvest losses were 34 percent and 37.5 percent if cassava roots were obtained from sandy and clay soil types respectively (Table 5.5). These losses were determined from initial reception loads of 680-700 kg of fresh cassava roots. Cassava roots originating from fields dominated with clay soils sustained as much as 16.5 percent losses due to dirt and peel from the power wash operation but secured only 3 percent losses from vascular streaking as opposed to 11.5 percent from fields dominated with sandy soils. Water stress was more severe in sandy soils than the clay soils and could be a factor

FIGURE 16
Ungraded and graded cassava roots with larger diameter roots with core splits

Ungraded desiccated roots — Grading scheme

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TABLE 5.5
Post-harvest losses of frozen cassava logs according to soil type

Type of post-harvest loss at the packinghouse CLP2#2	Processor (frozen cassava logs)	
	Sandy soil	Clay soil
Soaking/Washing/ Sanitizer (peel, dirt)	9.0	16.5g
Fresh-cut into logs (Broken pieces, distal and proximal ends)	13.5f	12.0e
Physiological: VS-1	3.5b	1.0a
VS-11	8.0d	2.0ab
Pathological and Entomological	5.5c	6.0c
Total Losses (%)	34.0h	37.5i

responsible for the differences encountered. It was also noted there was a lack of sorting and grading prior to the cassava roots being soaked at the packinghouse. Tubers without a definite core split, as shown in Figure 16, did not incur broken chips when chopped into logs compared to roots with a larger diameter where core splits were observed. Losses from broken chips and breakage at the distal and proximal ends were 12 percent and 13.5 percent for sandy and clay soils (Table 5.6).

FOOD LOSS REDUCTION STRATEGIES – CONCLUSIONS AND RECOMMENDATIONS

Field harvest (CLP#1)

The following food loss reduction strategies are recommended for producers and marketers. The use of a manual hand lifter shown in Figure 17 should be recommended and made available to farmers to reduce physical damage during harvesting. Consideration should be given to engineering inputs for the design of this harvesting aid, which must be at an affordable price, or subsidized by governments, national marketing boards or agricultural associations for cassava producers. Also harvesting containers should be sturdy plastic crates, ventilated and light coloured to reflect heat and stackable so that overfilling would be discouraged. Plastic crates with handles would also reduce abusive handling during loading and unloading as well as reduce potential damage caused by dropping from a height.

Trinidad and Tobago cassava producers should pattern the strategy used by their Guyanese counterparts who uproot the plants, isolate the roots and pack at the same time. This would signifi-

FIGURE 17
Hand lifter as harvesting aid to reduce damage of cassava roots

Harvesting aid to reduce injury Roots with no physical damage

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FIGURE 18
External and internal insect damages

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cantly reduce unwarranted exposure of roots to high field temperatures, as described previously, which would ultimately minimize water stress and postpone or delay the incidence of vascular streaking. Farmers in both countries must place roots in a shaded area such as under a tree or preferably in a field shed, and then sprinkle water to keep roots moist, and even cover containers with broad leaves or polyethylene bags.

Other activities could take place in the field shed such as removal of dirt from the roots, field sorting to eliminate defective roots, that is, roots that are undersize, with external and internal insect damage (Figure 18), oversized and woody roots with deep lateral skin and flesh wounds (Figure 19) and roots showing flesh breakdown and discolouration resulting from pathological agents (Figure 20) and other associated field-borne diseases.

It is essential that farmers transport harvested cassava in plastic crates to the packinghouse within 1 to 2 hours following harvest. The current practice of leaving harvested roots for more than 4 hours in the field, where they are exposed to high temperatures, and then placing roots into containers afterwards must be discouraged. The use of polypropylene bags should be discouraged and these should be replaced with plastic crates.

Logistical arrangements to rent, or encourage farmers' groups and associations to pool resources to purchase large amounts of plastic crates at affordable prices, would be beneficial

FIGURE 19
Skin and flesh wounds including lateral cracks

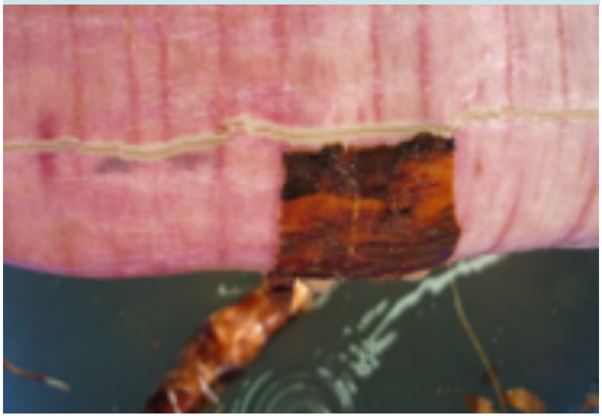

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FIGURE 20
Flesh breakdown and discolouration

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FIGURE 21
Cured and uncured cassava roots

Cured roots

Uncured roots

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based on their durability, sanitizing efficiency, multi-purpose uses and potential for reducing physical damage during loading, unloading as well as to optimize field to packinghouse to market transportation linkages. This suggestion will need to be guided by awareness and economic considerations. Construction of feeder roads, and the use of trucks equipped with conveyor belts, would significantly reduce the incidence of physical damages arising during loading and unloading.

Proper drainage and use of cambered beds would reduce losses caused by microbes and pests. Field sanitation, weed and pest management practices would also assist in reducing losses. Curing roots after harvest by exposure to temperatures of 32–35 °C for 2-3 days at 85-90 percent relative humidity would induce wound healing and decrease secondary infections (Figure 21).

Field days to demonstrate proper harvesting techniques, the use of the hand lifter equipment and curing procedures, sorting to remove defective and unmarketable roots, benefits of reducing moisture stress should be available to farmers, farmer groups and associations. Training should be accompanied by samples of successful root treatments as well as manuals, factsheets and techpaks.

Packinghouse (CLP#2)

Cassava roots that are transported to packinghouses should be subjected to the following post-

FIGURE 22
Modified atmosphere packaging

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FIGURE 23
Cassava treated with fungicide and waxed

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harvest treatments to maintain quality. A second sorting and grading procedure should be implemented at the packinghouse to remove damaged or unmarketable roots arising from transportation from the field to the packinghouse. Cured roots should be washed and dipped in an approved sanitizer, such as sodium hypochlorite at 500–700 ppm, followed by a fungicidal dip consisting of immazalil (Mertec). Treated cassava roots could then be packed in polyethylene bags, which would create a modified atmosphere (Figure 22) and high relative humidity within the sealed bags to reduce transpiration and respiration. This would induce an extended shelf-life of up to 4 weeks and also prevent vascular streaking. To achieve this, however, roots must have minimal, or preferably no physical damage, be protected from sunlight, treated with a fungicide and packed within 2 to 3 hours of harvesting. Another method that is employed to limit vascular streaking is to cover the roots with paraffin wax by dipping the root in wax at a temperature of 55-65 °C for a few seconds after treatment with a fungicide to achieve a shelf-life up to 2 months (Figure 23).

Post-harvest training is therefor recommended so as to increase the capacity of all stakeholders involved in cassava production, handling including treatments to prolong shelf-life. Such training must be reinforced with a cost–benefit analysis of the proposed investment.

Retail marketing (CLP#3)

Cassava roots must be subjected to rigorous sorting to eliminate all types of damage. Roots should not be marketed at CPL#3 beyond 2 to 3 days unless they are cured, treated with a fungicide, protected from sunlight and waxed and placed in refrigerated storage. Cassava can be stored under refrigerated conditions at 3–4 °C for up to 4 weeks. However, if roots are stored above 4 °C, roots develop vascular streaking more rapidly, and have to be discarded after 2 weeks of storage. Supermarket produce managers should package cassava roots in sealed polyethylene bags and store at 3–4 °C to acquire the benefits of modified atmosphere packaging, outlined above, since this technique is currently applied to other commodities at these outlets, where the equipment already exists for sealing packages and there are facilities for refrigerated displays. Demonstrations, short workshop sessions and exposure to information are highly recommended to educate suppliers as well as produce managers about these post-harvest procedures.

Tracing of value-added products

NAMDEVCO, in its capacity as facilitator, should devise a quality profile and mandate all processors engaged in the production of frozen cassava logs or any other potential value-added product to adhere to quality assurance guidelines. NAMDEVCO should also monitor and implement strict procurement policies to ensure cassava roots are sorted according to maturity, absence of defects, cultivar, and proper sanitation protocols. A grading system to standardize dimensions of root length and width should be encouraged. Random samples should be selected and examined for core splitting, as well as vascular streaking, and internal insect damage during growth and development. Processors should be classified as certified producers, who adhere to these quality control procedures, and even be given incentives to manage effective quality assurance initiatives.

Providing regular short courses for processors on post-harvest quality management for production of value-added products should be incorporated into the certification programme. Video presentations would demonstrate how to manage quality. Processors and packinghouse operators should follow a check-list of relevant postproduction activities. Processors should be encouraged to diversify their product base into other value-added products and NAMDEVCO should engage processors to be innovative and seek markets having export potential to enable growth and development of a viable cassava industry.

Selection of appropriate cultivars, sorting and grading protocols and processing steps should be monitored to prevent batch-to-batch variations in the quality of products. Appropriate equipment and tools can be introduced to beneficiaries through public-private sector collaboration. Training and outreach programmes, including food safety and sanitation practices, should also be incorporated within the processor certification system.

Investment programme to reduce food losses

Post-harvest losses of cassava were 20 percent for farmers who retailed at the public, roadside or mobile markets. At CLP#1 post-harvest losses averaged 3.5 percent similar to that measured for samples at CLP#2. At CLP#3 where roots were displayed for sale under ambient conditions post-harvest losses were 13 percent by day 6. Degradation of the quality of roots declined more at CLP#3 than CLP#1 and CLP#2 respectively, thereby confirming the cumulative nature of post-havest losses.

Based on the 2012 annual production of 2 000 tonnes of cassava/year at USD 1 250/ tonne, annual production is valued at USD 2 500 000 (Table 5.6). The percentage loss at each CLP level is then used to calculate the economic loss. Table 5.6 also shows that at CLP 1 and CLP2 the loss is USD 87 500 at each level and that at CLP3 the loss is calculated at USD 325 000; hence the total economic loss is estimated at USD 500 000. The economic loss estimate was derived from the data obtained from regions covered under the study, therefore these are rough estimates, and should not be taken as official national statistics.

Table 5.7 shows that a hand lifter will cost approximately USD 500; fungicides USD 450 and training workshops, and demonstrations for a group of 20 producers and marketers is an estimated USD 6 000. There are no perceivable risks associated with the interventions proposed.

At CLP#1 total losses averaged 6.5 percent and were mostly the result of physical damage, pathological was 3 percent and entomological 3.5 percent. No physiological losses were measured at CLP#1 and 2 and total losses at CLP#1 were at least three times higher than for CLP#2.

TABLE 5.6
Trinidad – Economic loss associated with respective critical loss points for cassava

Critical loss point	Percentage of losses	Value of annual production (USD)	Economic loss (USD)
Field harvest CLP#1	3.5	2 500 000	87 500
Packinghouse CLP#2	3.5		87 500
Retail marketing CLP#3	13.0		325 000
Total	**20**		**500 000**

USD 1.00 = TTD 6.40
Note: Based on 2 000 tonnes/year (2012) at TTD 8.00/kg or TTD 8 000/tonne (USD 1 250/tonne)

TABLE 5.7
Summary table of food losses, causes and solutions

Critical loss point	Percentage of losses	Economic loss (USD)	Cause of loss	Intervention to reduce losses	Loss reduction	Cost of intervention	Risks
Field harvest CLP#1	3.5	87 500	Wounds, VS1,2, decay	Tools, avoid heat, fungicidal treatment. Credit facility; Subsidies for tools	Commercial, economic	Cost of equipment = USD 500; supplies = USD 450 and training = USD 6 000	No perceivable risks
Packinghouse CLP#2	3.5	87 500	Same	MAP, waxing, training	Same	Cost of supplies (wax) = USD 300 and training = USD 4 000	
Retail marketing CLP#3	13.0	325 000	Same	Same	Same		
Total	**20.0**	**500 000**					

FIGURE 24
Cassava hand lifter in operation

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FIGURE 25
Example of plastic crates, to replace fertilizer bags, which are suitable for harvesting and handling of fresh cassava

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Losses were cumulative and the injuries to roots at CLP#1 created avenues for further quality degradation as the commodity moved along the value chain to CLP#3. Nevertheless, while the nature of all types of damage was almost the same (3.5 percent) after 6 days of retail marketing, the limit to marketability based on qualitative ratings was only up to day 2.

Cost benefit analysis of the proposed solutions

The cassava hand lifter is recommended for use in Trinidad, more so on sandy clays or clayey sands. Farmers generally grow no more than one acre of cassava pure stand as this is based on available markets. The crop is grown as part of a mixed cropping system. Table 5.8 shows the assumptions including an expected yield of 13 000 lbs/acre; a selling price of USD 0.31/lb; anticipated loss reduction of 50 percent; cost of hand lifter is USD 300 with 10 years depreciation. On one acre the profitability for the first year is merely USD 21; but on 5 acres profitability increases to about USD 300 as a result of the known theory of economies of scale (Table 5.9). Several small-scale farmers could work together and use one hand lifter or the larger farms could benefit from the use of this intervention.

Field crates in cassava production are also recommended for use. The main difference in the assumptions between those made for the hand

TABLE 5.8
Profitability of using the cassava handlifter on a 1-acre plot of cassava

No.	Item	Unit	Calculation formula	Value
A	Product quantity	lbs/year		13 000
B	Product value	USD/lb		0.31
C	Loss rate	%		0.035
D	Anticipated loss reduction	%		0.5
E	Cost of intervention (hand lifter)	USD		300
F	Depreciation	years		10
G	Yearly costs of investment	USD/year	e / f	30
H	Yearly costs of operation	USD/year		20
I	Total yearly costs of solution	USD/year	g + h	50
J	Client costs per tonne product	USD /lb	i / a	0.003846
K	Food loss	lbs/year	c x a	455
L	Economic loss	USD /year	k x b	141.05
M	Loss reduction	lbs/year	k x d	227.5
N	Loss reduction savings	USD/year	m x b	70.525
O	Total client costs	USD/year	i = a x j	50
P	Profitability of solution	USD/year	n - o	20.525

TABLE 5.9
Profitability of using the cassava hand lifter on 5 acres of cassava

No.	Item	Unit	Calculation formula	Value
A	Product quantity	lbs/year		65 000
B	Product value	USD/lb		0.31
C	Loss rate	%		0.035
D	Anticipated loss reduction	%		0.5
E	Cost of intervention (hand lifter)	USD		300
F	Depreciation	years		10
G	Yearly costs of investment	USD/year	e / f	30
H	Yearly costs of operation	USD/year		20
I	Total yearly costs of solution	USD /year	g + h	50
J	Client costs per tonne product	USD /lb	i / a	0.000769
K	Food loss	lbs/year	c x a	2275
L	Economic loss	USD/year	k x b	705.25
M	Loss reduction	lbs/year	k x d	1 137.5
N	Loss reduction savings	USD/year	m x b	352.625
O	Total Client costs	USD/year	i = a x j	50
P	Profitability of solution	USD/year	n - o	302.625

TABLE 5.10
Trinidad – Profitability of using field crates in cassava production (based on 1 acre of cassava)

No.	Item	Unit	Calculation Formula	Value
a	Product quantity	lbs/year		13 000
b	Product value	USD/lb		0.31
c	Loss rate	%		0.035
d	Anticipated loss reduction	%		0.60
e	Cost of intervention (field crates)	USD		300
f	Depreciation	years		5
g	Yearly costs of investment	USD/year	e / f	40
h	Yearly costs of operation	USD/year		20
i	Total yearly costs of solution	USD/year	g + h	60
j	Client costs per lb product	USD/lb	i / a	0.004615
k	Food loss	tonne/year	c x a	455
l	Economic loss	USD /year	k x b	141
m	Loss reduction	tonne/year	k x d	273
n	Loss reduction savings	USD/year	m x b	85
o	Total Client costs	USD/year	i = a x j	60
p	Profitability of solution	USD/year	n - o	25

TABLE 5.11
Trinidad – Profitability of using field crates in cassava production (based on 5 acres of cassava)

No.	Item	Unit	Calculation Formula	Value
a	Product quantity	lbs/year		65 000
b	Product value	USD/lb		0.31
c	Loss rate	%		0.035
d	Anticipated loss reduction	%		0.6
e	Cost of intervention (field crates)	USD		300
f	Depreciation	years		5
g	Yearly costs of investment	USD/year	e / f	40
h	Yearly costs of operation	USD/year		20
i	Total yearly costs of solution	USD /year	g + h	60
j	Client costs per lb product	USD/lb	i / a	0.000923
k	Food loss	tonne/year	c x a	2 275
l	Economic loss	USD/year	k x b	705
m	Loss reduction	tonne/year	k x d	1,365
n	Loss reduction savings	USD/year	m x b	423
o	Total client costs	USD/year	i = a x j	60
p	Profitability of solution	USD/year	n - o	363

lifter and those for the field crates are that the anticipated loss reduction is 60 percent; cost of a crate is USD 200 with 5 years depreciation. In Trinidad, on 1 acre the profitability for the first year is merely USD 25 (Table 5.10); but on 5 acres profitability increases to USD 363, once more as a result of the economies of scale (Table 5.11).

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Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla, 00153 Rome, Italy
www.fao.org

ISBN 978-92-5-130637-6

9 789251 306376

I9943EN/1/06.18