IICA

INVESTIGATIONS
on
GOLDEN APPLE (*Spondias cytherea*) PRODUCTION
with particular reference to
POST-HARVEST TECHNOLOGY
and
PROCESSING

by
Sophie Daulmerie
ENSIA-SIARC

October 1994

IICA OFFICE IN TRINIDAD AND TOBAGO

"WHAT IS IICA?"

The Inter-American Institute for Cooperation on Agriculture (IICA) is the specialized agency for agriculture of the Inter-American system. The Institute was founded on October 7, 1942 when the Council of Directors of the Pan American Union approved the creation of the Inter-American Institute of Agricultural Sciences.

IICA was founded as an institution for agricultural research and graduate training in tropical agriculture. In response to changing needs in the hemisphere, the Institute gradually evolved into an agency for technical cooperation and institutional strengthening in the field of agriculture. These changes were officially recognized through the ratification of a new Convention on December 8, 1980. The Institute's purposes under the new Convention are to encourage, facilitate and support cooperation among its 32 Member States, so as to better promote agricultural development and rural well-being.

With its broader and more flexible mandate and new structure to facilitate direct participation by the Member States in the activities of the Inter-American Board of Agriculture (IABA) and the Executive Committee, the Institute now has a geographic reach that allows it to respond to needs for technical cooperation in all of its member states.

The contributions provided by the Member States and the ties IICA maintains with its 13 Permanent Observer Countries and numerous international organizations provide the Institute with channels to direct its human and financial resources in support of agricultural development throughout the Americas.

The 1987-1993 Medium Term Plan, the policy document that sets IICA's priorities, stresses the reactivation of the agricultural sector as the key to economic growth. In support of this policy, the Institute is placing special emphasis on the support and promotion of actions to modernize agricultural technology and strengthen the processes of regional and subregional integration. In order to attain these goals, the Institute is concentrating its actions on the following five Programs: Agricultural Policy Analysis and Planning; Technology Generation and Transfer; Organization and Management for Rural Development; Trade and Agro-Industry; and Agricultural Health.

The Member States of IICA are: Antigua and Barbuda, Argentina, Barbados, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Dominica, the Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, the United States of America, Uruguay and Venezuela. The Permanent Observer Countries of IICA are: Arab Republic of Egypt, Austria, Belgium, Federal Republic of Germany, France, Israel, Italy, Japan, Netherlands, Portugal, Republic of Korea, Romania and Spain.

Ministère des Affaires Etrangères

FRANCE

Fonds Interministériel Caraïbes-Guyanes

IICA INTER-AMERICAN INSTITUTE FOR COOPERATION ON AGRICULTURE OAS

INVESTIGATIONS on GOLDEN APPLE (*Spondias cytherea*) PRODUCTION with particular reference to POST-HARVEST TECHNOLOGY and PROCESSING

by

Sophie Daulmerie

ENSIA-SIARC

October 1994

MISCELLANEOUS PUBLICATIONS SERIES

ISSN-0534-5391
A2/TT-94-04

Port of Spain, Trinidad & Tobago
October, 1994

"The views expressed in this document are those of the author and do not necessarily reflect those of the Inter-American Institute for Cooperation on Agriculture.

Mention of a proprietary product or commercial firm does not necessarily imply endorsement by the above mentioned Institution.

CONTENTS

LIST OF TABLES

ANNEXES

LIST OF FIGURES

LIST OF PLATES

ACRONYMS AND ABBREVIATIONS

AOAC	Association of Official Analytical Chemists
CARDI	Caribbean Agricultural Research and Development Institute
CARIRI	Caribbean Industrial Research Institute (Trinidad and Tobago)
CIRAD-FLHOR	Centre de Coopération Internationale en Recherche Agronomique pour le Développement – Département des Productions Fruitiéres et Horticoles (Montpellier, France)
CRITT	Centre Régional d'Innovations et de Transfert de Technologies (Guadeloupe)
DM	Dry matter
EC$	East Caribbean currency = US$2.65 (May 1994)
ENSIA-SIARC	Ecole Nationale Supérieure des Industries Agrio-alimentaires – Section Industries Agro-alimentaires des Régions Chaudes (Montpellier, France)
IICA	Inter-American Institute for Cooperation on Agriculture
ISU	International System of Units
MNIB	Marketing and National Importing Board (Grenada)
OECS	Organization of Eastern Caribbean States
OM	Organic matter
PCL	Produce Chemist's Laboratory (Grenada)
PFU	Productive Farmers Union (Grenada)
PMU	Pest Management Unit (Grenada)
RHS	Royal Horticultural Society (England)
RPM	Revolutions per minute
TSS	Total soluble solids
TTA	Total titratable acidity
UWI	The University of the West Indies (Trinidad and Tobago)

FOREWORD

This study on the golden apple or pomme-cythere (Spondias cytherea Sonn.) was conducted by Ms Sophie Daulmerie, a French student, as part of the requirement for her Master of Science degree at the Ecole Nationale Superieure des Industries Agro-alimentaires (ENSIA), Section Industries Agro-alimentaires Régions Chaudes (SIARC), Montpellier, France.

It was the continuation of a work started in 1992 by two Peace Corps Volunteers in Grenada, Mr Thomas Bauer and Mr Joseph Kim, and an officer from the Ministry of Agriculture in Grenada, Ms Indra Baldeo.

Ms Daulmerie spent 5 months in Grenda with IICA, the Ministry of Agriculture, CARDI and the Produce Chemist's Laboratory looking at the aspects of characterization of the species and selection of outstanding cultivars; she was also able to start some experiments there on post-harvest technology and processing. Then she came to Trinidad and spent 8 months with the Faculty of Engineering at UWI and with CARIRI to perform more detailed experiments on post-harvest and processing technologies.

We have to recognize that she showed much dedication to her work and was able to generate quite a lot of completely new information in a rather short period of time. These results have already been sanctioned by ENSIA since she was awarded the Master of Science degree with the highest grade, 'very good'.

There is no doubt that the present work constitutes a fundamental contribution to the development of the golden apple industry in the Lesser Antilles.

Gérard Barbeau
Regional Fruit Project IICA/France for the Caribbean
IICA Office in Trinidad and Tobago

FUNDING

The attachment of Ms Daulmerie to IICA and the work she developed both in Grenada and Trinidad was funded through the French Interministerial Fund for the Caribbean (FIC). This publication was financed through direct funding of the Ministry of Foreign Affairs (France). Both sources of funding are in support to IICA Regional Project "Supporting the Development of Tropical Fruits in the Caribbean".

ACKNOWLEDGEMENTS

While counuess individuals of the Caribbean countries are responsible for the completion of this document, I would like to acknowledge the following persons to whom I owe my utmost gratitude.

Firstly, I would like to thank the project supervisors – Mr Gérard Barbeau of the French Ministry of Foreign Affairs seconded to the Inter-American Institute for Cooperation on Agriculture (IICA) office in Trinidad and Tobago, Dr Rafael Marte presently at the IICA office in Costa Rica, and Dr Clement Sankat of the University of the West Indies (UWI), for their helpful guidance and advice. I would also like to thank Mr Max Reynes of the Centre de Coopération Internationale en Recherche Agronomique pour le Développement – Département des Productions Fruitiéres et Horticoles (CIRAD-FLHOR) for arranging my participation in the project.

Special appreciation must be conveyed to: Indra Baldeo (Ministry of Agriculture of Grenada) for her total dedication; Ms Linda Sammy (former researcher at the Caribbean Industrial Research Institute; CARIRI) for her contribution in juice technology; Ms Heida Rahim (Produce Chemist's Laboratory of Grenada) and Dr Menon (consultant) for their knowledge in food processing; Messrs Bruce Lauckner and Marcus Jones (Caribbean Agricultural Research and Development Institute; CARDI, Trinidad and Tobago) for their statistical expertise; and Dr Compton Seaforth (UWI) for his commitment and advice on chemical matters.

Thanks must also be extended to all the personnel of the Ministry of Agriculture of Grenada (Mirabeau Propagation Station, Pest Management Unit, Produce Chemist's Laboratory), especially Mr Cecil Winsborrow, and to Mr Juman of the Ministry of Agriculture of Trinidad and Tobago for their great assistance.

Sincere thanks to all the exporters, processors and farmers of Grenada involved in the project, in particular Mr John Viechweg of the Marketing and National Importing Board .

My sincere gratitude goes to the staff of IICA offices in Grenada and Trinidad and Tobago, with special thanks to Mr Naitram Ramnanan for his commitment in the verbal expression of this document. Their excellent administrative and office support made my efforts not only efficient but enjoyable.

ABSTRACT

Within a few years, the golden apple (*Spondias cytherea* Sonn.) has become a major non traditional crop for Grenada creating a need for scientific information. The Ministry of Agriculture in Grenada, the Tnter-American Institute for Co-operation on Agriculture and the University of the West Indies, therefore undertook a project to provide such information.

The existing literature was reviewed. Data recorded from pre-selected trees were subjected to varying correlation analyses which suggest that the fruit development seems highly influenced by the rainfall and by the calcium content of the soil. The colour of the pulp, the sugar content of the fruit are some of the representative criteria of fruit maturity whereas the acidity, the length of the spines or the fruit weight seems more influenced by genetic factors.

To reduce fruit losses and insure quality of exported fruits, greater care has to be taken during the fruit handling and procedures used have to be clearly defined. Fruit washing with Sodium Hypo clhorite (300 ppm) should be done by rubbing and soaking for 20 minutes.

The golden apple is a climacteric fruit. A detailed refrigerated storage study recommended a temperature of 13°C. The fruits ripen with poorer qualily after refrigerated storage but were still marketable. At 8°C, the fruit becomes chilled injured

Processed golden apples (jam, sauce, dried fruits, drink, nectar, pickles, chutney and kuchela) had a very positive consumer response especially for the sauce.

This work was an initial step in the scientific study on golden apple, however, more detailed research needs to be done in all the areas presented. With a good promotion of the fruit and its products, the golden apple has the potential to become a well appreciated fruit.

Keys words: *Spondias cytherea*, Production, Ecology, Selection criteria, Post-harvest, Respiration, Refrigerated storage, Processing, Grenada

Recherches sur la prune de cythère (*Spondias cytherea* Sonn.) avec référence particulière à la post-récolte et à la transformation

RESUME

En quelques années, la prune de cythère (*Spondias cytherea* Sonn.) est devenue une des principales cultures de diversification à Grenade créant ainsi un besoin en connaissances scientifiques. Le Ministère de l'Agriculture de Grenade, l'Institut Inter-Américain de Cooperation en Agriculture et l'Université des West Indies ont de ce fait entrepris un programme de recherche pour fournir de telles informations.

Une recherche bibliographique a été éffectuée. Des données mesurées sur des arbres préselectionnés et soumises à des analyses de corrélation suggèrent que le développement du fruit semble hautement influencé par la pluviométrie et par la teneur calcique du sol. La couleur de la pulpe, la teneur en sucre du fruit sont des paramètres représentant le degré de maturité du fruit, par contre l'acidité, la longueur des épines et le poids du fruit semblent plus influencés par des facteurs génétiques.

Pour réduire les pertes en fruit et garantir la qualité des fruits exportés, la récolte des fruits doit être réalisée avec grand soin et selon des procédures définies. Leur lavage à l'hypochlorite de sodium (300 ppm) doit être réalisé par frottage et trempage pendant 20 minutes.

La prune de cythère est un fruit climactérique. Après une étude de la conservation réfrigérée, une température de 13°C est recommandée, les fruits mûrissent avec une qualité inférieure mais sont toujours commercialisables. Des dégats dûs au froid apparaissent à 8°C.

Les prunes de cythère transformées (confiture, compote, fruit secs, jus, nectar, pickles, chutney et achards) sont très appreciées des consommateurs particulièrement la compote.

Ce travail est un premier pas dans la recherche scientifigue sur la prune de cythère. Néanmoins des études plus détaillées doivent être réalisées. Avec une promotion du fruit et de ses produits, la prune de cythère a le potentiel pour devenir un fruit exotique très apprécié.

Mots clefs: *Spondias cytherea*, Production, Ecologie, Critères de sélection, Post-récolte, Respiration, Conservation réfrigérée, Transformation, Grenade.

Investigaciones sobre la ambarela (*Spondias cytherea* Sonn.) con especial referencia a post-cosecha y procesamiento

RESUMEN

En pocos años, la ambarella ó jobo de la India (*Spondias cytherea* Sonn.) se ha vuelto uno de los principales cultivos de diversificación en la Isla de Grenada, generando así una necesidad de conocimientos científicos. El Ministerio de la Agricultura de Grenada, el Instituto Inter-Americano de Cooperación en Agricultura (IICA), y la Universidad de West Indies (UWI) han iniciado a tal efecto un programa de investigación para suministrar las informaciones requeridas.

Se ha hecho una investigación bibliográfica. Datos medidos sobre árboles preseleccionados y sometidos a un analysis de correlación sugieren que el desarollo del fruto está altamente relacionado con la pluviometría y el tenor de calcio en el suelo. El color de la pulpa y la cantidad de azúcar son parametros que representan el nivel de madurez del fruto; al contrario, la acidez, el largo de las espinas y el peso del fruto parecen estar más bajo la influencia de factores genéticos.

Para reducir las pérdidas y garantizar la calidad de los frutos exportados, la cosecha se debe realizar con gran cuidado y siguiendo procedimientos establecidos. Su lavado con hipoclorito de sodio (300 ppm) se debe realizar con frotamiento y remojo durante 20 minutos.

La ambarella (jobo de la India) es un fruto climactérico. Después de un estudio de la conservación refrigerada, se recomienda una temperatura de 13°C; los frutos maduran con una calidad inferior pero se pueden comercializar. Daños debidos al frío aparecen a partir de 8°C.

La ambarella transformada (dulce, compota, frutos secos, zumo, nectar, pickles, chutney, kuchela) es muy cotizada por los consumidores, especialmente la compota.

Este trabajo es un primer paso en el proceso de investigación científica acerca de la ambarella (jobo de la India), sin embargo, estudios más detallados se deben realizar. Con una promoción del fruto y de sus derivados, la ambarella tiene potencial para llegar a ser un producto exótico muy apreciado.

Palabras claves: *Spondias cytherea*, Producción, Ecología, Criterios de selección, Pos-cosecha, Respiración, Conservación refrigerada, Transformación, Grenada.

INTRODUCTION

The world crisis in cocoa production, the rivalries in the banana trade and their weak competitiveness on the nutmeg market are some of the obstacles Grenadian farmers and exporters are confronted with. The Grenada Ministry of Agriculture therefore encourages the development of non-traditional fruit crops.

Exports of golden apple (*Spondias cytherea* Sonn.) have risen tremendously since the first shipment of the commodity in 1985 and reached 681 tonnes in 1991, thereby becoming Grenada's leading non-traditional export crop. However, despite this fruit's worldwide distribution and its increasing interest and importance, it has received little recognition from the scientific community (Bauer et al. 1993).

Grenadian exporters have to deal with several problems: the tree is subjected to few cultural practices resulting in a lot of damaged fruits; little is known about its cultivation requirements; the fruit quality is very variable as cultivars have not been selected; production is not organized and comes from scattered trees; the fruits are handled without knowing the proper requirements for this crop, resulting in severe losses.

Consequently, the Grenada Ministry of Agriculture and the Inter-American Institute for Cooperation on Agriculture (IICA) started a research programme of general preliminary investigations (Bauer et al. 1993). The present study conducted in collaboration with the University of the West Indies (UWI) was the second step of detailed analysis, conducted to help the exporters and farmers. The main objectives were: to collect information on the crop agronomy and to pre-select some trees; to analyse the post-harvest handling of the fruit; to carry out experiments in response to the problems raised; to develop fruit processing.

This study was carried out as a French 'Mastere' thesis of the Ecole Nationale Supérieure des Industries Agro-alimentaires, Section Industries Agro-alimentaires des Régions Chaudes (ENSIA-SIARC), during 13 months, May 1993 to June 1994. The results of this study, made possible by collaboration with many Caribbeau institutions, are presented in this document as a first step in the scientific study of golden apple.

1. LITERATURE REVIEW

As very little is known on golden apple, a review of the literature was conducted to obtain a state of the art position on the crop and to compile the sparse information, making it more readily available.

1.1. ORIGIN AND DISTRIBUTION

The epithet 'cytherea' is derived from the island of Cythere or Tahiti in the Society Island group (Winton and Winton 1935; Backer and Bakhuisen 1965; Popenoe 1979) from where plants were brought to Mauritius in 1768 and later discovered and described by Sonnerat as a new species (Airy Shaw and Forman 1967). It was first introduced into Jamaica in 1782 and again 10 years later by Captain Bligh (Morton 1961). The US Department of Agriculture received seeds from Liberia in 1909 and in 1911 from Australia (Morton 1961).

It is impossible to give the exact area of indigenous occurrence as it is widely cultivated and there is little means of distinguishing between indigenous and naturalized forms. However the centre of maximum diversification of the genus *Spondias* is located in south-east tropical Asia in an area including Burma, Siam, Indo-China and south China (Airy Shaw and Forman 1967). In many islands, golden apple trees are found in primary forest, notably in New Guinea where they are rather common and of great size (30–40 m tall) (Ding Hou 1978).

Little threat of genetic erosion exists as this crop is mainly propagated by seed (Geurts et al. 1986) and there is no planned systematic selection described in the literature.

It is cultivated and grown on a small scale in many tropical and subtropical countries including Asia, Indonesia, USA (Florida Keys and Hawaii), the Caribbean and South America – Venezuela and Suriname, but hardly at all in Brazil and other tropical American countries (Backer and Bakhuisen 1965; Popenoe 1979; Weir et al. 1982; Paull et al. 1983; Geurts et al. 1986; Morton 1987; Gomez 1991).

1.2. NAMES

1.2.1. Classification

The golden apple belongs to the Anarcadiacae family which includes the mango, *Mangifera indica* (Popenoe 1979). The genus *Spondias* L. was established by Linnaeus in 1753 (Geurts et al 1986) and later the species *S. cytherea* Sonn. was described by Sonnerat.

Spondias cytherea has been variously reported by Airy Shaw and Forman (1967) and Ding Hou (1978) as:

- *Condondum*
- *Condondum malaccense* (*rumphus*)
- *Chrysomelon pomiferum*
- *Evia amara* var. *tuberculosa blume*
- *Evia dulcis comelin* (Forst f)
- *Poupartia dulcis blume* (Forst f.)
- *Spondias dulcis* var. *commersanii*
- *Spondias dulcis solander* (ex Parkinson and ex Forst)
- *Spondias macrocarpa*
- *Spondias mangifera* var. *tuberculosa* Engler.

At present two names are used: *S. dulcis* Forst. and *S. cytherea* Sonn. The latter always refers to golden apple whereas the former may be confused in the literature with other fruits such as hog plum (*Spondias mombin*).

1.2.2. Colloquial names

Many different names are used to refer to *Spondias cytherea* Sonn. which adds to the difficulty in communicating about this fruit among people of different nationalities. Besides, the same vernacular name can represent different fruits in distinct countries. *Spondias cytherea* is called great hog plum in India or otaheite apple in Florida whereas hog plum is the Caribbean name for *Spondias mombin* and otaheite apple the Jamaican name for *Syzygium malaccence*. The following are various colloquial names reported for *Spondias cytherea* Sonn.:

Asia
(Winton and Winton 1935; Morton 1987; Nahar et al. 1990)

Ceylon	Ambarella
Former English colonies	Otaheite apple, hog plum
Thailand	Ma-kok-farang
Cambodia	Mokak
Vietnam	Coe, pomme-cythere

South Pacific
(Winton and Winton 1935; Ochse et al. 1961; Morton 1961;Ding Hou 1978; Geurts et al. 1986)

Solomon Islands	Air
Sumatra	Kedongdong, kedongdong las,dudungdung tjind
Malaysia	Great hog plum, kedondong
Java	Dedongdong, dedongdong sem, kedangdang, kedongdong manis, klontjeng, pelentjing
Lesser Sunda Island	Ahang ehe, leheeng, ledem, eentji, makong, woa indjoong, maradda, kadondo, kadongdong, golo
Moluccas	Ustubal, otjo, tjotjo, wis
New Guinea	Aimemiek = awiminik, arama, baramijan, warea, bemoi, bikato, dren, gi, gungkia, huneg, hunek, iopeia, juwut, kanureskara, karisi, kedondong utan, maar, mur, ona, pehjet, wutiel, sutiek, unumi, vain, witosu
Philippines	Hevi
Fiji Islands	Ivi
Hawaii	Tahitian quince, vi-apple, wi-apple, vi, wi
Tahiti	Evi
Polynesia	Vi, evi, vee, Polynesian plum

SOUTH AMERICA
(Geurts et al. 1986; Morton 1987)

Brazil	Caja-manga, taperita do sertao, cajarana
Spanish-speaking countries	Ciruela judia, jobo de la India
Costa Rica	Juplan, yuplon
Colombia	Hobo de racimos
Venezuela	Jobo de la India, mango jobo
Ecuador	Manzana de oro

CARIBBEAN
(Geurts et al. 1986)

Jamaica	Jew plum, June plum
Cuba	Ciruela dulce

Suriname	Fransi mape, pomme de cythere
Martinique, Guadeloupe	Prune de cythere
Barbados, Grenada, St Vincent, Antigua & Barbuda, St Kitts & Nevis	Golden apple
Belize	Golden plum
Trinidad & Tobago, St Lucia, Dominica	Pomme-cythere

INDIAN OCEAN

Mauritius	Prune de cythere

NORTH AMERICA
(Popenoe 1979)

Florida	Ambarella, vi apple, otaheiti apple

There are no named cultivars although relatively improved forms with a thick mesocarp and a sweet refreshing taste exist in contrast to unimproved forms with long spines on the woody endocarp and a resinous pungent taste (Geurts et al. 1986; Popenoe 1979). The exceptions are two forms reported in east Java (kedondong beli and kedondong kreckil) but not described.

1.3. DESCRIPTION

1.3.1. Tree

The tree has a straight, cylindrical and high branched trunk (Ochse et al. 1961) with a thin irregular crown (Morton 1961). The smooth greyish, light to reddish brown bark has few lenticels and a yellowish viscous sap (Ochse et al. 1961; Ding Hou 1978; Popenoe 1979).

The height given by the various authors is usually between 15 and 25 m for mature trees and goes up to 45 m (Ochse et al. 1961; Ding Hou 1978; Popenoe 1979). The trunk diameter is approximately 0.45 m and can reach 0.90 m (Ding Hou 1978). Buttress roots (0.5–1.5 m high, 1–2.5 m wide, 0.04–0.1 m thick) are sometimes present (Ding Hou 1978).

The branches are thick, breakable, with numerous lenticels and large fallen leaf scars (Bauer et al. 1993; Morton 1961). The canopy is 10–14 m in diameter (Bauer et al. 1993).

1.3.2. Leaves

The leaves are compound, alternate, crowded at the end of the branchlets, thickened at the base of the petiole (9–15 cm), very aromatic after being crushed, 15–60 cm long (Figure 1, a) and attaining great length on the young shoots (Morton 1961; Ochse et al. 1961; Backer and Bakhuizen 1965; Geurts et al. 1986).

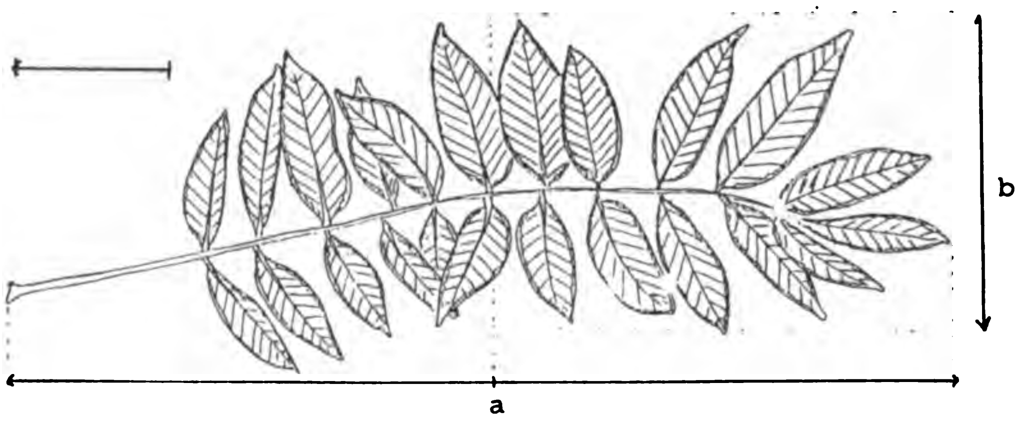


Figure 1 **Golden apple leaf**

The leaves have 4–12 pairs of lateral opposite or slightly alternate leaflets and usually a terminal one. The leaflets are described in detail by Ochse et al. (1961), Backer and Bakhuizen (1965) and Ding Hou (1978) as ovate oblong and 6.25–10 cm long (Figure 2, a), dark green and feebly shiny with more observable veins on the upper surface, pale green and dull on the lower surface (Ochse et al. 1961). The margin is entire with 14–30 pairs of lateral nerves horizontally patent, inconspicuous, reunited close to the margin by intra-terminal transparent reticulated veins (Ochse et al. 1961; Figure 2). The petiolule is narrow (0.2–0.75 cm), and the terminal one is longer (0.7–3 cm) (Morton 1961; Ding Hou 1978; Geurts et al. 1986).

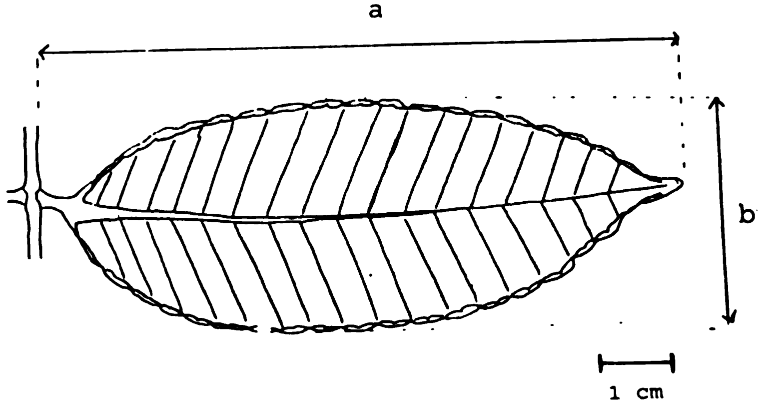


Figure 2 **Golden apple leaflet**

1.3.3. Inflorescence

The inflorescences usually appear before the leaves or are accompanied by very young ones (Ding Hou 1978). They are situated along the spreading branches of a terminal drooping panicle (Morton 1961; Figure 3, a) and measure up to 50 cm long (Airy Shaw and Forman 1967; Geurts et al. 1991; Winton and Winton 1991).

The small white flowers are hermaphrodite, pedicellate and clustered (Geurts et al. 1991). The pedicles are usually 1.25–4 mm long, the floral bracts 0.66–1.25 cm. The calyx is small with triangular lobes – 0.25 cm in diameter and 0.05 cm long (Ochse et al. 1961; Ding Hou 1978). The petals are ovate oblong, 0.1–0.3 cm long, reflexed with thin nerves (Morton 1961; Ding Hou 1978; Geurts et al. 1991).

There are 10 short stamens (Geurts et al. 1991); the five-celled ovary is sessile. In newly expanded flowers, the male state is hidden within the disk (Ding Hou 1978; Geurts et al. 1991). There are five erect styles, initially close to each other, later spreading and widely distant after fertilization; 0.72 mm long (Winton and Winton 1935; Ding Hou 1978; Geurts et al. 1991).

Figure 3 **Golden apple leaves (c), inflorescence (a) and fruits (b) (from Ochse et al. 1961)**

1.3.4. Fruits

The branches are usually heavily burdened with long-stalked fruits dangling in bunches of a dozen or more (Morton 1961; Plate 1). The fruit is a drupe (Ding Hou 1978), ellipsoid or oblong (Gomez 1919; Ding Hou 197), generally reported as being between 4 and 10 cm in length and 3–8 cm in diameter (Ding Hou 1978; Popenoe 1979; Bauer et al. 1993). A fruit usually weighs between 100 and 225 g but can be as heavy as 450 g (Gomez 1991; Bauer et al. 1993). (see Plate 7 on page 61).

The glabrous skin, initially green, appears bright orange when the fruit ripens (Ding Hou 1978). The skin is usually slightly rough with fine brown lenticels (Ochse et al. 1961; Popenoe 1979). At the apical end, there are scars of four or five styles (Ding Hou 1978).

The unripe fruit is crispy, juicy and acidic, with a pineapple-like fragrance but as it ripens it becomes fibrous, fleshy, with a thin tough skin, and a sour aroma and flavour (Morton 1961; Ochse et al. 1961; Popenoe 1979; Geurts et al. 1986).

The brown stone has numerous spines, radiating, straight or curved upwards or downwards (Figure 4, c and d). Some of the curved spines join up longitudinally in pairs to form characteristic arches (Airy Shaw and Forman 1967). These spines protrude into the flesh and complicate the separation of the flesh and the stone (Popenoe 1979). There are five main larger spines, curving downwards, originating from the outer edge of the five loculi.

From the numerous thin ridges, long tough fibres radiate in all directions (Morton 1961). Five main hard fibres come from the five main spines. Endocarps without this peripheral layer of fibres can be described and preserved in herbaria. Such endocarps that have been cleaned by eating give a wrong impression of the structure (Airy Shaw and Forman 1967; Figure 4, c and d). Some endocarps that have been cleaned by bacteria can be found with the preserved peripheral layer of meshes (Figure 4, a and b). Over the stone, there is a spongy parenchyma (Airy Shaw and Forman 1967).

The seeds are produced in five small cavities in the stone (Popenoe et al. 1935). The straight embryo has fleshy cotyledons and short radicle (Winton and Winton 1935).

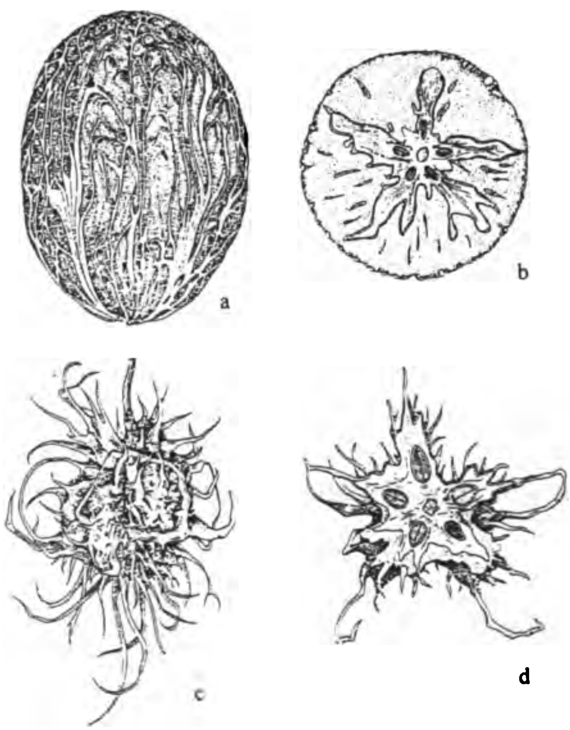


Figure 4 **Endocarps of golden apple.** a & b = fibres, c = irradiating spines, d = seed cavities (from Airy Shaw et al. 1967)

The histology of the fruit and embryo tissue is described precisely by Winton and Winton (1935) and Wannam and Quinn (1990) who report: occasional stomata in the epicarp, starch grains of 55 µm in the mesocarp and oxalate crystals in each cell of the endocarp.

1.4. COMPOSITION OF THE FRUIT

It is quite difficult to refer to the literature because precise names are not used. Also, when data are reported, often it is not stated whether they refer to the pulp or the skin; nor is the stage of maturity of the fruit (ripe or green) given, nor the units used. Therefore the results found are variable (Winton and Winton 1935; Morton 1961; Duke and Atchley 1986; Geurts et al. 1986; Nahar et al. 1990; Bauer et al. 1993). They are summarized in Table 1. Complementary information on the composition in carbohydrates, organic acids and amino acids are reported in Annex B1.

Table 1 General composition of golden apple fruits

Item	for 100g of fresh fruit	% of dry matter (DM)
Calories	46 - 87%	351
Water	60 - 87%	0
Proteins	0.2 - 1%	1.5 - 5
Fat	0 - 1.8%	0.8
Total carbohydrates	11.6 - 14.5%	94.7
Total solids	14.5 - 40.4%	-
Acids	0.45%	-
Fibres	0.6 - 3.6%	8.4
Ash	0.4 - 0.7%	3.1 - 7.7
Ca	10 - 56 mg	427.5
P	67	511.5
Fe	0.3 - 1.2 mg	2.3
Na	1	7.6
K	95	725.2
Vitamin A	205 - 260 UI	1564.9
Thiamine	0.05 - 0.12	0.38
Riboflavine	0.02 - 0.04 mg	0.15
Niacin	0 - 14	10.69
Ascorbic acid	36 - 42 mg	274.8

1.5. ECOLOGY

Little is known about the climatic or soil preferences of this tree; reported information is gleaned from observations of the existing situation and not from scientific experiments. The tree is usually found at low to medium altitudes (plains in Java and up to 1000 m in New Guinea (Ochse and Bakhuizen 1977; Ding Hou 1978; Geurts et al. 1986).

The climate ranges from continuously wet (6 months with over 100 mm rainfall per month) to seasonal wet – 6 months with under 60 mm rainfall per month (Geurts et al. 1986). The tree is tolerant to drought (Popenoe 1979), however in such conditions the trees remain small and bear only a few small fruits (Weir et al. 1982; Morton 1987). It is usually grown at temperatures between 20 and 35°C (Weir et al. 1982) and is sensitive to frost (Popenoe 1979).

The tree needs full sunlight in order to grow and fruit (Popenoe 1979). However, young trees require light shade for the first few years (Ochse et al. 1961). Mature trees are somewhat brittle and prone to damage by strong winds, therefore a sheltered location is preferred (Morton 1961).

The tree is usually found in well-drained soils, sometimes in flood plains (Ding Hou 1978; Morton 1987). It is adapted to sandy or calcareous clays (Ochse et al. 1961), but grows on all types of soil (Morton 1987). It does not need a rich soil but grows more vigorously with regular additions of NPK fertilizer, e.g. 10–5–10, two or three times a year (Popenoe 1979; Weir et al. 1982). It prefers soils of neutral pH, rich in Ca (Weir et al. 1982).

The trees go dormant for a short period in the early dry season; their leaves turn light yellow and then fall off (Morton 1961; Popenoe 1979). The flowers then come back and the fruits ripen 6 or 7 months after flowering (Ding Hou 1978; Geurts et al. 1986; Bauer et al. 1993). The trees produce flowers 4 years after planting and still exhibit good yields after 25 years (Bauer et al. 1993). Reported yields per tree are 800–900 fruits (Geurts et al. 1986) with an average weight of 270–450 kg, but this could reach 900 kg (Bauer et al. 1993).

1.6. PROPAGATION

No scientific research has been done on tree propagation and its influence on the rapidity of bearing, therefore the knowledge reported here is empirical. This crop is usually propagated from seed. Germination takes place from one to several months after planting a whole stone cleaned from the flesh (Morton 1987). More than one seed germinates from the same stone (there is potential for five plants) and it is possible to separate them when the plants are about 30 cm tall (Popenoe 1979). Ellis (1984) refers to the seeds as recalcitrant.

Tip cuttings (about 20 cm long, taken just after fruit-set, planted in a mixture of peat and perlite and placed in intermittent mist) produce roots in 4–6 weeks and grow well after transplanting (Popenoe 1979). Air-layering is also reported as a method of propagation (Popenoe 1979).

Green mature and smooth scions can be used for grafting. Large buds with ample wood-shield (6–15 cm long) are inserted in the stock at a point of approximately the same age and appearance as the scion (Morton 1987). The rootstock used can be *Spondias mangifera* (Ochse et al. 1961; Geurts et al. 1986) or *Spondias pinnata* (Morton 1961).

1.7. PESTS AND DISEASES

Various diseases have been reported. However, since golden apple is not a major crop, only little attention is paid to them and no control is done (Geurts et al. 1986).

Severe caterpillar attack could result in complete defoliation of trees. The leaves can also suffer from severe damage by specific beetles (Ding Hou 1978). Two main beetles (*Podontia punctata* and *Podontia affinis*) cause considerable damage to the leaves in Malaysia and Indonesia (Ochse and Bakhuizen 1977; Geurts et al. 1986). In India, the first beetles appear in June and strip the tree of leaves. Eggs, laid in clusters of 20–60, incubate for a period of 7–8 days ; the life cycle is 32–55 days. Some parasites of these beetles have been found as a nematode (*Mernis*) and a fungus (*Cephalosporium*). A foliar spray of spores of this fungus, or of 0.25% of Malathion, in June/July give effective control of the insect (Pratap Singh et al. 1989).

Nematodes were found in the roots of trees in Australia, including *Scutellonoma brachyurum* (Sauer 1981). Another nematode seems to parasitize the tree – *Meloidogyne* sp.(Gomez 1991). In Costa Rica, the bark is eaten by a wasp causing necrosis which leads to death (Morton 1987).

Gummoses of unknown origin have been reported in various countries (Ochse and Bakhuizen 1977; Geurts et al; 1986; Fortune and Dilbar 1993), as well as resinosis canker identified as *Lasiodiplodia* (Ponte et al. 1988). A bacterial canker was also described in Martinique (Rott and Frossard 1986). The responsible bacteria was clearly identified as a new pathogenic form of *Xanthomonas campestris* pv. *mangiferae indica* (Pruvost and Luisetti 1989a, b; Pruvost et al. 1992).

In the dry season, scales produce yellow spots on the green fruits (Bauer et al. 1993). The Caribbean fruit fly can also affect the fruits (Leather 1967; Geurts et al. 1986; Gomez 1991): in Costa Rica *Anastrepha monbin preoptans* infects 100% of the trees (Jiron and Hedstrom 1988) but causes little damage in Florida (Popenoe 1979).

Sooty mould, due to *Tripospermum* sp., is common on the fruit (Leather 1967; Bauer et al. 1993) *Phytophthora* has also been reported by Samson (1986). A fungus (*Sphacelema spondiadis*) was reported in Florida and Brazil causing round spots on the leaves and fruits (Geurts 1986). The fruits are damaged by a superficial scarring; trials, reported in Annex B2, have indicated that this is caused by a mite.

Different types of fungi, occurring mainly during the rainy season, are also observed on the fruits. On green fruits small spots of round black lesions (8 mm in diameter) with gumming develop slowly on the fruit as well as other large black spots of 1.5 cm of diameter. They remain superficial (3 mm depth) and do not cause rotting or softening. When the fruit ripens the infected area remains pale green and softens (Bauer et al. 1993)). Brown lesions with no gumming can be observed on ripe fruits which leads to rotting – this has been identified as due to *Colletotrichum*. A stem rotting, which is probably due to a bacterium, also occurs on ripe fruits (Bauer et al. 1993).

1.8. USES

Research on the use of the wood have been done in India. The wood, if appropriately treated, can be used under cover or outdoors without soil contact (Abdurrohim and Martawijaya 1987a, b), or be manufactured into wool-wood boards (Sulastiningsih et al. 1987). The wood has acceptable drying properties (Hidyat and Karnasudirdja 1987) and is traditionally used in Indonesia and the Society Islands (Morton 1961; Gomez 1991). The gum is also sometimes used (Gomez 1991).

Honey from *Spondias* does not have a very good taste and is not popular with humans (Barth 1990). The plant is used in traditional pharmacopoeia (Gomez 1991) – in Cambodia, the astringent bark is used with various species of *Terminalia* as a remedy for diarrhoea (Morton 1987).

The young leaves are consumed raw in south-east Asia and cooked with tough meat to tenderize it (Morton 1987). They eaten steamed (Ding Hou 1978; Geurts et al. 1986) and mixed with salt-fish, young fruits or fruits of other species in many traditional dishes of Java (Ochse And Bakhuizen 1977).

The green fruits, which are usually quite sour, are used for pickling and relish dishes (Ochse et al. 1961). They can also be used to make jelly, flavouring sauces, stews and soup or delicious juices. The ripe raw fresh fruits are relished by many (Morton 1987)..They are also used for making jams, preserves, juices (Geurts et al. 1986), wine and sparkling beverages (Gomez 1991; Massiot et al. 1991). They are also stewed to make a savoury sauce and mixed with cinnamon or any other spices to make an apple butter (Morton 196'· Ding Hou 1978). Dehydrated fruits keep their characteristics of flavour, texture and colour (Gomez 1991).

2. TREE OBSERVATIONS AND 'SELECTION'

The golden apples exported from Grenada are of varying quality due to the range of fruits found around the island. Therefore, there is a need to characterize and select improved trees. The first team working on the project observed hundreds of trees around the island of Grenada and pre-selected 33 trees for their high yields and general cleanliness, as well as five trees of apparent superior qualities (Bauer et al. 1993; Annex C1).

These pre-selected trees were studied in more detail and the results are reported in this section. The data were analysed for correlations and chi-squares in order to find out the major causes of variation of each parameter and to find out which parameter is more representative of each type of variation. Consequently, this study is only a preliminary step in the selection process. Trials are needed with a proper methodology to determine genetic differences for the parameters identified in this report as the representative ones. However, an attempt was made to separate characteristics which might be of genetic origin in order to identify trees which can constitute part of the first pool of trees for the selection study.

2.1. LEAVES

2.1.1. Materials and methods

Five mature leaves were harvested in July from the five main trees selected by the previous project. These were examined and the length and width of the leaves (Figure 1, a and b) and leaflets (Figure 2, a and b) were recorded. The number of leaflets was also counted.

2.1.2. Results

The leaves observed were similar to those described in the literature review with no significant variation. The terminal leaflet was sometimes absent probably due to earlier damage. The variations in the dimensions of the leaves and leaflets are reported in Table 2.

Table 2: Variations observed in golden apple leaves

Parameter	Range	Mean	Between trees variation (%)	Within tree variation (%)
Length of leaves (cm)	34 - 55	43	12	5 - 12
Width of leaves (cm)	15 - 21	18	11	2 - 12
Number of leaflets (n°)	14 - 22	18	13	6 - 15
Length of leaflets (cm)	8 - 11	9	11	2 - 10
Width of leaflets (cm)	3 - 5	3.3	13	6 - 12

The observed variations are not due to genetic factors since the results show that the variation between and within the trees was similar, therefore the variation between the trees was due to the variations within them.

2.1.3. Conclusion

The variation in the leaves of golden apple trees studied was around 12–15% which was due to the varying stages of growth of the leaves on a tree. This was later confirmed as, over time, the leaves from the same trees were observed to be longer.

2.2. TREES

2.2.1. Materials and methods

During the month of June, several field visits were made to measure parameters on the 33 trees pre-selected by the previous project as reported in Annex C2.

2.2.2. Results

The measurements of the quantitative and qualitative parameters of golden apple trees in Grenada are reported in Table 3 and 4.

Table 3: Qualitative measurements for golden apple trees in Grenda

Tree	Shape	90% round		10% slender	
	Trunk colour	56% brown / white	19% brown / white / yellow	25% brown / yellow	
	Bearing	13% early	66% normal	16% late	6% very late
	Splitted bark	19% none	50% few	16% average	16% much
Phytosanitary aspects	Ants	28% none	34% few	22% average	16% much
	Termites	44% none	16% few	25% average	17% much
	Sooty mould	22% none	31% few	38% average	9% much
	Algae	88% none	3% few	9% average	0% much
	Parasitic vines	97% none	3% few	0% average	0% much
	Epiphytes	88% none	12% few	0% average	0% much
	Gummosis	88% none	12% few	0% average	0% much
Vegetation	Cocoa	78% mixed		22% not mixed	
	Banana	50% mixed		50% not mixed	
	Nutmeg	59% mixed		41% not mixed	
	Fruit crops	34% mixed		66% not mixed	
	Secondary forest	19% mixed		81% not mixed	
Soil	55% brown earths	19% lithosols	13% shoals	9% red earths	6% alluvials
Climate	Rainfall level	58% high	29% medium	13% low	
	Elevation	58%>360 m	19% 180-360 m	19% 60-180 m	19%<60 m

Table 4: Quantitative measurements for golden apple trees in Grenada

	Parameter	Mean	Range	Variations (%)
Tree	Tree height (m)	10.4	8-15	16
	Trunk height (m)	6	2-9	28
	Trunk circumference (m)	1.6	1-2.4	22
	Canopy diameter (m)	13	1-20	18
	Tree age (years)	15	6-26	29
Phytosanitary aspects	Phytosanityary problems (Score)	4.3	0-10	58
	Mites (%)	4	0-13	75
	Fungi (%)	10	0-6	55
Soil	pH (IU)	6.6	5.6-7.5	162
	P (IU)	7.3	0.7-45.5	162
	K (IU)	0.94	0.3-3.2	77
	Na (IU)	2.2	1.1-6.4	60
	Ca (IU)	22	12.4-43.6	43
	Mg (IU)	8.6	4.2-22	49
	OM (IU)	3.4	1.7-4.1	19
Climate	Number of dry months	3.3	0-6	55

Trees did not reach as high as 45 m as stated in the review, but they were still too tall for adequate management. Also the first branches of the trees were usually very high from the ground which makes climbing to harvest very difficult.

The tree trunks were a mottled brown with shades of yellow or white. Some trunks were observed with splits in the bark but the cause of this is unknown.

The sample studied was clean and not representative of the trees in Grenada since they had been previously selected for their cleanliness. The trees were hardly ever infested by ants, but when they are, problems are experienced by the harvesters. There were few mites and fungi on the fruits due to irregular infestation in the tree itself.

2.3. FRUITS

2.3.1. Materials and methods

Ten green fruits of the pre-selected trees were harvested in the fields following the procedure used to pick the fruits for export (described in section 3.1.), then placed in a labelled paper bag, kept one night at 20°C and analysed on the following morning in the Grenada Produce Chemist's Laboratory (PCL).

The trial was conducted in August and September, therefore some fruits were not fully mature even though they were chosen by the harvester as adequate for export. Parameters were measured, as reported in Annex C2, on green fruits and on fruits ripened in a box at ambient temperature (30°C).

The average was calculated for the measurements on fruits from one tree. The statistical analysis, of correlation among the variables, was done on the 33 medium fruits of the pre-selected trees. The variations reported are therefore representative of trees, and thus single fruits could be found out of the range presented.

2.3.2. Results

The data on green fruits are reported in Tables 5 and 6.

Table 5 Qualitative measurements on green golden apple fruits

Fruit shape	41% totally oval	41% mainly oval	3% pear	13%Mainly round	3% mixed
No. of spines	9% average/few	47% average	28% average/abund	13% abundant	3% mixed
Taste	23% acidic	13% mild acidic	19% mild sweet	32% sweet	13% mixed
Scent	66% no scent		34% mild		
Texture	97% crispy		0% intermediate		13% soft
Pulp colour	43% yellow (Y10D)		57% yellow orange (YO15D)		
Skin colour	81% green (G144B)		19% green (G138B)		

Table 6 Quantitative measurements on green golden apple fruits

	Mean	Range	Variation (%)
Fruit length (cm)	7.4	6.1-9.2	8
Fruit diameter (cm)	6	4.9-6.9	7
Ratio length to diameter	1.24	1.09-1.41	5
Pulp thickness (cm)	5.2	4.3-5.7	6
Skin thickness (cm)	3.1	1.8-4.5	18
Stone diameter (cm)	1.9	1.2-2.4	16
Spines length (cm)	1.2	0.8-1.7	15
Fruit weight (g)	153	70-232	22
Stone weight (g)	10.5	4.3-15.5	23
Pulp yield (%)	72	60-85	11
Edible parts yield (%)	93	89-97	1.9
Firmness (lbs/cm)	23	17-26	8
Titratable acidity (TTA) (% malic acid)	0.69	0.45-1.07	19
Total soluble solids (TSS) (°brix /%malic acid)	8.3	4.6-10.9	13
Ratio TSS /TTA (°brix / % malic acid)	12.6	7.7-19.1	21
Time to ripen (days)	9.3	2-12	20

The data measured for ripe fruits are reported in Tables 7 and 8.

Table 7 **Quantitative measurements on ripe golden apple**

	Mean	Range	Variation (%)
Pulp thickness (cm)	5.3	4.3-6.7	9
Skin thickness (cm)	1.01	0.8-1.4	10
Stone diameter (cm)	2.1	1.5-2.7	15
Spines length (cm)	1.2	0.9-1.5	12
Fruit weight (g)	155	71-217	23
Stone weight (g)	13.7	5.4-26	33
Pulp yield (%)	79	69-93	7
Edible parts yield (%)	91	79-97	4
Firmness (lbs/cm)	8	4.5-15.3	28
TTA (% malic acid)	0.83	0.53-1.16	17
TSS (°brix)	11.9	9-16.3	13
TSS/TTA (°brix/% malic acid)	14.8	8.7-22.4	21
Time to overripen (days)	4.2	1-11	54

Table 8 **Qualitative measurements on ripe golden apple fruits**

No. of spines	23% average / few	53% average	20% average / abundant	3% abundant	0% mixed
Taste	13% acidic	13% mild acidic	48% mild sweet	19% sweet	0% mixed
Scent	42% no scent		58% Mild		
Texture	26% crispy		39% intermediate		35% soft
Pulp colour	35% yellow (Y10D)	48% yellow (Y10C)	13% yellow orange (YO15C)	3% yellow orange (YO15A)	
Skin colour	6% yellow orange (YO15D)	26% yellow orange (YO15C)	45% yellow orange (YO15A)	16% mainly yellow orange (YO23B)	6% totally yellow orange (YO023B)

The length and diameter of the fruit observed in Grenada corroborate the data reported in the literature review (4–10 cm and 3–8 cm respectively) and indicate that there are no very small fruits in Grenada. The shape of the golden apple is generally oval.

The values obtained for the skin thickness for ripe fruits were less than half of those for the green fruit which indicates that the green skin differentiates in two parts: a thin hard skin and an orange pulpy part. Therefore, there is proportionally more pulp in the ripe fruit.

Fruits from all trees usually had an average amount of spines. In some isolated cases, some fruits were found without spines and with spongy endocarp only. Those fruits were abnormal since the other fruits from the same trees did have spines. The difference of 1–2 cm in the length of the spines has an important effect on the eating qualities of the fruit. Some trees had fruits with the five main spines less differentiated and therefore less fibre. Their flesh was much more easily detached which is an important improved feature for both fresh consumption and processing.

The stone, made of light endocarp, was not important in the weight of the fruit. The average fruit size measured represents a good size for an easily marketable fruit – however, a single fruit was measured weighing 400 g. The texture of the green fruit is continuous but changes when the fruit ripens as there is a degradation of insoluble protopectins.

Golden apple is a fruit with a high level of acidity. The brix was higher in the ripe fruits, but the ratio TSS/TTA was not very different in green and ripe fruits. The scent of golden apple is generally unpronounced, however some fruits have a nice refreshing scent. The ripe fruits are always yellow but of varying intensity. The medium colour attained is of marketable quality; however, the fruits in some of the trees have much more attractive colours. The green fruit possesses essentially a white pulp colour, although a slight yellow shade tends to appear in fruits from some trees. The pulp colour of the ripe fruit is very different from one tree to another and may stay pale and make the fruits unmarketable.

2.4. CORRELATIONS AMONG ALL THE PARAMETERS

The correlations between among the parameters measured are reported in Annex C3 and the phenomena which may be responsible for the variations are detailed below:

- **Tree shape** was not correlated with any other parameter and might be a result of the environmental history of the tree as no low branches can develop when the trees are surrounded by vegetation.

- **Tree height, trunk circumference and canopy diameter** are mainly representative of the growth of the tree.

- **Trunk height** is probably a result of the environment and phytosanitary history of the tree. However, it was measured in a subjective manner which would explain the lack of precision.

- **Tree age** was visually estimated by farmers, therefore a study that follows the increase in trunk size, tree height, splits in the bark, and trunk colour should be conducted to produce accurate results on the influence of the age on the other parameters.

- **Trunk colour**: For young trees under 9 years old the trunks were mainly brown/white; between 10 and 13 years old, brown/white/yellow; and over 13 years old brown/yellow. Thus, the older the tree, the yellower the trunk.

- **Bearing**: Very late bearing trees were located in low rainfall areas whereas early bearing trees were found in high rainfall areas, therefore the bearing pattern was highly influenced by the precipitation. This is confirmed by Weir et al. (1982) as fruit set requires a good water supply. However, trees in the same location could be observed with a clear difference in time of bearing and therefore a genetic difference may exist too. In other locations with different rainfall level and drainage situation, this cannot be studied and trees can only be selected for further trials.

- **Phytosanitary aspects**: In the wild, on the clean trees selected, any resistance to diseases is difficult to evaluate. A general lack of field sanitation results in various diseases being linked together. A larger amount of P, K, Na in the soil seemed to enhance fungal growth and gummosis development. Larger canopies had more fungi and sooty mould. High rainfall levels enhanced sooty mould but inhibited algae.

- **Surrounding vegetation**: Only 4% of the golden apple trees were found with pure stands of nutmeg whereas 38% grew with both cocoa and nutmeg. This indicates that golden apple is used for shading cocoa trees in fields mixed with nutmeg and banana. The other mode of cultivation of golden apple trees is in backyards with other fruits or in very mixed fruit fields. Less frequently, golden apple is located in abandoned fields in secondary forest. There are no wild trees in the rain forest as the plant is not native to the island.

- **Climate**: The distribution of the trees showed a preference for high rainfall areas; nevertheless, the trees are tolerant to drought. But as the trees had been planted, this distribution could be due to the location of the fields only.

- **Soil**: As the variations observed were large, the tree did not seem to have strict soil requirements.

- **Fruit length**: The fruit length continually increased during development with a regular shape – heavier weight, larger pulp thickness and diameter. Consequently, the calibration of the fruit by its length gives a good representation of the weight of the fruit which is of interest for processing. Longer fruits were sweeter which indicates an increase of sugar content during fruit development. However growth cannot be the only factor to explain the important variation obtained which is probably also due to genetic differences. As the average size observed was smaller than the median, fruit size could be increased by selecting improved trees with large fruits.

- **Fruit diameter**: The diameter of the fruit indicated not only the growth of the fruit (also explained by the relationship between length and diameter) but also its maturity at harvest time which was characterized by a yellower ripe pulp colour.

- **Fruit shape**: Fruit growth followed a general oval shape. However, the fruits got chubbier as they became more mature which was confirmed by the ratio of length to diameter (rounder when it is sweeter). However, a few trees had a different shape (round or pear) which may be due to genetic differences, although fruits with those shapes were always mixed with oval ones.

- **Pulp thickness** increased during the growth of the fruit in respect to internal proportions for green and ripe fruits (heavier fruit, heavier stone and larger fruit diameter). The pulp thickness was smaller in fruits from very late bearing trees or with high acidity levels and therefore increased during maturation. Thus, the pulp thickness evolved continually during the growth of the green fruit and reached a maximum thickness after maturation.

- **Skin thickness** increased during the growth of the green fruit as larger skins were associated with heavier weights. It was an indication of the maturity of the fruit at harvest time (yellower ripe pulp colour) when it reached a large value. The skin undergoes a differentiation during ripening which leads to a ripe thin skin and a pulpy part. However when the fruit is not fully mature the differentiation is reduced and the ripe skin remains thick.

- **Stone diameter and stone weight**: Stone diameter was less linked with fruit weight than the other parameters and was consequently more distinct in its growth. Rounder fruits had bigger stones which confirms the development of the stone during maturation and is also corroborated by the fact that small immature fruits had an underdeveloped stone.

- **Spines**: In ripe fruits there were proportionally fewer spines as some spongy endocarp and sticky pulp hid the spines. No other correlations were observed between the number or length of the spines and the other parameters measured, thus genetic differences may exist.

- **Fruit weight**: The different parts of the fruit increased proportionally during fruit growth. Fruits of early bearing trees were heavier and ripened with more intense colours, therefore the fruit weight was also linked to the maturity stage of the fruit at harvest time. The ripe fruit weights varied by a factor of three from the smallest (71 g) to the largest (217 g), which can only be explained partially by genetic differences. However, the market does not ask for the heavier fruits due to an unawareness of their existence, and their scarcity. Very large fruits are suitable for processing into fruit in syrup, or for drying.

Errata

p2 South Pacific - Should read: (Winton and Winton 1935, Ochse et al, 1961; Ding Hou 1978, Geurts et al, 1986)

p7,12,77,78 Should read ISU (International Standard Unit) instead of IU or UI

p14 Table 7: Firmness - Should read:(lbs/cm^2)

p28,29,30,49 Should read: 'Sodium hypochlorite' instead of 'hypochlorite' or 'chlorine'

p44 Under Fig. 29, include subtitle: 'Firmness'

p67 Line 14: Should read EC\$ 1.25 to 10
Line 19: Should read with 'the' appreciation - instead of 'tan'

p80 Under C4, place C6 and subsequently move down one position all the other tree codes. Same for last column.

p94 c) Chlorophyll should read: 1 g of fruit sample (Ohaus Galaxy TM110) was reduced to a smooth paste in a mortar with 30 ml of solvent

p97 Reactions are missing:
After (Mohammed 1993), should read:

$$CL_2 + H_2O \text{ -------------------------> } H^+ + HCLO + Cl^-$$
$$HCLO + 2I^- + H^+ \text{ -------------> } CL^- + I_2 + H_2O$$
$$2S_2O_3^{2-} + I_2 \text{ -----------------> } S_4O_6^{2-} + 2I^-$$

After standardization of the thiosulfate solution, should read:
the reactions involved in this titration are:-

$$IO^{3-} + 5I^- + 6H^+ \text{ ---------> } 3I_2 + 3H_2O$$
$$6S_2O_3^{2-} + 3I_2 \text{ -------------> } 3S_4O_6^{2-} + 6I^-$$

p105 Sensory evaluation:
Line 2: Should read 59% instead of 5%
Line 6: Should read 23% instead of 2%

turation of the fruits as they
e yield of the pulp of green
ed by genetic factors linked

hand penetrometer as they
iit maturity at harvest as it

ees were intermediate, and
) the fruit maturity stage at

uit as it was not correlated
position of the green fruit.

re similar, thus indicating
urity of the fruit at harvest
lds of pulp were obtained.

associated with better rip

: maturity stage of the fruit
ased in ripe fruits.

s are not representative of
it of the interior quality of
maturity stage (high TSS/
vas also indicative of fruit

n to ripen or overripen are
egatively correlated to the
ger storage. The number of

(larger canopy) less light
ulting in a smaller size of
colours and a shorter time

ll weight of fruit and less
e lack of water delays the

l with high levels of Ca in
e correlated with rainfall,
his reason complementary
aturation.

- **Mg, Na, K and P**: Soils high in Mg, Na and K had a negative effect on the maturation of the fruit since a small pulp thickness was found for fruits from trees growing on soils rich in Mg, Na or K; high soil P and K tended to favour a thicker ripe skin and high P tended to lessen the skin colour.

- **Organic Matter (OM)**: A high OM content of the soil, was associated with higher yields of edible parts.

- **Phytosanitary problems**: The maturation of the fruit was delayed when the tree and the fruits suffered from infestation and diseases, as seen through various correlations with the ripe skin thickness, the pulp colour and the time to overripen. Diseased fruits had a larger stone, probably due to a reaction of gumming inside the fruit. Consequently, clean trees had proportionally more edible parts.

- **Tree age**: Old trees seemed to delay fruit maturation as they produced more acidic fruits (TTA, ratio TSS/TTA and taste) with a lower ripe skin colour intensity.

2.5. ANALYSIS OF VARIATION AND SELECTION OF RECOMMENDED TREES

2.5.1. Analysis of variation

In analysing the relationships between the parameters measured, seven main causes of variation were identified; these are described in Table 9.

Table 9 The main contributing factors to the variations in golden apple fruits

Factor	Parameters involved
Tree growth	Tree height, trunk circumference, age, trunk colour, quantity of splitted bark, acidity and taste of the fruit
Environment	Tree shape, trunk height, phyto-sanitary problems, ants, termites
Pedology	Trunk colour, algae, fruit maturity
Rainfall	Trunk colour, fruit maturity
Phytosanitary problems	Trunk circumference, quantity of foliage, bearing, quantity of splitted bark, fruit maturation
Stage of maturity at harvest time	Fruit length, fruit diameter, ratio length to diameter, fruit shape, pulp thickness, skin thickness, stone diameter, fruit weight, stone weight, pulp yield, firmness, TSS, TTS/TTA, taste, smell, skin colour of ripe fruits, pulp colour, time to overripen
Genetic differences	Fruit length, fruit shape, stone diameter, no. of spines, spines length, fruit weight, pulp yield, TTA, taste, skin colour of green fruit

Many of the parameters measured are linked to the maturity of the fruit at harvest. When the fruit reaches maturity, it gets chubbier, the skin increases in thickness, the pulp becomes yellow, the sugar content rises, and taste and smell are improved. The stone becomes heavier and the spines longer. The mature fruit develops a more attractive colour, becomes sweeter with an improved taste and a softer texture; a less mature fruit would be of inferior quality.

The colour of the pulp of the green fruit appears to be the parameter more representative of the level of maturity as it is linked with many other parameters and is not due to genetic differences. This colour should be carefully studied to define precisely the criteria of maturity for the different categories of fruit needed – fresh fruits to ripen or green fruits for processing.

Although golden apple trees are tolerant to drought, a higher rainfall results in earlier fruit maturity. Therefore fruit development requires a high water supply. To confirm this, grafted trees originating from the same tree should be planted in different locations of known rainfall and fixed environment and the time of bearing of these trees observed. An irrigation trial with trees propagated vegetatively from the same mother tree should also be conducted to investigate any possible delay in maturation. It would also be interesting to use irrigation at different stages of development of the fruit to determine the precise timing of water needs.

Some factors are influenced by the soil composition with an important role for Ca which may be responsible for delaying the maturation of the fruit. The same role was found for Mg, P and OM as they are linked in the soil with Ca. However as the Ca content in the soil is linked to the precipitation, some experiments need to be done to confirm these observations: trees vegetatively propagated from the same tree and planted in the same area (same rainfall level) should be fed with solutions containing different levels of Ca, and the effect of this on the time of bearing should be noted. The same experiment should be repeated with other soil nutrients.

A few parameters are influenced by the environment around the tree and other parameters by the growth of the tree itself. The more suitable parameter to represent the growth of the tree seems to be the trunk circumference. Fruits from old trees have a delayed maturation.

Some parameters are influenced by the phytosanitary problems of the tree, especially a delay in bearing, which shows that good field sanitation is needed for high quality fruits.

Some characteristics of the fruit are probably due to genetic differences, especially the size of the stone and spines, the acidity and weight of the fruit. However some varietal influence might exist for the other parameters but cannot be precisely identified in the wild because of the lack of control on rainfall and the soil composition. Trees with apparent contrasting behaviour should be planted at the same location to confirm the genetic effect. Some work needs to be done to select improved trees as germplasm is needed to improve the species.

2.5.2. Selection of recommended trees

The selection can start based on the parameters which seem to be due to genetic differences. Recommended trees (Table 10) have to be grafted, labelled and planted in a field collection. Nevertheless, their characteristics must be ensured when at the same stage of maturity and after being grown in a location with similar rainfall and soil composition. Observations on trees should also continue in the island to find other outstanding trees.

Two trees having fruits with smaller main spines, which allows the flesh to be taken easily from the stone, are highly recommended for selection. They would provide a clear improvement in fruit quality and a better potential for processing.

A dwarf variety of golden apple originating from Malaysia was introduced into Grenada from Trinidad by IICA and the Caribbean Agricultural Research and Development Institute (CARDI) (see Plate 2 on page 60). Trials should be conducted on grafting the recommended trees onto the dwarf variety. The purpose is to create trees with a reduced height, more manageable, with good quality fruits. Some preliminary trials on propagation of trees by grafting were initiated and are reported in Annex C4.

Table 10 Golden apple trees recommended for selection in Grenada

Parameter	Trees selected and named by the previous team
Early bearing	LL1, VA1, VB1, KG2
Late bearing	JO1,JO4, SR1, KG1, SP1, RB1, JB1
High yield of edible parts	C4, C6, GB, KG2, KG3, KG1
Small weight	RB1, JO4, JO1, C4
Heavy weight	GB, RB3, KG1, RB5, C1
Short spines	C6, WC1, KG2, KG1
Low acidity	GB, JB1, ET1, RB6, LL2
High acidity	HR1, MN1, C1, KGS
Pulp easy to detach	C6, C4
Small stone diameter	SP1,JO1, LL2, LL1, C4

3. POST-HARVEST TECHNOLOGY

Exporters handle the fruits in a manner which is mainly influenced by their a priori observations, but they are looking for more precise information. Studies were carried out in response to some of their questions. The results reported in this section represent an important first step in providing answers to these problems but in no way pretend to be the final solution. These studies were:

- **Follow-up of fruit handling.**

- **Field and pack-house observations and tests** carried out with the exporters in Grenada – in particular with the collaboration of the Marketing and National Importing Board (MNIB) as well as the Productive Farmers Union (PFU).

- **Laboratory trials** at the University of the West Indies (UWI) in Trinidad to highlight precise information on the storage and type of fruit respiration.

3.1. GOLDEN APPLE HANDLING PRACTICES IN GRENADA

It was not intended to conduct an exhaustive study of the variations in the handling of golden apple fruits, but rather to make general recommendations for the exporters. These are presented in section 3.4.

3.1.1. Harvest

Harvesting is done from trees growing in mixed cultivations with cocoa or in backyards; very few people consider it as an economical crop. The fruits mature during the months of June to December. Harvesting is done at any day of the week and at any time during the day (usually between 8 a.m. and 3 p.m.) and under any weather conditions.

The harvesting team comprises three to four individuals (one driver, one or two climbers, one harvester on the ground) employed on an oral contractual basis by the exporter to harvest and transport the fruits to the pack-house. They are paid EC$0.20 or 0.22/kg of golden apple harvested – the fixed price is not function of the distance travelled nor of the quality of the fruits, nor of the time taken to harvest them.

As the trees are very tall and as there is no protection for the climbers, it is a very dangerous work which requires trained personnel. The harvesters pick the fruits according to the exporter's request for types, quantities and time of delivery of the fruits. Therefore, the harvest is related to the demand of the market more than to the availability of fruits.

3.1.1.1. Location of a tree at the proper maturity stage

When harvesting other earlier crops, harvesters make a mental note as to the expected time the golden apple trees will be mature and then return to the site at that time. They continue to observe the trees throughout the season. This method of observation is their main means of localizing a tree. There is no coordination between the harvesting team or exporters for this evaluation and search. Occasionally farmers indicate their trees to the team, however the measure of fruit maturity is scarcely adequate.

The team leader examines the maturity of the fruits based on criteria well known to him but which he cannot describe. Generally, the fruit is regarded as full when it reaches 5–8 cm in length and appears chubby. The internal pulp colour is sometimes checked and must be turning pale yellow. The amount of ripe fruits on the ground is also an indicator of the maturity of the fruits on the tree. However no established criteria exist for fruit maturity. The phytosanitary aspect of the fruits, any dangerous location of the tree or the difficulty of climbing into the tree is also part of the decision to harvest.

The harvester asks the farmer for authorization to pick the fruits with no discussion regarding prices which are determined by the exporters.

3.1.1.2. Harvesting

To go inside the tree, the climber usually throws a rope around the first branches and climbs up the trunk with the strength of his arms, or climbs on neighbouring trees. Then he climbs onto the larger branches only of the tree as the branches are breakable (see Plate 3 on page 60). He chooses a good place for the harvest and attaches a bag next to him with rope.

According to their size and to the level of infestation by fungi or mites, he picks the fruits with a fruit-picker described in Annex D1. While he puts the fruits into the attached bag, he rejects more or less instinctively the 'bad ones' – mainly those too small or those with fungi or scarring problems. When the attached bag is full, it is lowered to the ground using the rope wrapped around an upper branch as a pulley (see Plate 4 on page 60).

As only mature fruits are harvested, some fruits remain on the tree after harvest. Two or three harvests, on an average about a month apart, are needed to pick all the fruits from one tree. Fallen fruits that do not appear damaged are sometimes picked up, but usually they are left on the ground to rot. (See plate 3 and 4 on page 60).

3.1.1.3. Transport from the field to the pack-house

One harvester stays on the ground and holds the bag full of fruits (50 kg) before it lands so as to prevent damage. This lowering is sometimes difficult as the tree is closely surrounded by other tree crops. The bag is detached and replaced by another empty bag.

The carrier weighs the full bag with a hand scale and records the weight. This method of weighing is difficult and results in a careless handling (see Plate 5 on page 60).

Bags are carried on the head of the harvester to the truck; this is also a difficult task due to the weight and the narrow, slippery and hilly trails in Grenada. No field storage usually takes place but may if the field is located far from the road. The bag is then emptied with caution into the truck in bulk. Fruits can also be transported directly in the bags to save time in the shipping procedures. The fruits are mixed together with the fruits of other farmers.

A storage stage occurs in the truck which usually stays out in the sun with no protection. Temperatures of 31–33°C and relative humidity of 85% have been measured in the bags on the truck.

Finally, a receipt is issued indicating the total amount harvested, the name of the farmer and date and a stamp from the exporter. The team searches for other trees with mature fruit until the truck is full (five or 10 trees) before going back to the pack-house. This occurs usually at the end of the day, but during the peak season they can also do two loads per day.

A pick-up truck (sometimes belonging to the driver) is used to transport the fruits. A plastic sheet is placed on the tray to prevent the fruit from being damaged. When the truck is full, the harvesters sit in the corners of the tray. This lack of space sometimes results in their sitting directly on the fruits. The driver is more careful with the load of fruits and drives at 40 km/h. The final transportation to the pack-house takes a maximum of 1 h.

On arriving at the pack-house, the fruits are transferred with good care from the truck into the exporter's crates to be weighed (see Plate 6 on page 60). The crates available to the harvesters are usually full of old decayed branches and leaves that have to be thrown out. The unloading of a truck takes about 30 minutes.

3.1.2. In the pack-house

If the fruits arrive at the pack-house early in the afternoon in average quantities, or if a shipment is being made, they are washed and packed in a matter of a few hours. In other cases, the crates of golden apples are stored overnight in the chill-room at temperatures between 10 and 15°C. This storage takes place with several other crops, packed or not. For the smaller exporters, the fruits are placed on a plastic tarpaulin on the floor or onto sorting tables.

On the following day, all the golden apples are removed from the chill-room in the morning. Condensation can be observed on the fruits due to contact with the ambient temperature (30°C). There are work breaks at 10 a.m. and for lunch at noon regardless of the packing state of the fruits.

3.1.2.1. Washing

At the small exporter level, the fruits are separated from their leaves and branches (the peduncle is left) and sorted for serious damage. They are placed into crates for transfer to the washing site (Annex D2). In other cases, the fruits are directly washed and this sorting is done inside the bath. The rejected fruits and residues of the tree are put into empty crates.

The crates, one after another, are manually placed on the edge of a bath filled with water and emptied in with no particular caution as is evident from sound of the fruits hitting the sides of the bath. The fruits are stirred by hand.

The criteria (described in 3.2.1.) used for sorting are subjective and variable with no written standards and depend on the sorter's training and experience.

At any time during the washing of the fruits, a person in charge adds hydrated calcium hypochlorite powder (from Saskaton Chemicals Ltd) into the water to remove sooty mould. Some other exporters use a mixture of this chemical and dish-washing liquid. Two small handfuls of the product (according to habit and trial and error procedures) are added at each side of the bath and the washer mixes it with bare hands to insure dissolution and dispersion. The concentration used is unknown and may vary. It was measured at around 300 ppm of calcium hypochlorite.

The fruits are soaked for an undefined and variable time (15–35 minutes) until they look cleaner; thus this is function of the initial cleanliness of the fruits and it may vary as the rainy season progresses. The water is changed subjectively every two or three baths of fruits when no more cleaning action of the chemical is observed.

During the soaking of the fruits, the washer uses a meshed plastic bag to rub the fruits free of sooty mould. Then he uses a perforated plastic crate to strain the fruits out of the bath of chemical and then rinses it in a bath of clear water for a few minutes. The crate is finally emptied onto the sorting table with no particular care. The washing table looks generally clean as it is washed with water and a piece of cloth but is not sanitized.

3.1.2.2. Sorting

The sorting process is continued by another person who is usually seated. The sorter takes two or three fruits in one hand and wipes them with a tiny piece of cloth to remove the traces of sooty mould that particularly accumulate near the peduncle. At the same time, the fruits are critically observed and sorted according to the criteria described in section 3.2.1. (See plate 7 on pages 61).

The rejected fruits are either placed in crates under the sorting tables or are thrown onto a pile about 2–5 m away from the sorting tables, or are placed on an empty sorting table. The location of the pile (Annex D2) leads to disorder in the pack-house.

The crates or piles of mixed crop rejects are thrown in the garbage approximately once or twice a week. There is little use of the rejects (1%). Sometimes, the 'not so bad' fruits are sorted again for sale on the local market. In the past, the fruits were given to livestock farmers.

Generally there is no grading, but sometimes, the importer requires it (i.e. bigger fruits with no damage at all) but does not pay a higher price for the high quality fruits. The equipment is not adapted for such double sorting and this leads to a cumbersome position of the boxes.

The wet fruits are finally put with good care into a box which lays on another table behind the sorter. It takes approximately 5 minutes to fill a box.

Fruits fallen on the ground at any stage of the procedure are not packed unless there are large quantities.

3.1.2.3. Packing

The cardboard boxes used for shipping are 50 cm x 30 cm x 20 cm in size with only two ventilation holes at two opposite corners. the empty boxes are labelled with the following information: Golden apple (or g/apple or June plum); 40 lb; the destination of the shipment (New York or London); the address of the buyer; the sticker of the airline; the name of the exporter. This is either hand-written or stamped on the box by a third person.

The packer adjusts the weight of the box to the required weight (40 lb or 18 kg which represents approximately 150 fruits) by unpacking one of the full boxes of fruits that are used as a reservoir. The packer then covers the boxes and places them in lines or on a pallet which is taken on a manual forklift into the chill-room. The fruits stay in refrigeration for two or three days waiting for a date of shipment. Storage is with several other fruits and vegetables at different stages of maturity, in boxes or not, washed or not. The temperature is fixed around 10–16°C but there are many variations due to the frequent opening of the doors.

3.1.3. Shipment

The time of the day for transfer to the carrier is different from one shipment to another and is a constraint for the exporter. The last labels are placed on the boxes before a random sanitary inspection by the Pest Management Unit (PMU). The boxes are then slid with medium care onto the truck by two men. Two other men pile them up in the truck (eight boxes form a pile) without any consideration for ventilation. The boxes of golden apple are mixed with boxes containing other fruits.

A white folded tarpaulin is carried in the truck and used only in case of rain or is put around the boxes and secured tightly with a rope to prevent them from falling. The time taken to fill the truck is approximately 1 h. The team finally waits 10 minutes for the official documents and then leaves the pack-house.

They drive to the airport at a speed of 40–80 km/h which takes 15 minutes to 1 h according to the location of the pack-house. The truck is parked in the limited shade available (Plate 8). The team waits (15–45 minutes) for the arrival of the person in charge from the exporter. During this delay, condensation can be observed on the fruits and the temperature inside the boxes has been measured at 22°C.

In the airport, the employees of the exporter take the boxes from the truck and put them on a scale. Two officials (one from the exporter and one from the airport) check the amount shipped for billing purposes. Then the airport employees throw the boxes on a plane palette (3 m x 4 m) without any caution, just as if they were ordinary baggage, and pack them without any respect for ventilation. This lack of care also influences the way in which the exporters' employees unload the trucks. (see Plates 8 and 9 on pages 61).

This loading lasts 1 h and then a net is placed over the boxes to secure them during the flight. The palettes are placed in the plane by an automatic lifter (Plate 9 on page 61). Generally the fruits spend 2 5 h in the airport – these delays may be quite different with other airlines, especially those with passengers.

In some cases, the boxes are delivered, without any caution, to the harbour where there are some traffickers for the regional trade to other Caribbean countries, especially Trinidad. This export is also done by very small specialized exporters who pack the fruits in polystyrene bags or in wooden buckets without cleaning them. In Trinidad, the fruits are delivered at the harbour to local buyers who take them directly to the Central Market where they are sold in bulk.

3.2. FIELD AND PACK-HOUSE OBSERVATIONS AND TESTS

After observing the handling of golden apples, some experiments were carried out to determine solutions to the main problems expressed by the exporters: washing difficulties; determination and measurement of fruit losses.

3.2.1. Study of the exporter's fruit losses

3.2.1.1. Bruising

Some fruits harvested from one particular tree were taken at various stages in the handling procedure. The first fruits were taken just after harvest and transported with care in a crate by wrapping them in tissue to avoid further bruising as much as possible. The second set of fruits was taken after they had been transported to the pack-house. The third set was taken on the sorting table just after the washing.

The fruits were stored for 24 hours in a chill-room at 15°C to allow the bruises to appear on the fruits. Then the fruits were sorted and the bruised fruits weighed. Two different sizes of bruise were observed: small (less than 5 mm) and large (1 cm).

Table 11 Evaluation of bruising occurring during the handling

	Small bruises (%)	Large bruises (%)	Total (%)	Difference between stages (%)
Harvest	1.1	0	1.1	
Transport	1.6	1.6	3.2	2.1
Washing	1.4	2.7	4.1	0.9

The 4.1% of rejected fruits (Table 11) is an underestimate as other bruises would occur during the packing, storage and transport of the fruits. Transport seems to be the main cause for most of the bruises on the fruits. During harvesting only small bruises occurred due mainly to fingernail marks. At the transport and packing stages there were more of the larger bruises due to the bouncing around of the fruits in the crates, in the bath and on the sorting table.

3.2.1.2. Rejects

The study was conducted on one young tree in River Salee with good sanitation, therefore the rejects are likely be minimal as there were few infestations and few large branches difficult to reach. Many fruits are generally found on the ground after harvest and farmers complain about it. Two types of losses occurring during harvest were evaluated: fruits falling to the ground due to handling difficulties and fruits voluntarily rejected by the picker.

In the pack-house, a known quantity of fruits was washed, sorted and packed. The crates of rejects coming from the first sorting done by the washer and those from the second sorting done by the sorters were analysed separately.

Losses at harvest

The percentage of fallen fruits was high for a commercial crop, due to difficulties of handling (Table 12). However the total loss recorded at harvest was 9.65% which does not confirm the previous figures of 50% (Bauer et al. 1993). Few fruits were rejected by the picker.

The main cause of rejects at harvest was mite damage which is the easiest damage to see and the best known. The second reason for rejects was immature fruits (2 cm long) which was due to the varying stages of maturity within the same cluster. Fungal infestation occurred to a very small extent. Deformity and mechanical damage were other reasons for rejections. The small percentage of the latter indicates that reasonable care was taken during harvest (Table 12).

Table 12 Cause and evaluation of fruit losses of golden apple during harvest and sorting

Cause	Limit of rejection	Harvest (%)	1st sorting (%)	2nd sorting (%)	Total (%)
Mites	1/3 brown scaring	1	1.9	0.5	3.4
Fungus	any black spot	0.05	1.1	0.3	1.45
Deformity	any sign	0.1	0.1	0.07	0.27
Scales	any yellow spot	0	0.14	0.1	0.24
Small size	<2 to 3 cm of diameter	0.3	1.4	1.0	2.7
Overripe for export	turning yellow	0	0.02	0.3	0.32
Mechanical damage	any sign	0.1	0.1	0.3	0.5
Falling		7	0	0	7
Bruises	any over-soaked green lesion	1.1	0.5	2.5	4.1
Other		0	0.05	0.19	0.24
Total		9.65	5.31	5.26	20.24

Losses in the pack-house

Leaves and branches with the fruits represent 1%. The amount of fruits rejected in the pack-house was low (10.5%) as it was the beginning of the season. The losses measured by the previous team of 20–50% may have been influenced by a seasonal effect (Bauer et al. 1993).

About half of the pack-house rejects came from each sorting. The fruits rejected during the washing were mainly those damaged by mites and fungi as these are more easily seen. A lot of the fruits rejected were those of small size, as these are easier seen singly compared to bulk fruits.

At the sorting step fruits were rejected mainly due to their small size and there was an increase of rejects due to minor causes as the fruit was more carefully examined.

General losses

A 20% loss (Table 12) is highly significant for a commercial crop and any reduction in this loss would result in an increased production. Mite scarring was the main reason for rejection. However, it is a superficial problem which does not evolve during transportation or storage, consequently it has to be controlled for the appearance of the exported fruits only. Fruits of this type can be used for processing or sold on the local market.

The second reason for rejection was the small size of the fruits. It would be interesting to know if these tiny fruits were mature but of small size, or immature; also, if it was due to the quality of the trees (small fruits) or to the quality of the harvest (too young). The rejected fruits were bigger in the pack-house (3–4 cm long). These small fruits could be used for processing.

Another important cause of rejection was the presence of fungi. It probably be the same percentage as that for mite damage and small fruits in the rainy season. Development of the fungi during storage and transport is of great importance for quality. These three major problems were also the main reasons for rejects during the previous study (Bauer et al. 1993).

Bruising is another important source of damage which can be easily controlled as it is directly due to the handling practices. As the appearance of the bruises is delayed, those due to handling in the pack-house would probably appear later in the box, and are therefore more important since they would be found by the buye whereas fruits with bruises that occurred during harvesting and transport may have been eliminated during the sorting process (see Plate 10 on page 61).

3.2.1.3. Conclusions

The sorting process does not appear to be very accurate since it is possible to find some poor quality fruit in the final box that should have been rejected. This inconsistency is due to an haphazard procedure.

Some losses (mites, fungi, deformity, scales) are due to agronomic problems (5.36%), others (too young, overripe, mechanical damage, bruises, falling) are due to the harvesting practices (10.52%) while still others (bruises etc.) are due to the handling in the pack-house (4.34%). Harvesting can be improved in different ways: reducing the height and width of the trees by pruning or grafting with the dwarf variety; improving the tools used for picking the fruits.

The other important losses are due to the initial quality of the fruits; research should therefore be carried out and measures taken to control mites and fungal infestation. Generally, rejects due to the handling in the pack-house are not low but are underestimated as the fruit still undergoes bruising during transport.

3.2.2. Washing trials

Some fruits heavily infected with sooty mould were subjected to various treatments and rated for cleanliness as indicated in Table 13 to determine the best conditions for the washing process.

Table 13 Scheme for determination of the cleanliness of golden apple fruits

Score	Meaning
1	Very dirty = not washed
2	Average dirtiness
3	Slightly dirty
4	Traces of dirt
5	No dirt = clean

The fruits were also closely examined after the treatment in order to see the effect of the treatment on the fruit skin. The number of days to ripen and the additional number of days to overripen (unpacked at ambient temperature) were measured. The location of the initial overripening was also noted (top or side). A lot of fruits seems to rot from the top, near the peduncle (stem rotting), and an attempt to evaluate the effect of washing, or the penetration of water, on rotting was made. After a while shrivelling was observed on some ripe fruits.

The experiment was done in a small (10 l) bath with five fruits per treatment. The results were subjected to analysis of variance. Sooty mould occurred in a very non-uniform manner which constituted a source of error in the results. The hypochlorite was difficult to dissolve and to ensure the right concentration a special effort was made to dissolve it.

3.2.2.1 Water soaking effect

An initial trial was done on soaking the fruit in water only as a control treatment and to evaluate the relationship between soaking and stem rotting. Fruits were plunged into a bucket of water. Every 10 minutes, five fruits were removed and allowed to air-dry.

The number of days taken to ripen or overripen was not significantly different ($P>0.05$). However, the total shelf-life of the fruit tended to be stable after a short soaking and decreased with too long a soaking ($P<0.05$) (Figure 5). The fruits spoiled more quickly in high moisture conditions.

No significant conclusions ($P>0.05$) could be made either on the effect of the location of rotting or on shrivelling.

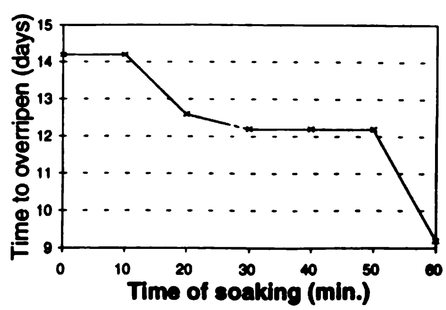


Figure 5 Effect of the length of time of soaking in water on the total shelf-life of golden apple fruits

3.2.2.2 Peduncle effect

Another experiment was conducted to examine the influence of the existence of the peduncle on the rotting of the fruit. Fruits with a piece of branch (approximately 20 cm long) were soaked for 15 minutes in water and allowed to air dry. Five other fruits without a peduncle were similarly treated.

The number of days to ripen was significantly longer for fruits without a peduncle ($P<0.05$), but the number of days to overripen was not significantly linked with the presence or absence of a peduncle ($P>0.05$). The peduncle may contain some substance that induces ripening, and in removing it ripening is slowed down; this is of interest for the storage of the green fruits.

No significant differences were observed in shrivelling or location of rotting ($P>0.05$).

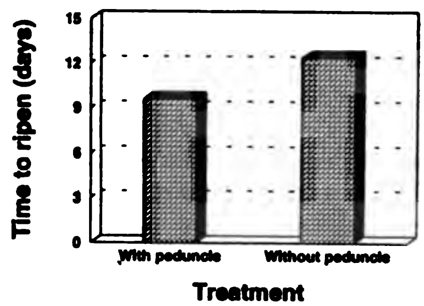


Figure 6 **Influence of the peduncle on the time taken for golden apple fruits to ripen**

3.2.2.3 Chlorine tests

Time of soaking

The fruits were soaked in a solution of 150 ppm of chlorine (Mohammed 1993), removed at various times, hand-rubbed and then allowed to air-dry. The washing efficiency was noted.

The cleanliness increased significantly ($P<0.001$) with the time of soaking (Figure 7). If this trend were extrapolated, 2 hours would be needed to wash the fruits which is not commercially feasible. Therefore, a stronger concentration and/or some complementary action must be used. Twenty minutes of soaking may be a good compromise for commercial purposes.

No effects were observed on the skin. The fruits looked dull after the washing but if they were rubbed again, they shone. This could have been due to destruction of the first layer of wax or the deposit of a mineral pellicle.

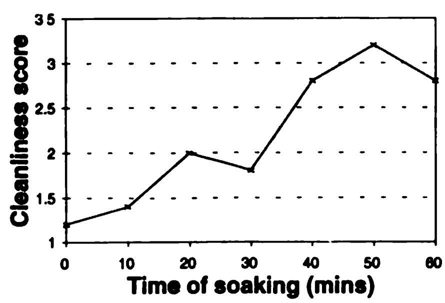


Figure 7 **Effect of the time of soaking golden apple fruits in chlorine solution on washing efficiency**

The number of days to ripen or overripen, the location of the top rotting and shr:velling were not significantly influenced by the treatments (P>0.05). However side rotting was influenced by the time of soaking in the chemical (P<0.01), but in an irregular way probably due to irregular fungal infection.

Concentration

An experiment was conducted on soaking the fruits in varying concentrations of the product for 15 minutes. The fruits were then hand-rubbed and allowed to air-dry.

Cleanliness increased significantly with the concentration used (P<0.001) (Figure 8). Even at very high concentrations the fruits were not totally clean, a few traces of sooty mould were left, nevertheless this type of cleaning was more efficient than just soaking.

At 50 ppm, which represents the lower limit, no effect was observed; between 50 and 300 ppm, the improvement was regular with a good slope; and from 300 to 1000 ppm there was an increase in washing efficiency but with a very low slope. Therefore a concentration of 300 ppm could be considered as optimum since at higher concentrations there was a reduction in efficiency.

Even at high concentrations no damage was seen on the skin which is surprising. However when some 'chlorine' powder was put directly onto the skin, holes could be observed with a yellow discoloration. The fruits did not ripen normally and stayed hard. This shows that the product is highly corrosive and care must be taken when dissolving it to avoid any direct contact between the powder and the fruit.

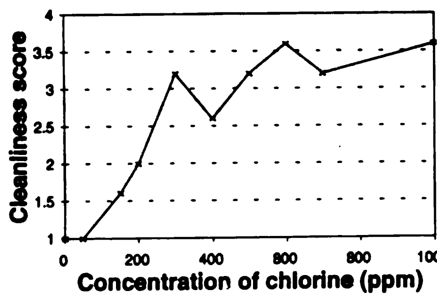


Figure 8 **Effect of the concentration of the chlorine solution on washing efficiency for golden apple fruits**

Increasing the chemical concentration produced no significant effects on the time taken to ripen or overripen, nor on the location of rotting and shrivelling (P>0.05).

3.2.2.4 Tools used

The fruits were soaked 15 minutes in a 150 ppm solution of chlorine, washed with various tools and allowed to air-dry.

The fruits were clean after the treatment, showing that rubbing with a 'tool' is more efficient than just soaking or using a higher chemical concentration. The cleanliness of the fruit was significantly different from the use of one tool or another (P<0.001) (Figure 9). A soft sponge or a tissue still left some traces of sooty mould on the fruit but harder tools produced very clean fruits.

Surprisingly no damage was observed on the skin of the fruit with any of the tools used. However, during other manual washing of the fruits with very hard tools, scratches on the skin were observed which inhibited proper ripening.

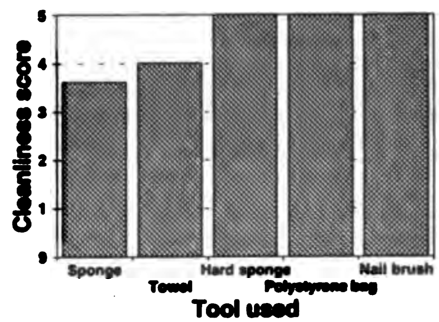


Figure 9 **Washing efficiency of different tools**

The number of days to ripen or overripen was not significantly different with the various tools used nor was the appearance of shrivelling symptoms or location of rotting (P>0.05).

3.2.2.5. Conclusions

- Soaking the fruit in water longer than 10 minutes resulted in a decrease of the fruit's shelf-life. However, 10 minutes of soaking seemed to have a favourable stabilizing effect which was probably due to higher initial moisture delaying water loss.

- The presence of the peduncle decreased the ripening time of the green fruit.

- Side rotting was probably due to irregular fungal growth; however, the top rotting could not be explained. The shrivelling may have been due to the low air moisture.

- Chlorine has a positive effect on washing efficiency of the fruits but no significant effect on ripening or overripening. The optimum conditions for washing golden apples were: soaking for 20 minutes in a 300 ppm solution of sodium hypochlorite and rubbing them with a tool of medium hardness.

- In the experiments each fruit was treated individually, which cannot be done commercially, therefore a trial simulating the optimum conditions should be carried out to transfer them to the pack-house scale.

3.3. LABORATORY EXPERIMENTS

3.3.1. Fruit respiration

3.3.1.1. Materials and methods

Fruits were harvested from one particular tree using a pole. Eighteen fruits were selected of a homogeneous size, fully mature, nearly turning (traces of green yellow on the skin), with no bruises, mechanical damage or fungi. The fruits were soaked for 10 minutes in 1% solution of sodium hypochlorite and hand washed.

A jar was filled with the fruits and the amount of water needed to fill the free air space was measured. The initial and final weights of the fruits were recorded and a proportional decline in time was used to evaluate the weight of the fruits for each day.

The fruits were placed in a jar covered and sealed with vacuum grease and allowed to respire half an hour in that confined atmosphere. The rate of CO_2 released in the desiccated atmosphere was measured with a CO_2 analyser (Annex D3) and calculated as :

$$\frac{\text{Container free space x 10 x\% of } CO_2 \text{ measured}}{\text{Weight of fruits x time of closed storage}} \text{ (ml/kg per h)}$$

The same measurement was done every 24 hours to follow respiration during the ripening of the fruit stored at ambient temperature in a box filled with shredded paper.

3.3.1.2. Results

The fruits ripen non-homogeneously (Annex D3) therefore the values measured are not representative of a precise stage of ripening. Thus, the level of respiration (Figure 10) obtained is only an indication of a general level.

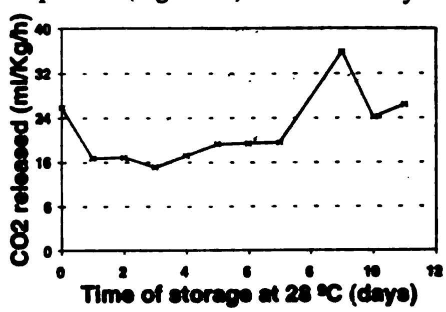


Fig 10 Respiration of golden apple during ripening at ambient temperature

The emission of CO_2 decreased considerably after harvest. As young fruits have high respiration rates compared to the mature fruits, this could be due to an immaturity of the fruits (Pantastico 1975). The CO_2 released decreased up to 3 days after harvesting; the fruits were still green. A slight increase was observed when the first fruits began to ripen and an important increase was visible after the ripening of all the fruits and the beginning of overripening.

This sharp increase in the respiration indicates that this fruit is climacteric (Wills et al. undated). It is very remarkable that the pre-climacteric phase lasted such a long time at ambient temperature. The fruits can be described as having a 'late peak type of respiration', with the maximum rate of respiration being shown from the full ripe to overripe stages, similar to the Japanese persimmon or peaches (Pantastico 1975).

The climacteric nature of golden apple is confirmed by the analysis conducted by Fahrasmane and Parfait (1988) on the amino acid content of the fruits at different degrees of ripening (Annex B1). The amino acids increase considerably during the ripening (4 g/100 g DM after hydrolysis) with important amounts of alanine detected; this is a precursor of ethylene.

Respiration can be described as an oxidative breakdown of the more complex materials normally present in cells (starch, sugars, organic acids) into simpler molecules such as CO_2 and H_2O (Wills et al. undated). The sharp increase of the respiration shows the difficulty in keeping ripe fruits. A high rate of respiration is usually associated with a short storage life (Pantastico 1975) and a quick deterioration in quality and food value.

3.3.1.3. Discussion and conclusions

An inhibitor may be produced in the tree which migrates into the fruit as long as the fruit is attached. This prevents the fruit from reacting to ripening inducers such as ethylene. When the fruit is detached from the tree, the inhibitor is destroyed and the fruit starts to ripen (Pantastico 1975). For golden apple, large quantities of this inhibitor may be accumulated in the fruits and may be difficult to destroy.

It is also interesting to note that the ripening of golden apple is usually activated by fungal growth (ripening starts where fungus grows), and it may be that the fungus metabolizes this inhibitor. The ripening of golden apple usually begins at the uppermost portion of the fruit and very often the fruit starts to spoil around the peduncle, while at the same time it is not fully ripe at the base. This was first suggested to be due to a fungal growth inside the peduncle (Bauer et al. 1993), but it can be provoked by an accumulation of the inhibitor.

Another theory is that disgeneration of chloroplasts leads to a cessation of the photosynthetic activities resulting in a process of degradation. Ethylene increases the permeability of membranes of cell walls making the substrates more accessible to the enzyme released in the cytoplasm. The climacteric rise would therefore be the end of active synthesis and beginning of senescence of the fruits (Pantastico 1975).

In any case a treatment with a ripening accelerator such as ethylene (0.1–1.0 µl/l per day) during the climacteric phase should accelerate the ripening and make it more uniform (Wills et al. undated).

3.3.2. Storage of golden apple in a refrigerated atmosphere

3.3.2.1. Materials and methods

Fruit material

The fruits (fully mature green, nearly turning) were harvested in the morning from one tree, picked with a pole and caught with a tarpaulin to reduce bruising. Fruits of a homogeneous size were selected and fruits wi... gums or fungi were rejected. However, the fruits used were more affected than those the exporters would normally select.

The fruits were washed by dipping for 10 minutes in a 1% solution of sodium hypochlorite, and rubbed with a towel to remove the sooty mould. They were allowed to dry in cool air ventilation and were then randomly packed in a closed box filled with shredded paper following two treatments: 'unpackaged' (wrapped in tissue paper, but without causing changes in the thermic and gas transfer conditions) and 'packaged' (thermo-sealed in a polyethylene film – 0.04 mm low density).

Fruit sampling

Six fruits were removed from the chamber at each sampling interval (5 days), three to be studied at a stage called 'green', which means when just removed from the chamber, whereas the other three, called 'ripe', were allowed to ripen unwrapped under ambient conditions and were studied after ripening.

The measurements of shrivelling, firmness (with penetrometer or compression tester), colour and aroma were done separately on three whole fruits. The measurement of chlorophyll, total carotenoids, total phenols, acidity, brix and pH were done in duplicate on the mixture of the three fruits. For the measurements of total phenols, acidity, brix, pH and taste, the skin and pulp of three fruits were blended with 50% water.

The 'green' fruits were peeled twice with a potato peeler to remove a thickness of 4 mm (the entire greenish skin). The 'ripe' fruits were peeled once with a knife to remove the thin, distinct skin. The skin was then cut in small pieces approximately 0.7 cm thick. These were mixed together and a smaller homogeneous sub-sample was taken to be cut into very small bits of less than 1 mm thickness and weighed. The pulp for these measurements was obtained by hand-grating down to the seed; it was then homogenized and weighed. The methods of measurement are given in annex D4.

Fixed parameters

An unpublished preliminary study done in Grenada gave some baseline information for this trial. Ideal conditions of storage of golden apple appeared to be between 10 and 15°C. Therefore storage temperatures were chosen with a slightly larger range to observe the full effects at 8, 13, 18 and 28°C. The chambers (Bally Engineered Structures Inc) were regulated at ± 3°C.

Buckets of water were placed in the chambers to regulate the relative humidity at approximately 90% during the storage. For fruits at ambient temperature or during ripening the relative humidity was not controlled..

Analysis

The study was conducted with analysis of variance for all the fruits, for the fruits at 28, 18 and 13°C, and with comparisons of 28 and 18°C and of 28 and 13°C.

3.3.2.2. Storage of green golden apple

Shrivelling

At 28, 18 and 13°C, no signs of shrivelling appeared during storage contrary to the situation at 8°C (P<0.001) (Figure 11). Shrivelling, therefore, is a sign of chilling injury. This temperature-dependent phenomenon was confirmed with packaging as only packed fruits at 8°C developed shrivelling symptoms (P<0.01).

At 8°C, the shrivelling was a function of the length of storage (P<0.05). The symptoms appeared after a delay in time and finally decreased. Shrivelling resulted in pitting: mummification of the fruit with holes due to the collapse of the chilled cells beneath the surface (Wills et al. undated).

Packaging reduced both the onset and the extent of shrivelling (P<0.01). Appearance of the main damage occurred after 20 days instead of 10 for packaged fruits. Modified atmosphere reduced the extent of chilling injury and packaging minimized pitting by maintaining a high relative humidity (Wills et al. undated).

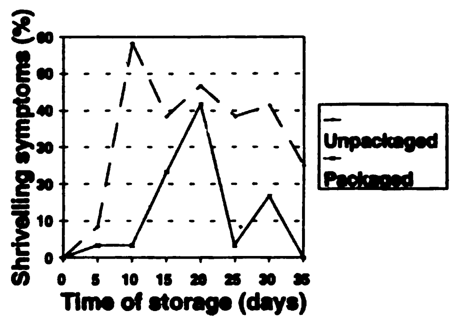


Figure 11 **Shrivelling of green golden apple fruits stored at 8°C**

Weight loss

After harvesting, the fruits continually lost weight despite the temperature at which they are stored (P<0.001) (Figure 12). This was due to the cessation of the nutrition of the fruit from the tree and loss by respiration and transpiration in particular. It is remarkable that shrivelling was not observed even with a final weight loss of 12% since only 5% of weight loss could cause damage to a lot of other commodities (Wills et al. undated).

The weight loss decreased with temperature (P<0.001). This was due to the reduction in the vapour pressure deficit as the temperature is lowered. This non-metabolic reaction explains the constant loss trend and why at 8°C chill-injured fruits lost weight too.

Packaging the fruits resulted in a 50% weight loss reduction (P<0.001) which increased with time (P<0.001) because the polyethylene film acts as a barrier against the transpiration of the fruits (Wills et al. undated)

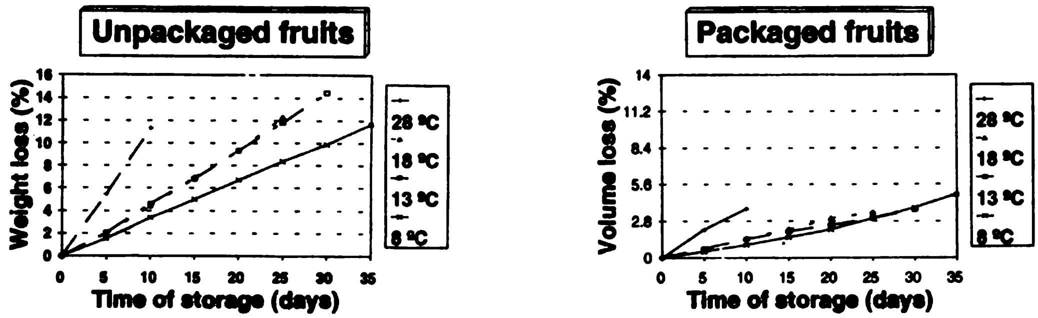


Figure 12 **Weight loss undergone by green golden apple fruits during storage**

Volume loss

During storage volume losses occurred at all temperatures as the fruits lose water by transpiration (P<0.001) (Figure 13). This volume loss decreased with refrigeration (P<0.001) due to reduced weight losses at lower temperatures. However, fruits without chill injury tended towards a stabilization of their volume loss during the final ripening.

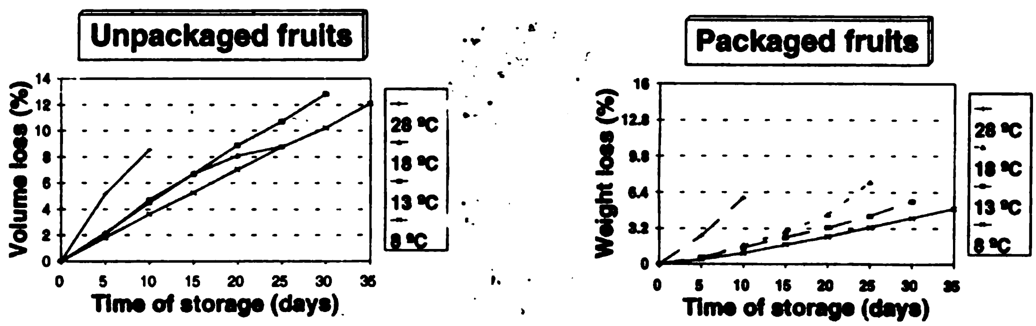


Figure 13 **Volume loss undergone by green golden apple fruits during storage**

Packaging reduced the volume loss (P<0.001) as transpiration was lowered. The difference observed between packaged and unpackaged fruits decreased with refrigeration (P<0.001) and increased with time (P<0.001).

Specific gravity

The changes in the specific gravity were not significant (P>0.05).

Skin and pulp colour

Skin:
The colour of the skin became yellower with the storage time of the fruit (P<0.001), as the fruit ripened (Figure 14). However at 8°C, the colour stayed green with no increase due to the chilling injury (P<0.001).

The appearance of the yellow pigmentation was delayed in refrigeration indicating a slower ripening (P<0.05). In refrigeration at 13 and 18°C, the fruits attained a less intense colour than at ambient temperature (P<0.05) – however, the fruits were still attractive and marketable. At 13°C, they had a final colour which was more intense than that at 18°C as they did not deteriorate in storage but remained ripe for a longer period of time.

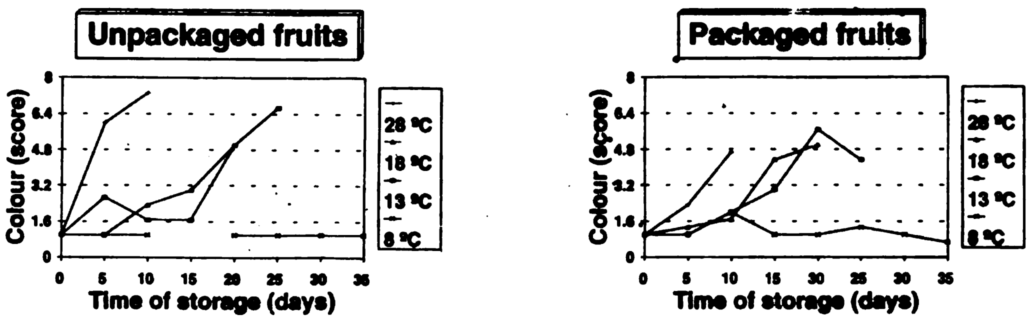


Figure 14 **Changes in the skin colour of green golden apple fruits during storage**

At 8°C, packaged fruits became brown as they deteriorated after 35 days of storage ($P<0.05$). At 28°C, the packaged fruits stayed green for a longer period of time ($P<0.001$), because they did not ripen properly, but spoiled instead. A similar spoilage was observed at the end of the storage at 13 and 18°C.

Pulp:

The yellow colour of the pulp increased with the storage time ($P<0.001$) as the fruits ripened (Figure 15). The pulp of overripened fruits was more translucent and the colour more intense. The changes under refrigeration were not significantly different ($P>0.05$). Therefore the final level of carotenoid attained after storage in refrigeration was similar to a ripening under ambient temperature.

At 8°C, there was a very slow colour development ($P<0.001$), consequently the effects of chilling injury were less in the pulp than in the skin. The internal fruit temperature was probably higher which protected it against chilling injury. The chill-injured golden apples observed previously in Grenada were undergoing an oxidization of the pulp which led to a browning of the pulp. The storage temperature was less regulated in Grenada and could have been lower inside the fruit and therefore this browning phenomenon could have been a sign of further chilling injury inside the fruit.

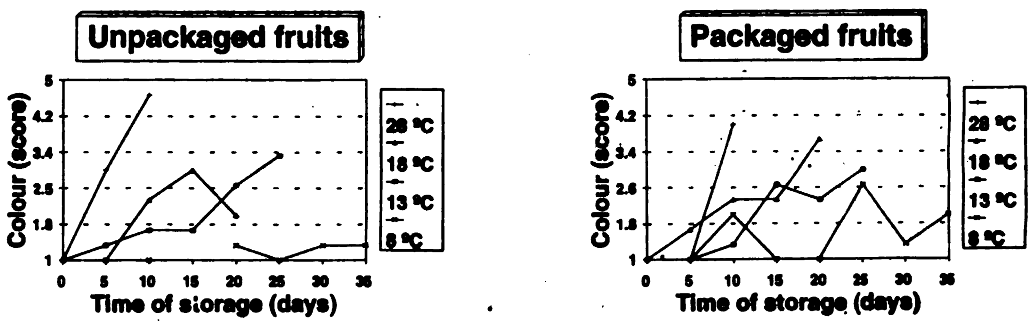


Figure 15 **Changes in the colour of the pulp of green golden apple fruits during storage**

At 28°C, the pulp colour of packaged fruits remained green after 5 days of storage showing interference with the ripening phenomena because of the packaging (modified atmosphere) ($P<0.05$).

Chlorophyll

The chlorophyll content of the skin decreased continually during storage at 28, 18 or 13°C ($P<0.001$) (Figure 16). This explains the reduction of the green colour as the fruit ripens. The degradation of the chlorophyll structures is due to pH changes, oxidative systems and action of the chlorophylases (Pantastico 1975).

At 8°C the chlorophyll was destroyed to a lesser extent ($P<0.001$). It should be noted that chlorophyll synthesis still took place during the first 5 days of refrigeration ($P<0.05$).

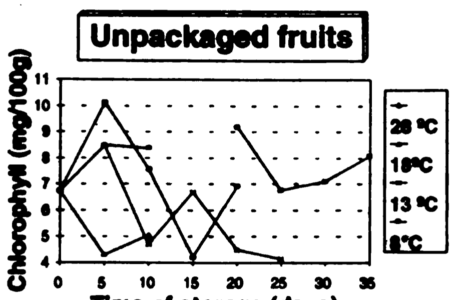


Figure 16 Changes in the chlorophyll content of the skin of green golden apple fruits during storage

There were no significant differences between packaged and unpackaged fruits (P>0.05). However, the continuation of chlorophyll synthesis after 5 days occurred in packaged fruits at 28°C (P<0.05) because the ripening process is thwarted.

Total carotenoids

Skin:
The carotenoid content of the skin diminished with the shelf-life of the fruits (P<0.05), whereas the colour of the fruit became yellow (Figure 17). This phenomenon was probably due to the degradation of the chlorophyll which was masking the yellow pigments. This is similar to what happens in bananas or tree leaves (Pantastico 1975), whereas the carotenoid content usually increases in other fruits.

The final level reached was lower in refrigerated storage (P<0.05) but similar values were obtained for fruits at 18 and 13°C which explains the similar colour observed.

At 8°C, the level of carotenoid dropped until chilling injury occurred when carotenoids were no longer degraded (P<0.01). However, fruits remained green as the chlorophyll was not destroyed sufficiently and continued to hide the pigments.

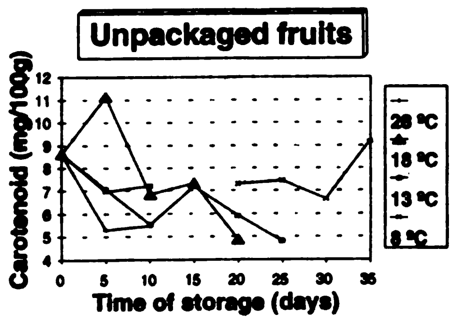


Figure 17 Changes in the skin carotenoids of green golden apple fruits during storage

At 8°C, the carotenoid level in packaged fruits decreased continually in storage (P<0.05) as the polyethylene film reduced the chilling injury symptoms.

Pulp:
The carotenoid content in the fruit pulp is less than that in the skin, therefore few significant differences were observed (P>0.05).

Firmness

Penetrometer:

The main decrease in firmness appeared at the end of the shelf-life of the fruit, with overripening due to changes in the skin (Figure 18). In ripening, the skin became thinner but was still hard, whereas during overripening the skin became soft and nearly non-existent. The measurement with the penetrometer was therefore more representative of the changes in skin firmness. An important breakdown of the insoluble protopectin into soluble pectin occurs in the skin of the fruit.

Firmness changes were not significantly different at 28, 18 and 13°C but were at 8°C ($P<0.01$) at which temperature the skin stayed hard. Penetration increased slightly due to surface damage near the pitted areas ($P<0.001$). No differences were observed between packaged and unpackaged fruits ($P>0.05$).

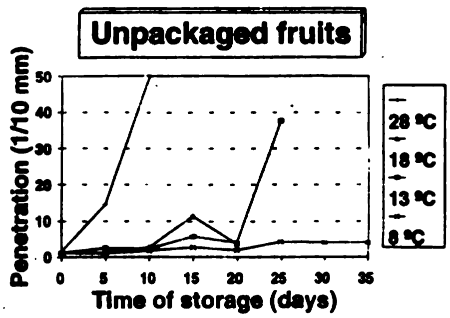


Figure 18 **Changes in the firmness (measured with a penetrometer) of green golden apple fruits during storage**

Compression test:

This measure is more representative of the textural changes both of the pulp and skin of the fruits as compared to the penetrometer. The pulp and skin of the fruit soften due to a breakdown of insoluble protopectins into soluble pectins during the ripening process (Pantastico 1975; Wills et al. undated). The final level obtained was close to zero showing a total loss of the texture and this decrease is a critical phenomenon observed for stoned fruits.

The softening was reduced with refrigeration ($P<0.001$) as the degradation of the protopectin is a metabolic phenomenon (Figure 19). This is another indication of the delay of ripening in refrigeration. At 13 or 18°C, little differences were observed and the final textural level reached was similar to that at 28°C. At 8°C, the fruit remained firm (loss of elasticity) as the degradation of the insoluble pectin was inhibited by the chilling injury.

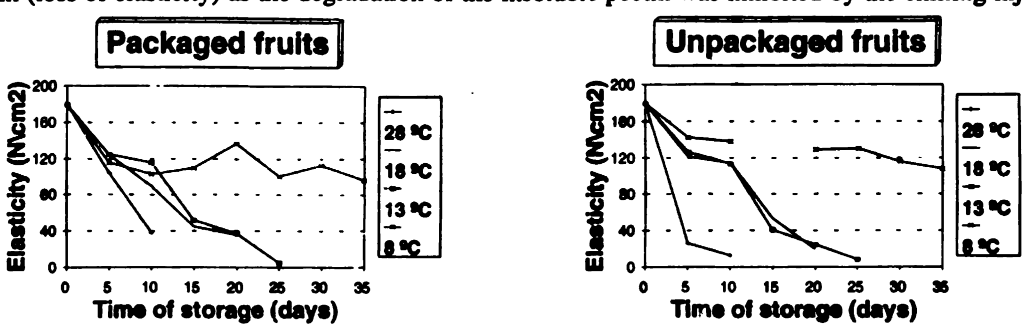


Figure 19 **Changes in the firmness (measured with a compression tester) of green golden apple fruits during storage**

Packaged fruits at ambient temperature, 18 and 13°C were firmer ($P<0.001$) as the high CO_2 levels inhibit the breakdown of pectic substances (Wills et al. undated). However this phenomenon did not exist at 8°C probably due to the reduced respiration. Textural differences increased with time ($P<0.001$) and with the storage temperature as respiration is proportionally reduced ($P<0.001$).

Total soluble solids (TSS)

The TSS in the pulp or skin, with or without packaging during the ripening or the shelf-life were not significantly different (P>0.05). The TSS tended to increase in time compared to the initial value as the complex polysacharrides are degraded into soluble solids, but this was independent of the storage conditions (P<0.05).

Titratable acidity (TTA)

Table 14 **Mean values obtained for the TSS (°brix) of the unpackaged green fruits**

Time (days)	0	5	10	15	20	25	30	35
Skin:28°C	7.3	7.4	6.8					
18°C		4.8	5.4	6.3	6.1			
13°C		3.9	5.9	6.0	6.0			
8°C		4.6	4.2	5.0	5.0	5.1	5.8	6.0
Pulp:28°C	4.4	7.7	6.8					
18°C		6.1	6.3	7.0	6.2			
13°C		5.0	6.8	6.8	5.7			
8°C		5.0	4.9	6.2	5.4	5.5	6.0	6.9

Skin:

The TTA decreased significantly during ripening at 28°C (P<0.001), similarly to what happens in mango (Pantastico 1975). In refrigeration, the acidity decreased while the fruit was still green, representative of a quick change in the taste of the fruit after harvest. On the commencement of ripening in storage, the acidity rose and then decreased with overripening due to organic acids being metabolized (P<0.001). The acidification was higher at colder temperatures (P<0.001).

Chilling injury, at 8°C, did not influence the changes in the acidity of the skin. At 28°C, packaged fruits also suffered an acidification (P<0.01).

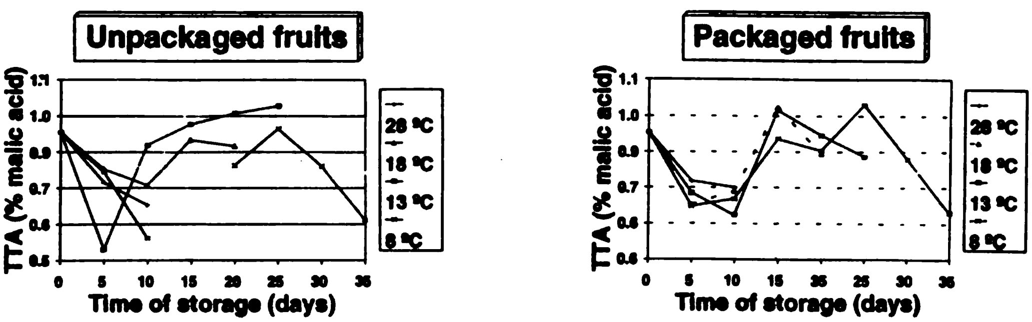


Figure 20 **Changes in the acidity of the skin of green golden apple fruits during storage**

Pulp:

Changes in the acidity of the pulp (Figure 21) followed a behaviour similar to that of the skin as a function of time and temperature (P<0.05). However the acidity continued to rise at the end of the storage. At 8°C, there was no acidification, the acidity being stabilized with the chilling injury (P<0.01) and this separate evolution is confirmed with packaged fruits (P<0.01). Packaging did not influence the pulp acidity (P>0.05) therefore its effect was directly exerted on the skin.

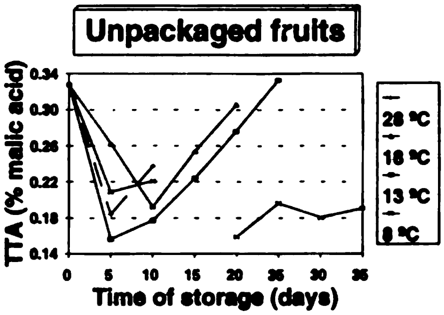


Figure 21 **Changes in the acidity of the pulp of green golden apple fruits during storage**

TSS/TTA, taste and scent

The ratio, TSS/TTA, taste and aroma of the skin and pulp were not significantly different (P>0.05).

pH

The pH of the skin and pulp (Figure 22) was not significantly different at 28, 18 and 13°C, with packaged or unpackaged fruits (P>0.05). However, the pH of the skin and pulp followed the changes in acidity with time (P<0.01).

At the end of the storage period, at 8°C, a decrease in TTA of the pulp was detected which was the opposite to the evolution of acidity. This could have been due to a high degradation and release of basic pectinic components.

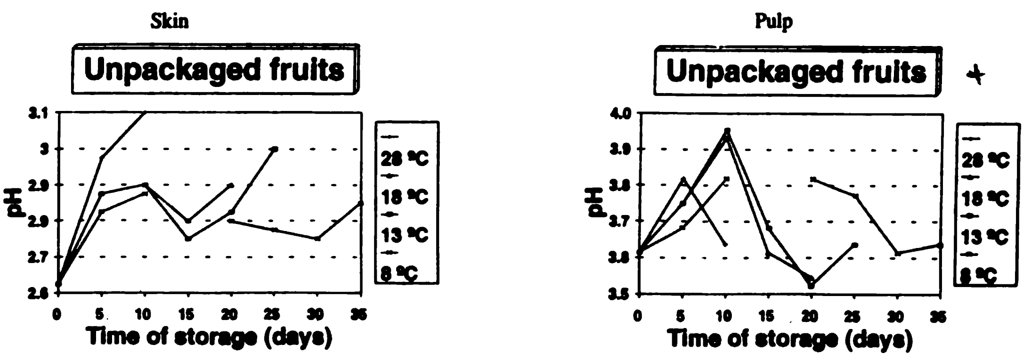


Figure 22 **Changes in the pH of the skin and pulp of green golden apple fruits during storage**

Phenols

Skin:

The quantity of phenols in the skin (Figure 23) generally decreased with time (P<0.001); this minimizes astringency as in other fruits (Pantastico 1975). In refrigeration and after the first 5 days of harvest, there was an increase in the phenol content which indicated a continuation of phenol synthesis. After chilling injury, at 8°C, the phenol content of the fruits increased as the phenols were released from the broken vacuoles. However noticeable browning did not occur.

Packaging inhibited the continuation of phenol synthesis in refrigeration after harvest (P<0.001) and reduced the content of phenols in the fruit skin (P<0.001).

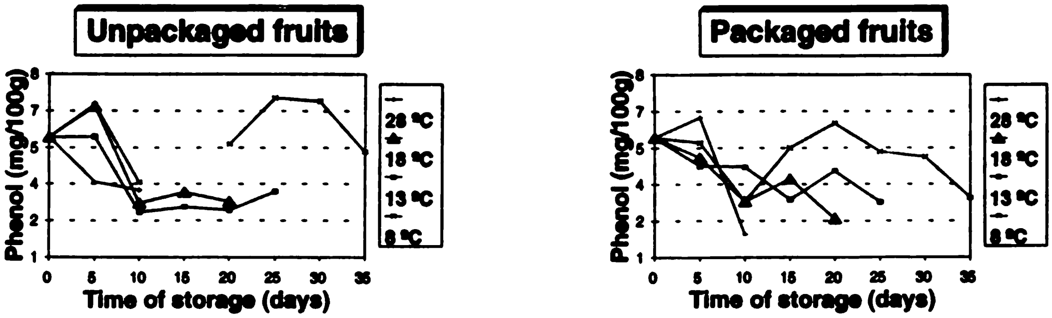


Figure 23 **Changes in the phenol content in the skin 1/1 of green golden apple fruits during storage**

Pulp:

In the pulp (Figure 24), the same decrease in the phenol content was seen with time (P<0.001). However after 15 days in refrigeration, the level increased which was probably due to the beginning of fermentation. At 28°C, the phenol content was reduced compared to 18 or 13°C (P<0.05). At 8°C, the phenol content increased due to the chilling injury even if no browning occurred (P<0.05).

At 8°C, the phenol content of the pulp of packaged fruits decreased further as chilling injury was delayed.

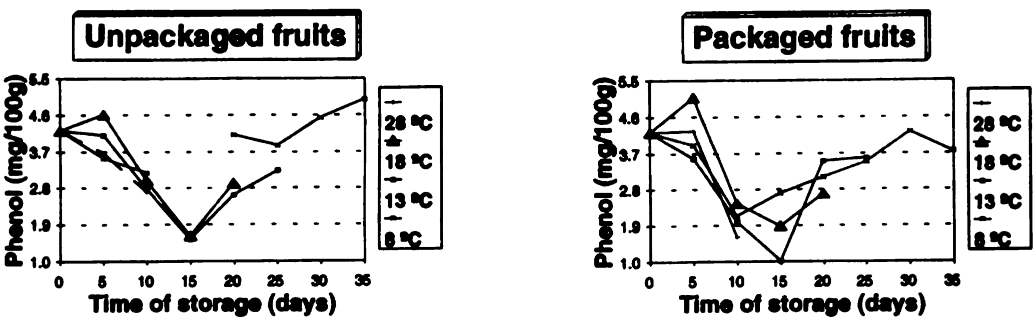


Figure 24 **Changes in the phenol content in the pulp 1/1 of green golden apple fruits during storage**

3.3.2.3. *Ripening of fruits after refrigerated storage*

Time to ripen

The differences observed between the treatments were small. After refrigerated storage at 18 or 13°C, the time to ripen decreased, finishing at a level close to zero: the fruits ripened in the chambers. The fruits ripened slowly in the refrigerated atmosphere and took less time to reach a final ripening stage when they were removed from the chamber. After 5 days of storage, the fruits did not ripe any quicker but were studied until 7 days for practical reasons. The chilled injured fruits at 8°C did not ripen further and were arbitrarily studied after 8 days.(Figure 25).

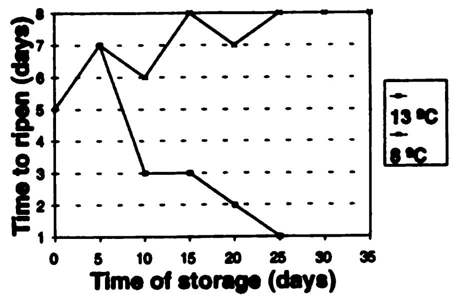


Figure 25 **Time taken by green golden apple fruits to ripen after storage**

Shrivelling

At 28, 18 and 13°C no signs of shrivelling occurred on the fruits as opposed to the situation at 8°C (P<0.001) (Figure 26). Thus chilling injury of the green fruit was also seen after ripening. The first signs of shrivelling were visible on the green fruits after 5 days only and after 10 days on the ripe fruits (P<0.01); therefore ripening seemed to compensate for the first shrivelling symptoms. However, the percentage of symptoms was hi-' or ripe fruits, consequently, chilling signs were later increased by the ripening.

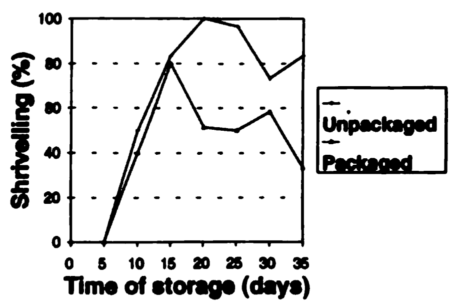


Figure 26 **Shrivelling of golden apple fruits ripening after storage at 8°C**

Packaged fruits had a lower percentage of symptoms (P<0.01). After 10 days, however, shrivelling signs were already seen on ripening packaged fruits but not on the green fruits. Thus packaging delayed the appearance of the symptoms on green fruits but ripening revealed them.

Skin and pulp colour

At 8°C, the fruits did not ripen and their skins turned greenish brown (P<0.001) (Figure 27). The look of the fruit was less appealing after storage than after ripening at 28°C (P<0.01) but the fruits still had a marketable colour. This decrease in colour, identical at 13 and 18°C, was due to the initial degradation of the carotenoid content of the green fruits.

Similarly the pulp colour of the ripening fruits did not change significantly at 13 or 18°C but did at 8°C (P<0.001). Whenever the fruits were chill injured, they did not ripen and the pulp colour stayed whitish.

Packaging did not influence the evolution of the skin or pulp colour of the fruits (P>0.05).

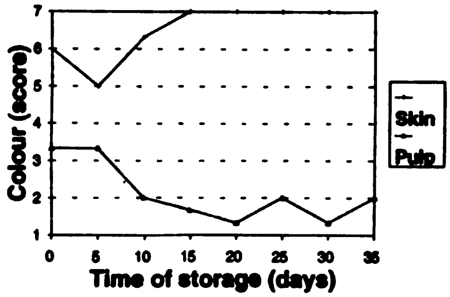


Figure 27 **Colour of the skin and pulp of unpackaged golden apple fruits ripening after storage at 8°C**

Chlorophyll

The chlorophyll content of the skin (Figure 28) of the ripening fruits was similar to that of the green fruits due to a different thickness sampling. The level of chlorophyll in ripening fruits stored at 18 or 13°C increased after storage (P<0.01). As the green fruit contained less chlorophyll after storage in such conditions, this increase meant a reduction in chlorophyll degradation during ripening. The chill injured fruits contained the same level of chlorophyll during storage at 8°C (P<0.05).

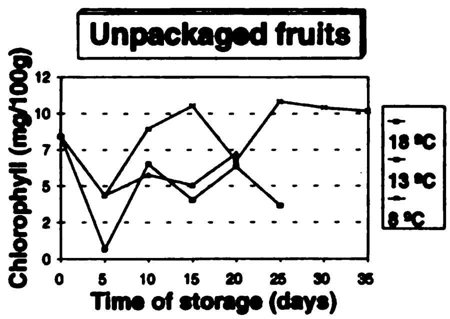


Figure 28 **Changes in the chlorophyll content of the skin of unpackaged golden apple fruits ripening after storage**

Total carotenoids

After 5 days, the carotenoid content of the skin of ripening fruits (Figure 29) was low due to a delay in the experiments. The carotenoid content was stable with time but to a lesser degree compared that at 28°C (P<0.001 for 18°C and 0.05 for 13°C) following the level of the initial carotenoid in the green fruit. At 8°C, the carotenoid content stayed stable without further degradation (P<0.05).

The carotenoid content of the pulp of a ripe fruit decreased with the time of storage at 18 or 13°C (P<0.001 and 0.05 respectively). The pulp colour of a fruit turned from white to yellow while it ripened. This change in colour cannot be attributed to a degradation of masking chlorophyll and may have been due to carotenoid synthesis which was reduced with refrigeration. At 8°C, the changes were not significantly different (P>0.05). The colder storage temperature inhibited the synthesis.

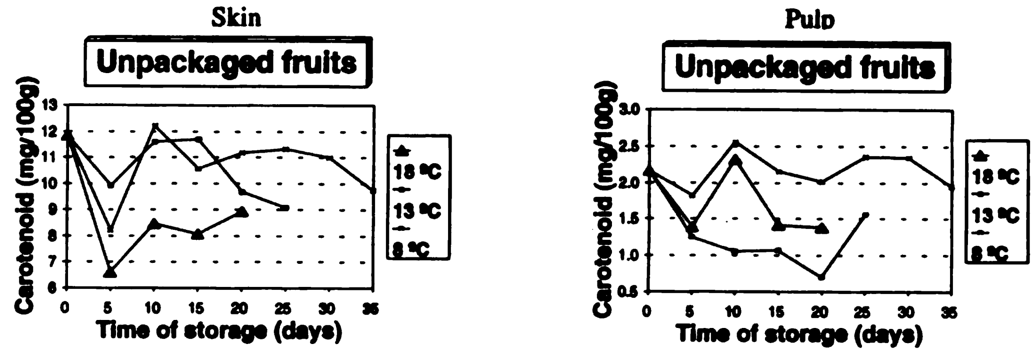


Figure 29 **Changes in the carotenoid content of the skin and pulp of golden apple fruits ripening after storage**

Using a penetrometer, the measurements were not significantly different ($P>0.05$). However with a compression test a difference was seen (Figure 30). At 8°C the fruits stayed very hard and lost their elasticity ($P<0.001$); this could be because chill injury inhibited the degradation of the insoluble protopectin which occurred during ripening. After a prolonged storage the fruits spoiled on the surface with overripening and therefore the measure of compression decreased.

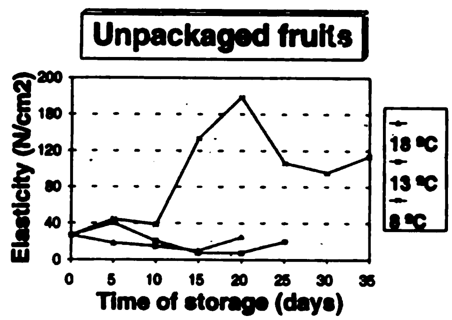


Figure 30 **Changes in firmness (measured using a compression tester) of golden apple fruits ripening after storage**

TSS

No significant change of the TSS (Table 15) was observed in the fruits ripening after a refrigerated storage ($P>0.05$).

Table 15 **Mean values of the total soluble solids (TSS) of golden apple fruits ripening after refrigerated storage**

Time (days)	0	5	10	15	20	25	30	35
Skin 28°C	4.3							
18°C		4.9	5.2	5.1	5.6			
13°C		6.2	5.8	6.2	6.3	7		
8°C		5.4	5.2	4.2	4.8	4.3	5	4.8
Pulp 28°C	7							
18°C		5.2	6	5.8	6.5			
13°C		6.2	6.5	6.2	7	7.4		
8°C		6.2	6.2	5	5.6	5.2	5.8	5.2

TTA

In the pulp, the TTA (Table 16) did not change significantly (P>0.05). In the skin, the acidity increased after storage at 13 and 18°C (P<0.01 and P<0.001 respectively) in contrast to the acidity in the skin of the green fruit. The explanation of this may be the difference in sampling of the two skins. The green skin is composed of several diffuse layers of cells of 4 mm depth which become, on ripening, the ripe skin and a pulpy layer.

Table 16 Range of acidity of treated golden apple fruits

Acidity (% malic acid)	Green fruits	Ripe fruits
Skin Pulp	1.02-0.53 0.33-0.25	0.77-0.39 0.44-0.25

Whereas the acidity of the 'skin' decreased, the acidity of the pulp increased. This was probably due to a higher level of acidity in the middle part which belongs to the green fruit for the skin and to the pulp for the ripening fruits. However this hypothesis needs to be confirmed by more precise analyses of the skin acidity.

At 8°C, the acidity in the chilled injured fruits gradually decreases (P<0.001).(Figure 31)

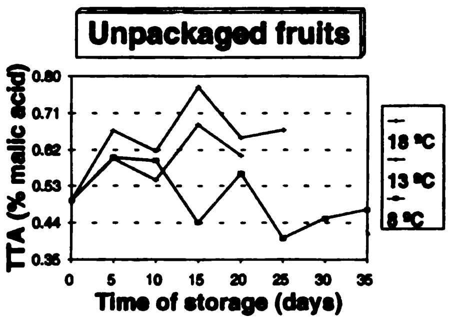


Figure 31 Changes in the acidity of the skin 1/1 of golden apple fruits ripening after storage

pH

The pH of the skin did not change significantly (P>0.05). The pH of the pulp (Figure 32) decreased during storage (P<0.01) at 8°C as there was an acidification of the fruit. At 18°C or 13°C, the change was not significant (P>0.05).

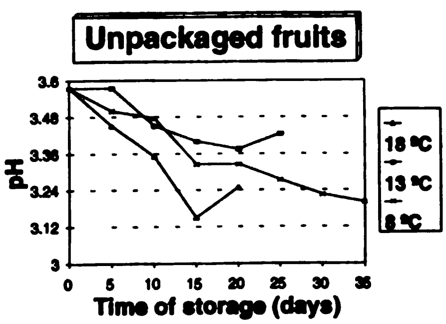


Figure 32 Changes in the pH of the pulp 1/1 of golden apple fruits ripening after storage

Taste, scent

The taste of the pulp was not significantly different during storage (P>0.05). The chill injured fruits did not ripen but spoiled and developed alcoholic off-flavours, especially in the packaged fruits. Similarly, the fruits developed alcoholic aromas at 8°C (P<0.001) which increased with packaging (P<0.05).

TSS/TTA .

The TSS/TTA ratio was not significantly different for the skin of the ripe fruits. However, with time, it was reduced in the pulp at every temperature ($P<0.01$), following the increases in acidity. Packaging reduced this ratio in ripening fruits at all temperatures studied ($P<0.05$).(Figure 33)

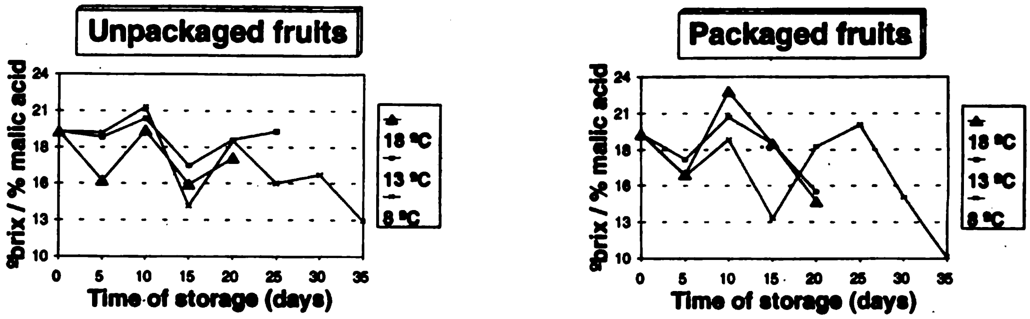


Figure 33 **The TSS/TTA ratio in the pulp 1/1 of golden apple fruits ripening after storage**

Phenols

The phenol content did not change significantly in the skin of the ripening fruits. However, in the pulp (Figure 34), the level decreased for 10 days and then increased at each temperature ($P<0.01$). In the green fruits the phenol content decreased, therefore the ripening mechanism must have been involved. The difference was significantly different between 28 and 13°C ($P<0.01$).

At 8°C, the increase in the phenol content was accelerated ($P<0.01$) and also increased by packaging ($P<0.05$). However no browning occurred in the pulp.

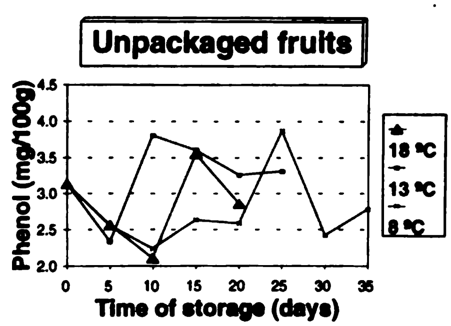


Figure 34 **Changes in the phenol content of the pulp 1/1 of golden apple fruits ripening after storage**

3.3.2.4. Conclusions

- The golden apple fruit is very sensitive to cold temperatures. At 8°C, chilling injury symptoms were seen on the skin with lesser signs in the pulp. The chill-injured fruits appeared shrivelled, green and did not ripen.

- The critical temperature varied according to the time of storage. At 8°C the fruits were quickly injured but at 13°C no signs were observed. Experiments should be continued to define the precise chilling temperature and to investigate the behaviour of the fruit between 8 and 13°C. At 13°C the fruits changed slowly and could be stored for 20–25 days, after which they were ripe and no longer satisfied the market requirements.

- Packaging delayed the appearance and extent of the chilling injury and thereby becomes an interesting and promising area of research for longer storage of green fruits.

- The fruits that ripened after storage were of slightly lower quality, especially with regards to acidity, but they were still marketable.

- A temperature of 13°C is recommended for long storage, until any further investigations, to ensure no appearance of chilling injury.

3.4. CONCLUSIONS AND RECOMMENDATIONS

After the general observations of the handling and some trials, some initial recommendations and conclusions on the improvements needed are presented in this section focusing on quality and uniformity obtained by careful and well defined procedures.

3.4.1. Harvest

3.4.1.1 Tree localization

- Searching of mature trees could be improved by fixing a geographic area for each harvesting team who would know the trees and farmers better, thus resulting in a saving in time.

- Farmers need to be trained with respect to recognizing the maturity of the fruits, so as to be able to give the right information to the teams. Also they should always be the ones who decide when to harvest. Farmers should also be encouraged to consider this fruit as an economical crop.

- Maturity criteria for harvest must be defined for each category of fruit (green mature ones for ripening, or young ones for pickling) according to the requirements of the market to ensure fruit uniformity. It is important to harvest mature fruits as they develop a wax pellicle which helps in storage (by restricting water loss through evaporation and by blocking the lenticels so that respiratory exchange occurs only by diffusion through the cuticle) and gives a brilliant appearance to the fruit (Wills et al. undated).

- Farmers should be paid according to the quality of their fruits to induce them to take care of the trees and sensitize them towards the crop.

3.4.1.1. Harvesting

- A better harvesting tool has to be developed to reduce the bruising on the fruits and the quantity of fallen fruits. This has to be done in consultation with the harvesters who have knowledge of this material and the experience of using it. The main problem comes from the rubbing of fruits against the wire; it could be coated with foam or plastic to reduce bruising of the fruits.

- The procedure using a bag and a rope to lower the fruits from the tree seems difficult to improve upon. A platform is inadequate because of the topography of the island. A tall ladder would be difficult to carry, and climbing up and down several times in such a tree would be exhausting.

- Medium-sized bags should be used to decrease bruising, improve ventilation and also keep to a manageable size. Crates could be used by lifting them up into the tree with a similar system.

- The fruits fallen on the ground should not be harvested because they are injured even if this appears only a few hours later. However, they should be removed from the field by the farmer to reduce the fungal inoculum.

- The harvesters should wear gloves or keep their nails trimmed.

- Field sorting of the fruits has to be developed and defined precisely in the interest of farmers, harvesters and exporters. Farmers, who complain about the rejects, should be made aware that they are partially due to fruit quality problems which could be improved with good field sanitation and taking care of the trees.

3.4.1.3. Transport from the field to the pack-house

- The truck has to be parked in the shade to reduce field heat. A white tarpaulin should be used to reduce the temperature, some banana or coconut leaves can also be used with low cost.

- It would be better to use crates with ventilation holes and pack them in the trucks with regard for ventilation; this would help to reduce field heat and bruising. Even if the crates belong to the exporters, an arrangement should be found for the harvesting team to use them. Using crates from the beginning would reduce the time taken to transfer the fruits from the truck to the crates in the pack-house and would permit easier and more accurate field weighing.

- A foam lining on the bottom of the truck must be used to avoid bruising and more care should be taken during loading and unloading.

- The crates available in the pack-house should be cleaned because of fungal contamination and production of ethylene from vegetable decay, which increases fruit ripening.

- Proper sanitation should be practised at all levels in the pack-house, otherwise the packing contributes to fungal inoculum which would only be apparent when the fruits reach the consumer.

- It would be better if harvesting takes place in the early hours of the morning to reduce the heat. Therefore a new system should be developed: harvesting early in the morning and delivering the fruits around 9 or 10 a.m. to the pack-house where they would be directly washed and packed. This would not avoid the wait in cold storage for a shipment but would allow less time at ambient temperature and therefore the shelf-life would be increased.

3.4.2. In the pack-house

To increase quality and uniformity all the procedures have to be clearly defined, accepted by every one and done the same way at each level.

- Fruits should not be stored on the ground which leads to problems of crushing, insect damage and poor ventilation and they should stay the least possible time at ambient temperature. Therefore the removal from the chill-room has to be spaced out during the day to avoid condensation which promotes rots (Wills et al. undated).

3.4.2.1. Washing

- A new system should be developed beginning with a sorting before washing in order to reduce the amount of fruits to be washed and thus the amount of chemical needed and also the cost of the operation.

- Better care has to be taken in putting the fruits in the bath in order to reduce bruising. It is probably possible to put the crate directly in the bath which would reduce the bruising and would allow for a quicker transfer.

- It is not necessary to rinse off the sodium hypochlorite (bleach or 'chlorine'); it will evaporate from the skin naturally and constitutes a fungal treatment. However, detergents such as dish-washing liquid must be washed off (Mohammed 1993).

- The recommended concentration of chlorine is 300 ppm, with a soaking time of 20 minutes. The latter needs to be defined clearly for uniformity of the treatment as soaking in water influences the fruit shelf-life. The chemical powder should be previously dissolved in water and added to the bath before the fruits. A procedure has to be developed to ensure that the water still contains some active chemical Annex D5).

- A tool of medium hardness has to be used to ensure proper washing. Thus, it is advised that the MNIB search for an adequate brush for their washing machine, which is probably the more efficient way to clean the fruits. However all this advice results from small-scale experiments and would need to be adjusted for larger scale operations by the exporter.

- Two baths should be used, one for soaking and the other one for washing.

3.4.2.2. Sorting

- Better care has to be taken to transfer the fruits from the bath to the sorting table; the table should have a foam base to decrease bruising, but covered with an easily cleanable material.

- A sanitized and larger cloth should be used to clean the fruits.

- Some drying time must be allowed to avoid moisture in the box which results in a more fragile box and encourages fungal growth (Wills et al. undated).

- Better sorting criteria, precisely defined at all levels, are needed to ensure uniformity and quality of the fruits. Simple tools could be used: a coin as a reference for the size of scarring to reject; a colour card for overripeness; a metallic ring with a diameter of the limiting size of the fruits to be rejected.

- The two-step sorting is a good procedure but in order to increase its efficiency, it should be clearly defined as two different sorting activities with particular criteria for each.

- Proper sanitation of the sorting tables should be maintained to avoid contamination, especially when they have been used to store dirty fruits.

- Grades should be developed to improve the uniformity of the product. To attract both markets (fresh fruits for ripening and young ones for pickling) two good quality products are needed but with different characteristics. Grading should become a voluntary action of the exporter and prices should be determined accordingly.

3.4.3. Rejects

- The rejects have to be used to increase profits. The processors are a possible outlet, but the price of the fruits has to be cheaper.

- They should be quickly removed out of the pack-house to reduce the level of fungal infection and ethylene production. The rejects should not be placed on the ground which would otherwise become a source of inoculum. The crates used to store the rejects should be carefully washed as they contained infected fruits.

3.4.4. Packaging

- A better box has to be designed: smaller, allowing for less movement of the fruits in one layer; with more and better defined holes to ensure proper ventilation; with good, attractive printing to give an impression of quality. The required boxes should be more like the mango box than the banana box. The boxes should be closed quickly to decrease water loss (Wills et al. undated).

- The general care taken in moving the boxes has to be improved.

3.4.5. Storage

- A temperature above 8°C should be used for storage otherwise chilling injury will result; 13°C is recommended. Shipments at 11°C, for sanitized fruits with ethylene absorbent, should be attempted as the fruit can be stored 25 days at this temperature. However, the fruits should be ripe at their reception.

- Relative humidity should be checked and containers of water placed in the chill-room to ensure a proper humidity of 90% – not more, otherwise growth of moulds and rotting would be encouraged (Wills et al. undated).

- Ripe or overripe fruits should not be mixed with green ones; they produce ethylene which increases ripening.

- Some products should not be stored in the same chill-room, e.g. banana, papaya, guava and passion fruit, since they produce a lot of ethylene which increases ripening (Wills et al. undated). Therefore a better system for the various chill-room activities has to be developed.

- Better organization inside the chill-room is also needed to ensure proper ventilation (proper alignment of the crates) and avoid accumulation zones of ethylene.

- Clean fruits ready for shipment and dirty fruits containing infecting agents should not be stored together. A general procedure of handling should be developed separating the clean and dirty fruits.

- An intermediate temperature should be used when the fruits are removed from the chill-room to reduce the temperature shock.

3.4.6. Transfer to the airport

- Filling the truck should be done more carefully. The order of filling has to be planned in advance in order to cut down on lost time at the airport and reduce the storage at ambient temperature.

- Ventilation channels should be arranged in the truck. Tarpaulin should be placed over the truck to reduce the heat.

- A shaded area should be made available at the airport. All the persons in charge of this transfer should be there at the right time to reduce delays.

- It would save time to have equipment at the airport and in the pack-house so that palettes could be used during transport in order to move all the boxes at once. It makes no sense to palletize for storage and then spend time transferring boxes individually.

- The exporters' staff should set an example in taking good care of the boxes. This is the only way to make the airport team conscious of this need. The exporters should also insist on this care by the airport authority.

3.4.7. General organization

- Different times for lunch breaks should be used to decrease the waiting time of the fruits. For example, if the washer stops at 11 30 a.m., the packer can stop at 12 noon to ensure the continuity of work, and reduce the amount of fruits remaining at ambient temperature during the hot hours. Even if there is a fixed agreement with the staff, the reasons for a change needs to be explained and a compromise found.

- Light colours should be used for all the equipment in order to reduce the heat.

- A proper organization of the work stations for every step of the procedure should be developed for a more efficient job. This should be based on the model of an assembly line. Ergonomy of the work stations has to be improved - by adding stools for example. This will improve the final quality of sorting.

- The equipment should be improved to match with the local needs, e.g. using a table of good height instead of a chair and a box. The work has to be thought out in a simple way by the exporter and small cheap adjustments made.

- The definition of the criteria, procedures and work stations has to be done in collaboration with the staff who possess the experience and will use the system.

4. FRUIT PROCESSING

As in many Caribbean islands, Grenadians use the golden apple fruits mainly in the fresh state. In Trinidad, however, it is traditionally used in variety of local dishes such as 'chow', chutney, curried , kuchela, pickles or 'red preserve'. Therefore a few cottage industries process the fruit into some of these products. In other Caribbean countries, home processors prepare jams, jellies, chutney, juices of green or ripe fruits and wines. In Trinidad, the seed is also used to make earrings.

The processing of golden apple has important prospects. As the fresh fruit market seems to be saturated (Bauer et al. 1993), processed fruits could result in new markets and thereby increase the value of fruits produced in Grenada. Processing can utilize the rejected fruits from the export trade resulting in higher incomes to the exporters and to a lesser extent to the farmers. Processing in Grenada would add value to the fruits.

At the Produce Chemist's Laboratory (PCL) in Grenada, six products were developed at the cottage industry level – jam, golden apple sauce, dried fruits, pickles, chutney, kuchela (see Plate 11 on page 61). The purpose was to develop formulas for the local processors and not to analyse scientifically the products or the process. The fruits used were part of the rejected fruits from the MNIB. A consumer reaction study was then conducted on 50 persons per product to evaluate their potential. Some trials on beverages (nectars and drinks) were conducted in Trinidad at the Caribbean Industrial Research Institute (CARIRI) with ripe golden apples.

4.1. MATERIALS AND METHODS

All the equipment used (washed and sanitized) is described in Annex E1. The methods of measurement used in the beverages trials are reported in Annex E2.

A questionnaire, pre-tested on IICA staff in Grenada (Annex E3), was designed to evaluate the quality of the products (general feeling, spontaneous problems and detailed appreciation), as well as to obtain some information on the packaging or economic data. Three categories of nationality were identified: Grenadians, foreigners living in Grenada and tourists of all nationalities. The survey was conducted in several places in Grenada: supermarkets (Foodfair, St George's and Grand Anse; Foodland, St George's and Grenville), vegetable store (MNIB, St George's) and the World Food Day exhibition (Sauteurs).

The results were analysed by the percentage of response obtained for each parameter and by correlations and chi-squares. The general consumer does not seem to be very critical (always positive answers) and would probably still be pleased with the product if slight modifications were done. In consequence, the analysis was based on the second response obtained with more critical consumers.

In Trinidad, the beverages were sampled by three judges inside CARIRI's laboratory for the general formulation. Later, a panel of 15 tasters (UWI students) was questioned on 15 ml of chilled products presented in a coded plastic glass following the recommendations of Larmond (1977) (Annex E3).

4.2. FRUIT PRE-TREATMENT

4.2.1. Sorting, washing and weighing

Fruits were visually chosen and sorted to produce an homogeneous sample of the maturity needed for each product. In Grenada, the fruits were hand-washed in water before processing. As the fruits came from an exporter, they were previously washed with sodium hypochlorite solution. In Trinidad, the fruits purchased at the Central Market were sanitized with a mixture of sodium hypochlorite and detergent before rinsing.

During these experiments no data were available on the quantities of pectin content and acidity of the fruit, therefore approximations were made and the usual percentages of ingredients were added.

4.2.2. Peeling, de-stoning and cutting

The fruits were peeled manually with a knife. No peeling at all leads to yields of 87% for green fruits and 70% for ripe fruits, compared to a ratio of edible parts of 92% of the fruit. Removing a fine layer of skin (1 mm) leads to a yield of 70% of the green fruit. Removing the total green layer (3–4 mm) leads to a yield of 45% for the green fruit and 38% for the ripe fruit.

An efficient way of cutting the fruits into wedge shapes is by inserting a knife close to the stone, turning it with some pressure to detach the pulp from the spines. This was used in Grenada as a de-stoning technique due to the unavailability of any other suitable equipment. Peeling the fruits and cutting them into attractive shapes leads to a very low yield (less than 40%) and this procedure is only viable if the wasted parts are used for another product; also it is time-consuming.

A test was done to try to facilitate peeling and cutting by boiling the fruits. This makes the peeling very easy (as with tomatoes) but the fruit is then very soft and the cutting is not improved. Later in Trinidad, it was observed that a small processor had developed a destoner. The system is to press a whole fruit until it splits, then the stone is removed manually which is based on the traditional method of crushing the fruit by throwing it on the ground.

A search for a method to avoid the manual de-stoning was undertaken in Trinidad. The optimum techniqu to obtain a fibreless and seedless pulp is to reduce the fruit to a puree with a food chopper (Hobart model 84181D) and then pulp it to eliminate fibres and stones (pulper, Dixie model 18, screen of 4 mm and 2.5 mm). The result was then satisfactory as the waste was mainly composed of stones and of the quantity needed to flush the pulper. Golden apple stones are mainly parenchymous and are supposed to be inactive on the product. However, it would be interesting to measure the effect of pulping with the stone to see if there is any product oxidization.

4.2.3. Pulping, grating and pressing

In Grenada, after pre-cooking the ripe de-stoned fruits with a little water to tenderize them, or blending the green fruits, fruits were reduced into pulp with a mechanical paddle Sterling pulper (holes of 0.4 and 0.2 mm of diameter) . The pulping produced good results with the golden apple as a smooth pulp without any fibers was obtained with yields of 80%.

Some whole green fruits were hand-grated which resulted in the highest recovery of edible parts (89%). Mechanical graters should produce good results as manual ones are labour consuming. The grated green fruits were pressed to extract some moisture. But as no pressing machine was available this was done by hand. However it gives an idea of a minimum yield of juice – 34%.

4.2.4. Packaging

The principles of packaging used were common to several products. Many of them were allowed to boil and then were manually bottled while hot with a funnel and a cup. The beverages were pasteurized by boiling for 3 min at 85°C (Bhalla 1990) with a final addition of sodium metabisulfite as a preservative. The jars, bottles and covers had been previously placed in an oven at 110°C to sterilize them and avoid thermal shock.

The jars and bottles were totally filled to eliminate all air spaces, cleaned and allowed to cool down at room temperature. Further studies such as shelf-life considerations need to be done by processors willing to develop such products.

4.3. PROCESSING TECHNOLOGY

The precise proportions used in each product as well as the precise consumer comments on their composition are reported in Annexes E4 to E11.

4.3.1. Dried fruits (half crystallized)

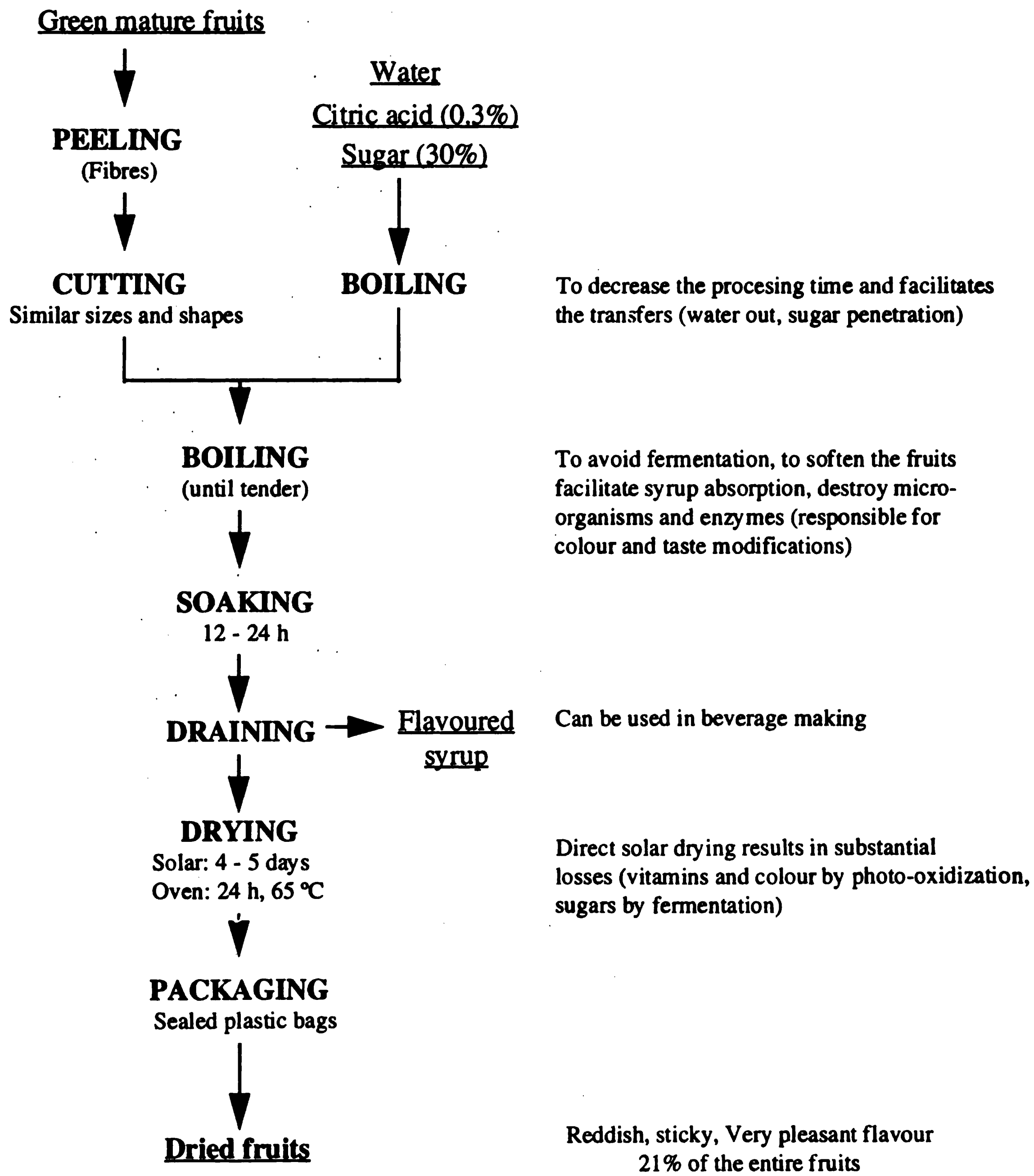


Figure 35 **Flowsheet for the golden apple dried fruit process**

A trial was conducted without osmosis. The fruits were drained directly after boiling and allowed to dry. The fruits obtained were brownish yellow, with a different taste and were not as sticky as the previous ones. Another trial with a smaller amount of fruits also gave brownish fruits. Apparently, letting the fruits stand longer in the hot syrup, results in a greater absorption of sugar and to the development of a Maillard reaction. The fruits then become caramelized and reddish.

Consumer evaluation

The taste of the dried fruits was well appreciated (56%, good and 30%, excellent), but less so than the other products. The main spontaneous comment from the tasters was of the toughness of the fruit (35%) which corroborates the shortcomings of the texture (22%, fair and 30%, poor). Therefore the fruits have to be dried for less time and soaked longer to tenderize them. The other interesting comment was on the presence of fibres (7%) which corroborates the 40% of the surveyed population bothered by them. Thus, the fruits should be completely peeled.

The average price that the tasters were willing to pay was EC$1.29 for a bag of 20 g. It ranged from EC$0.25 to $5.00 compared to the usual price snacks of any type sold with a range of EC$1.00–2.00. The package size preferred was 100 g (50%) followed by 20 g (37%) which reflects the use of the product as junk food or fruit for cakes. Two different packages can be developed for the separate uses.

The buying intention reached the second highest level of the eight products (94% said yes) which is surprising as the texture needs to be improved. The only tasters who would not buy the dried fruit did not appreciate the fibres (2%). The respondents said they would eat the dried fruit every day (50%) or every week (31%) which shows a high market potential. There was a change in the consumption pattern with the age ($P<0.01$): young people ate the dried fruits more often than the older tasters.

4.3.2. Jam

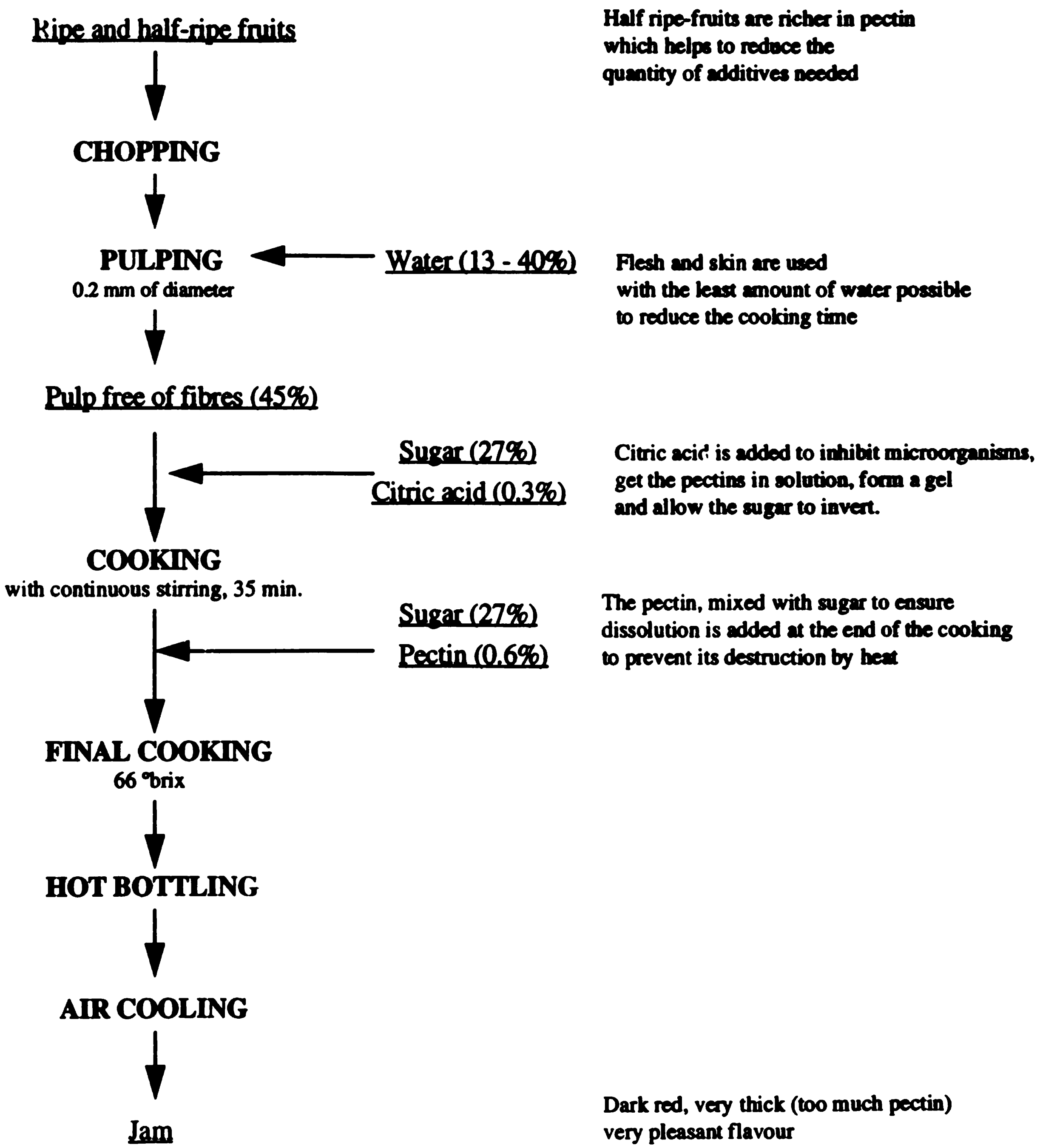


Figure 36 **Flowsheet for the golden apple jam process**

Consumer evaluation

Forty-eight per cent of the tasters really enjoyed the fruity flavour of the jam and regarded it as excellent which is necessary if it has to compete with the traditional guava jelly. Tasters preferred smooth jams without pieces of fruit (83%).

The tasters were willing to pay an average EC$3.47 for a 130 g jar with a range of EC$1.50–10.00 and 48% variation. The preferred package is 230 g (62%). Tasters were also interested in the larger (450 g) jar (23%), probably for family consumption. The size of package preferred was correlated to the likeness of the taste ($P<0.01$) and age ($P<0.05$) – young consumers would like larger jars.

The buying intention (90%) was relatively low compared to the high acceptability. Younger tasters (0 to 40 years old) had a greater intention of buying the jam ($P<0.01$). Some tasters would not buy the jam as they would make their own (4%) and a further 2% did not appreciate the taste. Jam would be consumed every day (54%) or weekly (35%). The frequency of consumption was correlated to buying intention ($P<0.001$), therefore tasters who really enjoyed the product would buy more of it.

A market with such an acceptability and frequency of consumption is a very good one. The product was well accepted but some changes such as less pectin, sugar and citric acid would make a higher quality product (Annex E5).

4.3.3. Golden apple sauce (stewed fruits)

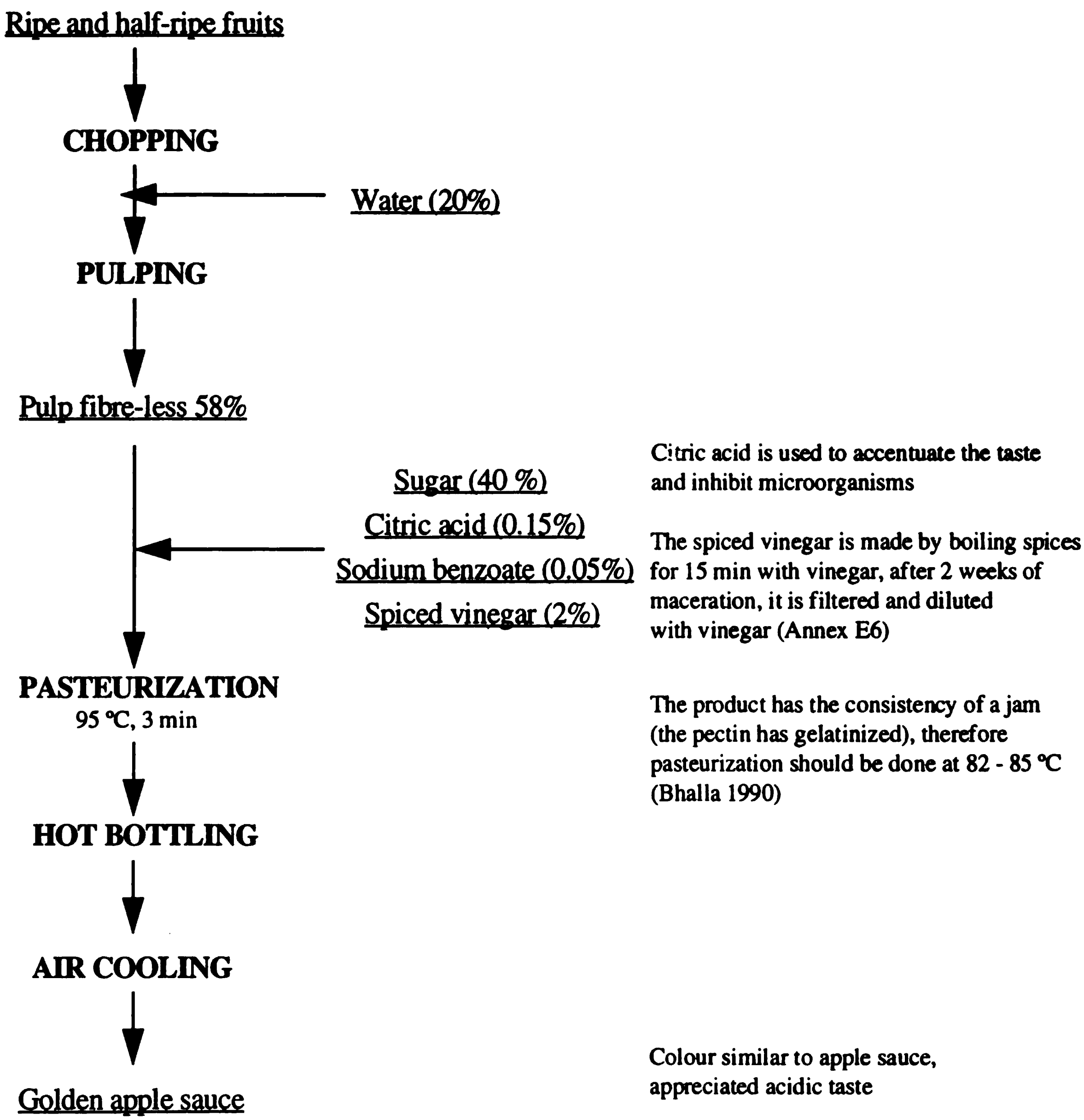


Figure 37 **Flowsheet for the golden apple sauce process**

Consumer evaluation

The respondents regarded the taste as excellent (55%) which is the best score for the eight products surveyed.

The average price the tasters would be willing to pay was EC$3.46 for a 125 g jar and ranged from EC$1.20 to $7.50. The package size preferred was 230 g (66%) with an equivalent range of 130 g and 450 g. The expected problem in packaging is the label. As Grenadians do not know this product, even finding a name is difficult. Therefore, this product would also need recipes on the labels to make people use it really like an apple sauce.

The answer on buying intention was astonishing: 98% indicated that they would, which was the best score for all the products. Moreover, the only woman who would not buy the golden apple sauce said she would make her own (2%). This shows that this product is really appreciated and has a very high commercial potential. The consumers would eat it every week (49%) or every day (45%). The consumption frequency is linked to the nationality of the taster ($P<0.01$), Grenadians would eat the golden apple sauce more often, foreigners on a regular basis and tourists less often.

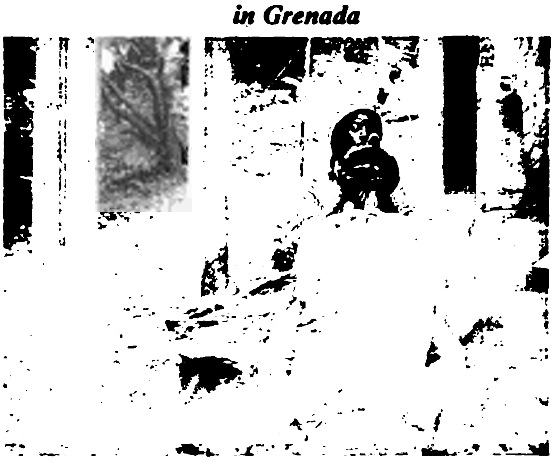
This is the best of the eight products tasted. It could become a good product for pie-filling (the tropical apple sauce). Slight changes could be done in reducing the level of sugar and acidity and pasteurizing with a more adequate technology (Annex E6). Nevertheless, a lot of promotion and recipes need to be made as it is a totally unknown product.

Golden apple fruits in tree

Adult dwarf golden apple tree in Trinidad

Harvest in a golden apple tree in Grenada

Lowering of a bag of golden apple fruits



Weighing of a golden apple bag in the field

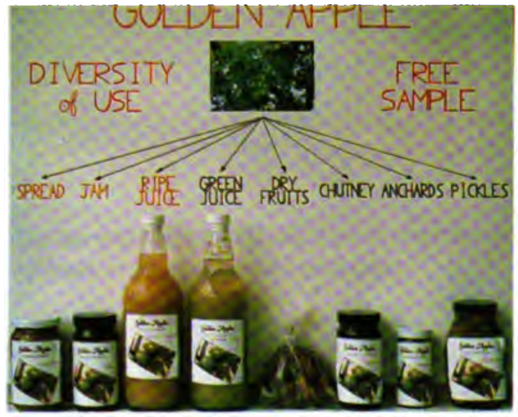
Transfer of the fruit to the pack-house: Grenada

PLATES

Handling of the fruit inside the MNIB pack-house: Grenada

Transfer facilities

Embarkment of golden apple boxes in a plane



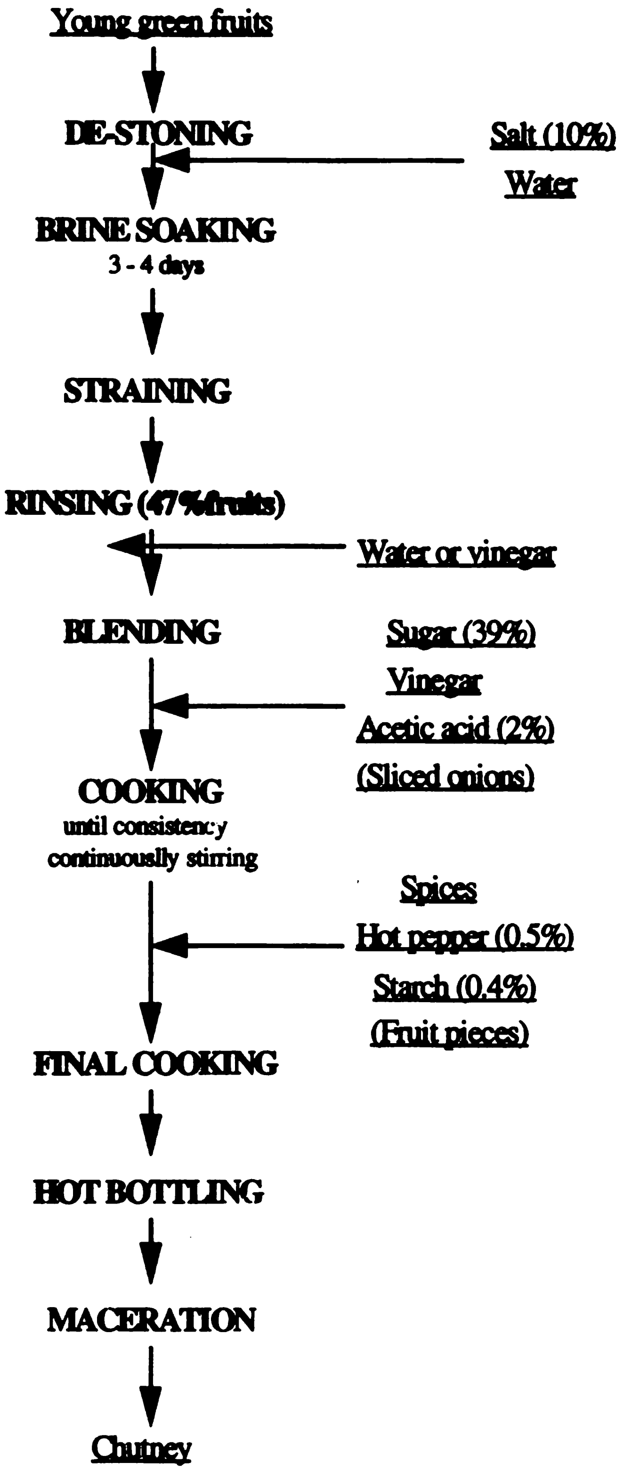
Presentation of golden apple fruits

Mites scaring on golden apple fruits

Reasons for fruit rejection

Material used for respiration measurement

4.3.4. Chutney



The fruits can be stored in brine for several weeks. No test has been done on the exact duration or changes that would take place. Good way to store the fruits for the off-season.

The blended puree should still contain some pieces of fruits which are expected in chutney

Acetic acid is used in addition to th vinegar to reduce the dilution needed and thereby the cooking time

Whole spices placed in a bag in the pot and removed after cooking, would result in a more pleasant aroma

With pieces of fruits, the puree phase is taken separately and cooked further on another fire to reduce the water content. The fruits are cooked less to avoid too much softening. The two phases are put back together for a final cooking.

The product has to stand several days for maceration before evaluation since the spices take time to penetrate in the fruit and develop the final aroma and taste

Figure 38 **Flowsheet for the golden apple chutney process**

Consumer evaluation

Generally the taste was considered 'good' (48%), with 28% regarding it as excellent. However, a significant percentage of the sample regarded it as fair (18%) and some definitely as very poor (5%). Grenadians are generally not used to this kind of product and they either like it well or not at all. The respondents preferred smooth products (66%), but 31% of those surveyed would like pieces of fruits in it. A smooth product is the first one which should be developed followed by a second one with pieces of fruit.

The average price given by the respondents was EC$3.37 and ranged from EC$1.50 to $10.00 for a 130 g jar. This is the lowest price obtained for golden apple products packaged in jars and, according to the responses, men would pay less for it ($P<0.05$). The preferred package size is 230 g (61%) and the size of 130 g and 450 g are preferred to the same degree. The preferred package was correlated to the taste ($P<0.05$), therefore the size of package represents an appreciation of the product. Men tended to prefer the chutney in smaller jars ($P<0.05$).

The buying intention (87%) was correlated to the appreciation of the taste ($P<0.001$). The respondents who would not buy are those who did not like it (11%) or found it unappealing (2%). The tasters would consume the chutney every day (4%) or every week (41%) which can be considered very regular; however this would be in small quantities with a variety of dishes. The consumption frequency was also correlated to an appreciation of the taste ($P<0.001$).

The product is quite new to Grenadians but is suited to their style of cooking and seems to be well appreciated. However some changes should be done to improve it (Annex E7).

4.3.5. Kuchela

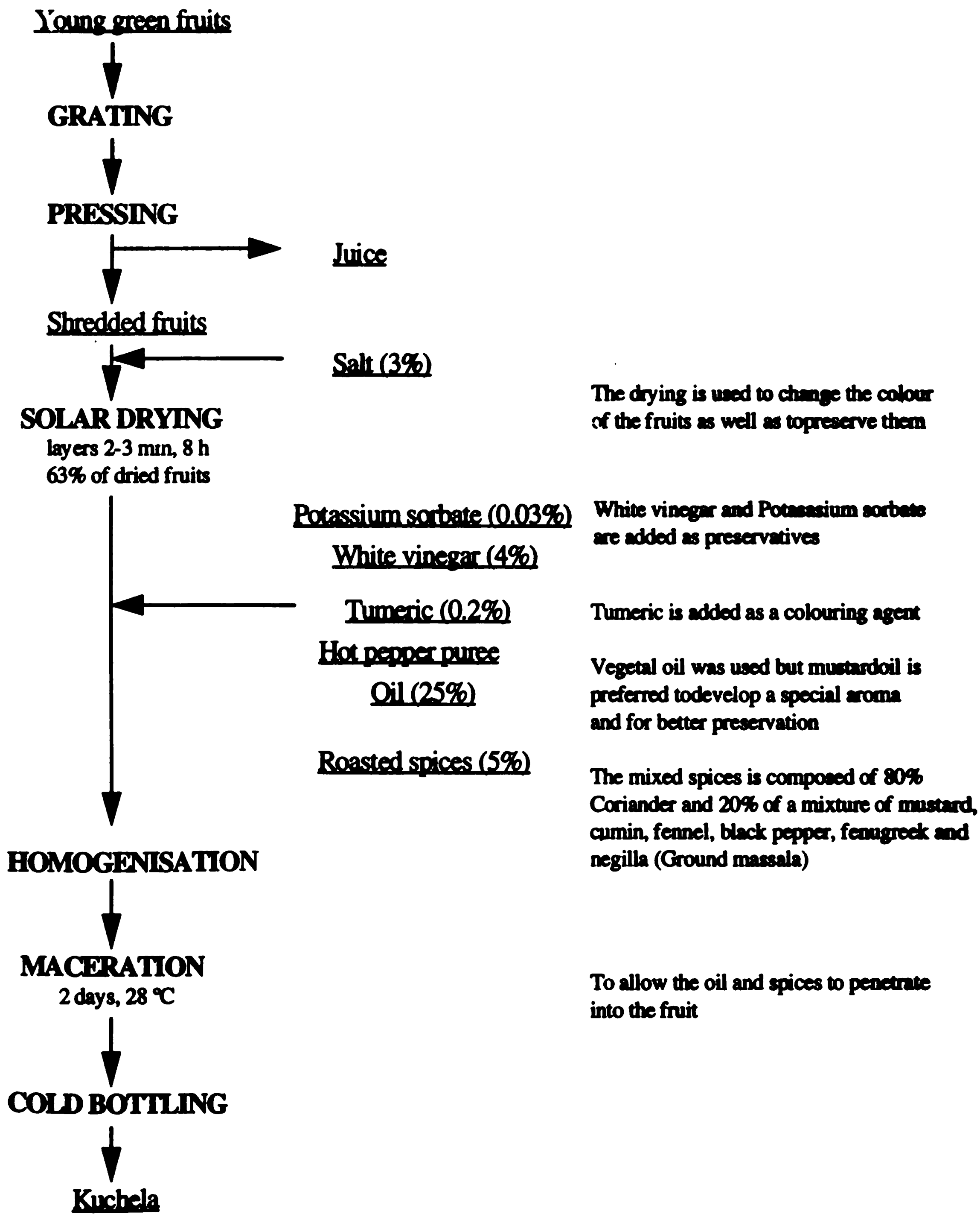


Figure 39 **Flowsheet for the golden apple kuchela process**

Consumer evaluation

The main responses obtained for the taste were 'good' (46%), 'excellent' (40%) and only 13% not so favourable. This tasting for many Grenadians was their first one for this product which resulted in a less critical assessment than for a product they are accustomed to. Women preferred the kuchela ($P<0.05$) as well as older consumers ($P<0.05$) and foreigners ($P<0.05$).

The average price the tasters were willing to pay for a 125 g jar was EC$3.95, however the responses ranged from EC$1.50 to $15.00. The large spread shows that people had no precise idea of the price. The size of package preferred was 230 g (46%) closely followed by 130 g (37%). The small amount desired compared to the liking is due to the type of product which is very spicy and used in small quantities.

Only 8% of the respondents said they would not buy the kuchela. The buying intention was correlated to the appreciation of the scent and texture ($P<0.01$). When the tasters did not appreciate the taste (2%) or do not find the kuchela appealing (2%), they would not buy it. Therefore the reasons for not purchasing were not due to any shortcomings in the product.

The sampled population would consume the product every day (48%) or weekly (29%). This is a high consumption frequency as the product can flavour each meal. Those 41 to 60 years old would consume the product on a weekly basis, for the other age groups it was on a daily basis.

4.3.6. Sweet and sour pickles

Green fruits

↓

CUTTING
in wedges of similar size

The fruits are sliced to facilitate the transfer of the ingredients (salt, sugar and vinegar)

↓ ← Salt (10%) Water

BRINE SOAKING
4 days

The fruits have to be immersed to avoid air contact
A longer storage in the brine (20 days) would probably result in lactic fermentation:
the taste of the pickle would be different,
however it might be an interesting product

↓

DRAINING

↓

RINSING

↓ ← Acetic acid (2.5%) Sugar (40%) (Spices)

SYRUP SOAKING
3 - 4 days

↓

COLD BOTTLING
cold syrup as a filling

↓

Pickles

Figure 40 **Flowsheet for the golden apple pickles process**

Some very young immature golden apples (1–2 cm in diameter) were harvested and treated using this process but as whole fruits. These young fruits have immature seeds and smoother skins and make a very pleasant pickle– very tasty and crunchy. However it is not economical to harvest the fruits at that stage due to their small weight but this could be a method of using some of the fruits rejected in the pack-house.

Consumer evaluation

The major response for the taste of the product was that 'it's good' (45%), but there were also 43% of the people who thought that it was excellent. People were surprised since they are not used to this product and responded very positively to it.

The texture was of low acceptability, less than 40% regarded it as good and 51% as fair, poor or very poor. Some complementary trials should be done to improve the texture by slightly boiling the pickles or adding boiling syrup. The skin, which is harder than the pulp, was the cause of the tough texture.

The average price tasters were willing to pay was EC$3.50 for a 130 g jar with the responses ranging from EC$1.25 to%10.00. The ideal package size was 280 g as indicated by 47% of the respondents. However, 21% of them would like a 500 g jar, therefore different packaging sizes are needed. To the question 'how often you will purchase?', the responses were dispersed and ranged from once a day (32%), to once a week (40%) to once a month (25%).

Eighty-nine per cent of the respondents said that they would buy the product even with some deficiencies in the hardness and acidity, therefore the product has promise. The buying intention was correlated with tan appreciation of the taste ($P<0.001$) or scent ($P<0.01$). The few people who did not want to buy gave as their main reason the hardness of the product (4%). The taste (%) or appearance (2%) were other reasons given for not buying. Two per cent of the population sampled said they would make their own.

4.3.7. Nectar

Ripe fruits

↓

CHOPPING

↓

PULPING
4 & 2.5 mm

↓

Pulp (80%)

↓

COOKING

↓

ENZYMATION
30 °C, 12 h, 0.01%

The enzymation is ued to reduce the thickness of the nectar.
A trial was conducted todetermine the adequate concentation
and time of action of the enzyme and is reported in Annex E10

The enzyme used is the available cytolase PCL5 from Genencor
International related to fruit juices and wine processes

↓

FORMULATION
0.48% acidity, pH 3
40% fruit, 14 °brix

After tasting different dilutions of the pulp, 20% water
was selected as it maintains a strong taste and a good texture.
The final water content is 40 %

↓

STABILIZATION

0.05 and 0.1% of xanthan gum were added after dispersion
in some sugar but it was not enough to avoid
the separation of the phases

↓

HOMOGENIZATION

A toothed colloid mill is used toreduce the particle size and
homogenized the nectar, however it increases the viscosity

↓

PASTEURIZATION
3 min, 85 °C

The enzymation reduces the pulp colour and DM whereas
the TSS, TTA or pH remain constant throughout the process.
Very little calcium pectate is formed with the enzymed pulp

↓

Nectar

Figure 41 **Flowsheet for the golden apple nectar process**

Test panel

A preference test was conducted on nectar of 12 and 14 °brix. Fourteen tasters preferred the nectar of 14 °brix ($P<0.01$)

The panel was also questioned on the thickness of the nectar at 12 and 14 °brix. No significant difference was observed ($P<0.05$). The mean ratings were 5.2 and 5.7 respectively, therefore the thickness can be considered as optimum.

4.3.8. Drink

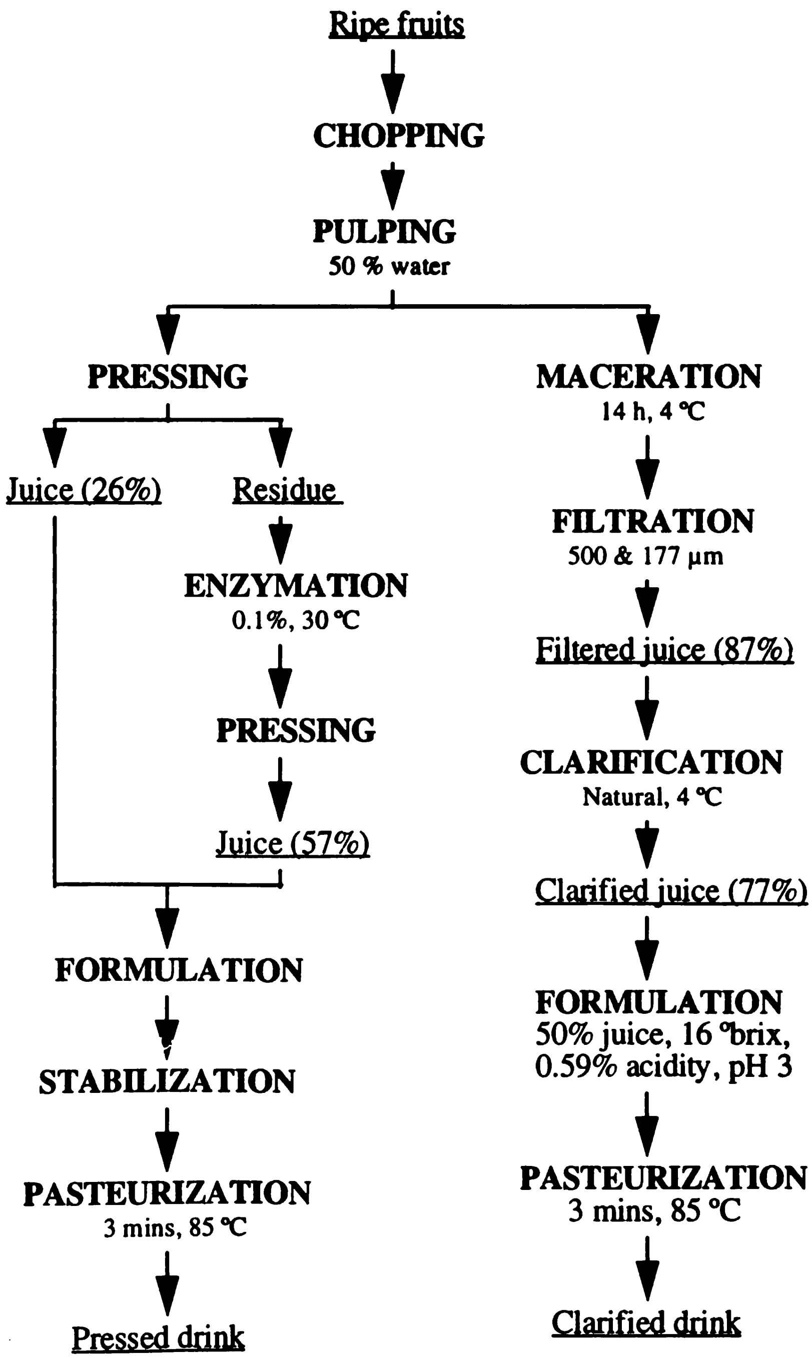


Figure 42 **Flowsheet for the golden apple drink process**

By pressing

The pulp was pressed through a double cotton cloth. As the waste of first pressing was very watery and the yield low, an enzyme treatment was tested. A concentration of 0.1% of enzyme produced the same quantity of juice as 0.2% of the enzyme. The enzyme treatment lasted for 14 h and the fruits started to ferment, therefore this time should be reduced. Similar experiments were done with a direct enzymation of the chopped fruits with a single pressing. A similar yield of juice was obtained for both concentrations. However it would be advisable to develop this process of using the juice from the first pressing as high quality product added to the second juice.

The juice of the first pressing is more colourful than the other and has a higher viscosity. The pH and the DM of the juices are comparable. The pectate precipitate of the enzyme-treated juices was nearly non-existent compared with the juice of the first pressing (Annex E11). The juice of the first pressing was formulated as it was the only one available. The trials led to a formulation of 12 °brix and 60% of juice. After 1 day in the bottle, some sediment was observed at the bottom. A stabilization with gum or a further filtration should be tried; it was not done because quantities of juice available were too small..

By clarification

Maceration was done to ensure a proper extraction of the taste. A filtration was first needed as there were too many particles in the mix to allow any clarification. After trials on different ways of clarification, natural clar fication was chosen (Annex E11), any further clarification was not possible. Analysis of samples at different steps in the process (Annex E11) indicated that the colour of the juice remained in the residues. The pH was stable during the process. The second filtration retained more sugars than the first one; however, both retain DM and TTA. The pectins were reduced at each level but a precipitate was still formed with the clarified juice.

The pulp already contained 50% water, therefore no more dilution was needed. After a laboratory sampling of four concentrations of sugar, the levels 14 and 16 °brix were found to be acceptable. The acidity of the juice at 16 °brix was reinforced by adjusting it to 0.5% acidity with citric acid. Very little stabilization was necessary. After sampling in the laboratory it was observed that there was a loss of the fresh golden apple aroma due to the pasteurization. Only a high temperature/short time pasteurization technology with aroma recovery would inhibit this loss.

Taste panel

The response obtained after panel sampling was either 'like' or 'dislike' which was due to the volatilization of the aromas. The clarified drink was preferred to the pressed drink ($P<0.01$). This preference was explained by the tasters in remarks on the greater sweetness of the product more than to a difference in technology or taste. The ratio of sugar to acidity was in that case 27, (°brix to% malic acid), close to the nectar's ratio, and this seems to enhance the golden apple flavour.

5. CONCLUSIONS

- The golden apple industry has shown attractive prospects within recent years; these were confirmed by this study.

- Fruits of a superior quality were previously observed on some of the trees around Grenada; these was further investigated with the aim of selecting some of them for propagation. However, further investigations are needed to accomplish this aim. The maturity and fruit development seems to be highly influenced by the level of rainfall and therefore a spreading out of the harvest period may be possible with appropriate orchard management. Proper field sanitation would also help in diminishing fruit losses.

- A careful, sanitized and well-defined handling procedure for the fruit, as described in this report, associated with a proper refrigerated storage at 13°C would considerably reduce the losses. Shipments should be tried to provide this crop with new possibilities of extension and diffusion.

- Processing golden apple into jam, sauce, dried fruit, chutney, kuchela, pickles, nectar or drink, demonstrated good consumer prospects and adequate feasibility. Therefore it should be encouraged, both at the cottage level and the small processing level.

- It should be emphasized that, by tradition, the market has been limited to the ethnic market. An effort should be made, by all the participants of this industry, to promote the fresh fruit and the fruit products to other markets. Thereby the golden apple should have a bright future.

6. BIBLIOGRAPHY

Abdurrohim S and Martawijaya A. 1987a. Hot and cold soaking treatment of 20 wood species from Irian Jaya. Journal Penelitian Hasil Hutan (Indonesia) 4 (3):1–9

Abdurrohim S and Martawijaya A. 1987b. Dip diffusion treatment of 10 wood species from Irian Jaya. Journal Penelitian Hasil Hutan (Indonesia) 4 (3):35–70

Airy Shaw H K and Forman LL. 1967. The genus *Spondias* L. (Anacardiaceae) in tropical Asia. Kew Bull. 21:1–19

Backer C A and Bakhuizen, van den Brink R C. 1965. Flora of Java, vol. 2. Groningen: NVP Noordholf, pp. 150–151

Barth O M. 1990. Pollen in monofloral honeys from Brazil. Journal of Apicultural Research, 29(2): 89–94

Bauer T, Kim J and Baldeo I. 1993. A preliminary study on the golden apple (*Spondias dulcis*) Production and marketing in Grenada. Grenada: Inter-American Institute for Cooperation on Agriculture

Bhalla A S. 1990. Conservation des fruits àpetite échelle. BIT, pp. 1–221

Chan H T and Heu R.A. 1975 Identification and determination of sugars in starfruit, sweetsop, green sapote, jackfruit and wi-apple, J. Food Sci. 40:1329–1330

Ding Hou. 1978. Anacardiaceae. Flora Malesiana, Ser. I, vol. 8, pp. 479–483

Duke J A and Atchley AA. 1986. CRC Handbook of proximate analysis tables of higher plants. Florida, USA: CRC Press

Ellis R H. 1984. Revised table of seed storage characteristics. FAO/IBPGR Plant Genetic Resources Newsletter, 58:32

BIBLIOGRAPHY

Fahrasmane L and Parfait A. 1988. Etude sur la fabrication de boissons àbase de prune de cythére. Unpublished data from INRA Guadeloupe.

Fortune M and Dilbar A. 1993. New diseases of mango (*Mangifera indica*), passion fruit (*Passiflora edulis* var. *flavicarpa*) and pomme cythére (*Spondias cytherea*) and their treatment to sustainable agriculture. Proceedings of NIHERST Workshop, Trinidad, 1993.

Geurts F, Blaak G and El Baradj T. 1986. Genetic resources of tropical and subtropical fruits and nuts (excluding Musa), International Board for Plant Genetic Resources, pp. 18–19

Gomez P. 1991. Le pétillant de prune de cythére. Mem ESAT (French)

Helrich K. 1990. Official methods of analysis, 15th edn, vol. 2. The Association of Official Analytical Chemists, pp. 911, 915, 918, 942, 962

Hidyat S and Karnasudirdja I. 1987. Air drying of some Indonesian timber species, Journal penelitian Hasli Hutan, 4 (3):41–44

Jiron F and Hedstrom I. 1988. Occurrence of fruit flies of the genera *Anastrepha* and *Ceratitis* (*Diptera* = *Tephritidae*) and their host plant availability in Costa Rica. Florida Entomologist, 71(1):62–73
Larmond E. 1977. Laboratory methods for sensory evaluation of food. Agriculture Canada pp.1–73

Leather R I A. 1967. A catalogue of some plant diseases and fungi in Jamaica. Ministry of Agriculture and Lands Jamaica News Series, 61:43

Martin F W. 1984. Handbook of tropical foods. Florida, USA: CRC Press, p. 267

Massiot P, Baron A, Farasmane L and Parfait A. 1991. Evolution of cell wall polysaccharides of cythere plum (*Spondias cytherea*) in the extraction and clarification of juice. Sci. Ali., 11:477–489 (French)

Mohammed M. 1993. Post-harvest handling of golden apple. IICA workshop in Grenada, pp. 1–8

Morton J F. 1961. Why not use and improve the fruitful ambarella. Hort. Adv., 5:13–16

Morton J F. 1987. Fruits of warm climates. USA: Media incorporated

Nahar N, Rahman S and Mosihuzzaman M. 1990. Analysis of carbohydrates in seven edible fruits of Bangladesh J. Sci Food Agric. 51:185–192

Ochse J J and Bakhuizen, van den Brink. 1977. Vegetables of the Dutch East Indies. Australian National University Press, pp. 43–45

Ochse J J, Soule M J Jr, Dijkman M J and Wehlburg C. 1961. Tropical and subtropical agriculture (English edition of Indishe Groenten 1931), vol 1. New York: Macmillan pp. 548–551

Pantastico E. B. 1975. Postharvest physiology handling and utilization of tropical and subtropical fruits and vegetables. AVI Publishing Co, pp. 75–101.

Paull R E, Deputy J and Jung Chen N. 1983. Changes in organic acids, sugars and headspace volatiles during fruit ripening of soursop (*Annona muricata* L.). J. Amer. Soc. Hort. Sci. 108(6):931–934

Ponte J J, Athayde C, Sena C B de, Vae C C and do BezerraJ L. 1988. Aetiology of resinosis of fruit trees of the genus *Spondias*, Fitopatologica Brasileria, 13(3):280–281

Popenoe J. 1979. The genus *Spondias* in Florida. Proc. Fla. State. Hort. Soc. 92:277–279

Pratap Singh, Misram R and Singh P. 1989 Bionomics of the ambara defoliator *Podontia punctata* lin (Coleoptera = Chrysolmelidae) Indian Forester, 115(2):910–915

Pruvost O, Couteau A and Luisetti J. 1992. Pepper tree (*Schinus terebenthifolius radli*) a new host plant for *Xanthomonas campestris* pv. *mangiferae indicae*. J. Phytopathology (Germany), 135(4):289–298

Pruvost O and Luisetti J. 1989. Strains of *Xanthomonas campestris* isolated from the ambarella (*Spondias cytherea* Sonn) in the French West Indies are probably a new pathogenic form of *Xanthomonas campestris* pv. *mangifarae indicae*. Fruits 44(10):539–542

Rott P and Frossard P. 1986. A bacterial canker of golden apple trees (*Spondias cytherea*) in Martinique Fruits, 41(10)605–613 (French)

Ruck J A. 1963. Chemical methods for analysis of fruits and vegetable products Canadian Department of Agriculture publication, pp. 8–9

Samson J A. 1986. Tropical fruits. Publisher Tropical Agriculture Series

Sauer M R. 1981. Plant nematodes associated with fruit trees in northern Australia. Aust. J. of Agric. Anim. Husb. 21:129–131

Singleton V L. 1965. Colorimetry of total phenolics with phosphomolybdie - phosphotungstie acid reagents. American Jour. End. Viticult. 16(3):144–158

Sulastiningsih I M, Sutigno P and Memed R. 1987. Properties of wood-wool board manufactured from 19 wood species from central Sulawesi, Journal Penelitian Hasli Hutan, 4(3):21–25

Thomas P. 1975. Effect of postharvest temperature on quality carotenoids and ascorbic acid content of 'Alphonso' mangoes on ripening. J. Food Sci. 40:704–706

Wannam B S and Quinn C J. 1990. Pericarp structure of Anacardiaceae. Bot. J. of Linnean Soc. 102(3):229–233

Weir C, Tai E and Weir O. 1982. Fruit tree crop production in the Caribbean region. Barbados: Caribbean Development Bank, pp. 118–121

Wills R B H, Lee T H, Graham D, McGlasson W B and Halle G. Postharvest: an introduction to the physiology and handling of fruits and vegetables. AVI, pp. 17–37; 52–69

Winton L A and Winton K B. 1935. The structure and composition of foods, vol. 2. London: John Wiley pp.733–734

ANNEXES

ANNEX A

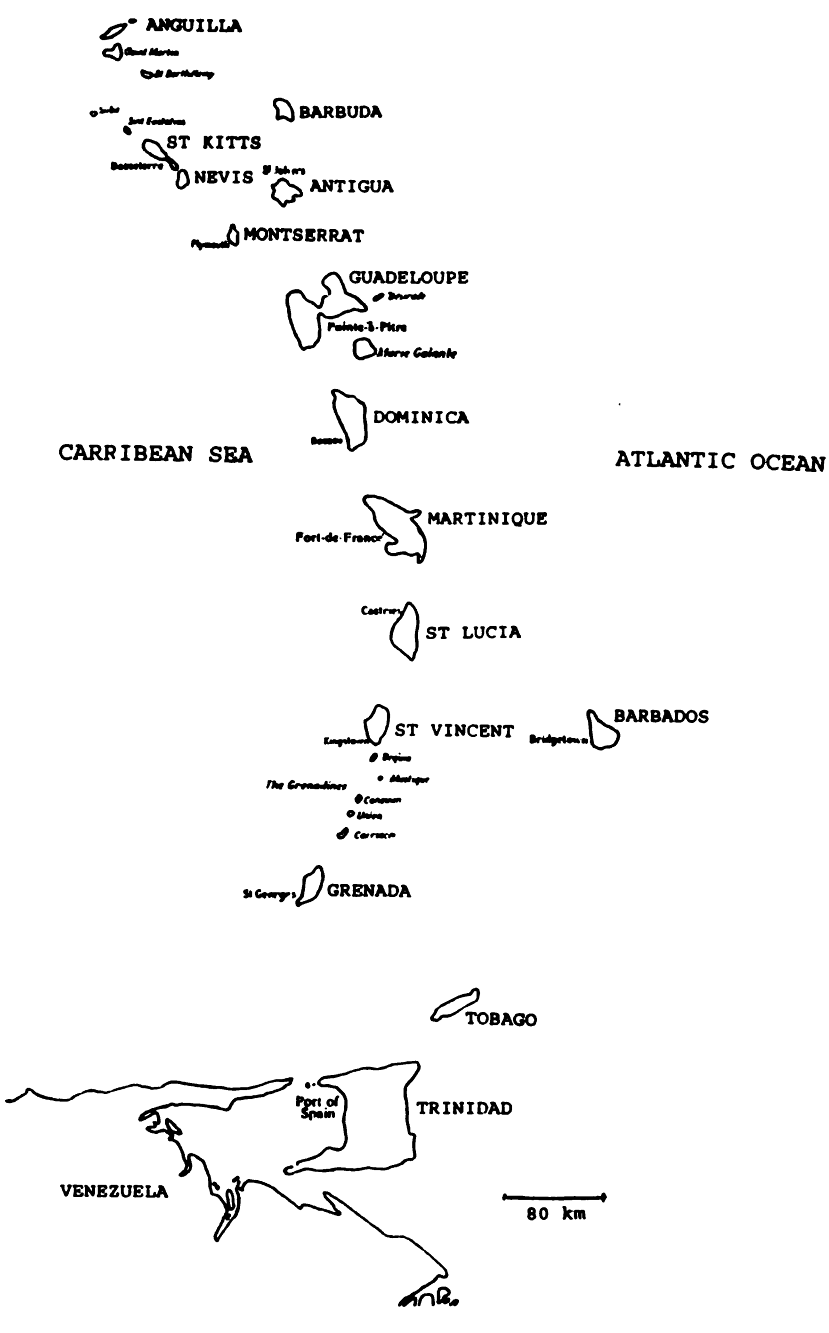


Figure 43 **Map of the Caribbean region**

COMPOSITION OF GOLDEN APPLE FRUITS

Table 17 **Composition of golden apple fruit carbohydrates**

	Pulp and skin
Dry matter (DM)	12.5%
Lignin	5.9% of DM
Dietary soluble fibres	10.3% of DM
Dietary insoluble fibres	36.9% of DM
Total fibres	47.2% of DM
Starch	18.6% of DM
Rhamnose	0.4 IU
Arabinose	8.5 IU
Xylose	2.3 IU
Mannose	0.4 IU
Galactose	13.1 IU
Glucose	67.8 IU
Uronic acid	7.5 IU
Glycerol	0.1 mg/g
Glucose	1.23 IU
Glucoseß	1.13 IU
Fructose	2.23 IU
Myo-inositol	0.8 mg/g
Total free sugars	0.3 %
Sucrose	13.61%

Sources: Nahar et al. (1990); Chan and Hheu (1975).

Table 18 **Main organic acid composition of golden apple fruits**

Acid	Green fruits: Skin and Pulp (mg/g)	Half ripe fruits Skin and Pulp (mg/g)	Ripe fruits Skin and Pulp (mg/g)
Malic acid	2.78	2.26	1.7
Citric acid	0.540	0.177	0.105
Acetic acid	0.266	0.280	1.180
Oxalic acid	0.036	0.042	0.033

Source: Fahrasmane and Parfait (1988)

Table 19 Amino acid composition of golden apple fruits

	Green fruits: Skin and pulp (IU)	Half-ripe fruits: Skin and pulp (IU)	Ripe fruits: Skin and pulp (IU)
ASP	77.5	23.6	39.2
GLU	89.3	48.1	76.5
ASN	309.9	81.5	180.0
SER	53.4	28.6	60.9
GLN	235.4	65.4	184.6
HIS	9.7	5.6	6.5
GLY	27.2	10.4	18.1
THR	49.1	19.6	38.9
ARG	12.2	5.0	4.4
ALA	86.3	117.8	304.6
GASA	18.2	10.7	16.9
TYR	8.5	10.6	20.5
MET	11.0	5.7	13.0
VAL	32.1	15.1	34.7
PHE	14.4	9.9	12.2
ILE	19.4	10.4	13.4
LEU	12.6	7.6	11.8
LYS	30	14.5	33.1
Total	1096	490	1069.3

Source: Fahrasmane and Parfait (1988)

FRUIT SCARRING

On the tree, the fruits are damaged by a superficial alteration of the first layer of skin cells resulting in a brown scarring. After easy removal with a fingernail, the fruits appear green but dull, therefore this sort of damage destroys the cuticle of the fruit. It also causes some fruit deformity if it happens during the early stages of fruit development. Trials were conducted in Grenada, in collaboration with the Pest Management Unit (PMU), to determine the causal agent of this problem.

The organism was identified as a mite which could be seen on the fruit in the fields as a tiny white spot running on the surface of the green fruits. These mites live under the darker part of the scarring (like a fish under a coral reef), and move around the fruit with a rise in temperature. The mite was isolated on a slide and sent to Trinidad for identification. However, there was some confusion in the sampling and more samples must be sent back for confirmation.

Even very young fruits, 2 cm in length, can show the symptoms, indicating that the parasite attacks the fruit at any stage of development. The mite was observed in every location sampled in Grenada. The infection of the parasite occurred in a very diffusive way and the percentage of attack per fruit and on the tree is variable (see Plate 12 on page 61).

ANNEX C: TREE OBSERVATIONS AND "SELECTION"

ANNEX C1

TREES SELECTED BY THE PREVIOUS PROJECT

From observations on over a 100 trees, 33 trees were selected by the previous team for their higher yields and phytosanitary cleanliness; five main trees were also recommended for their superior qualities (Bauer et al. 1993).

Table 20 List of pre-selected trees in Grenada

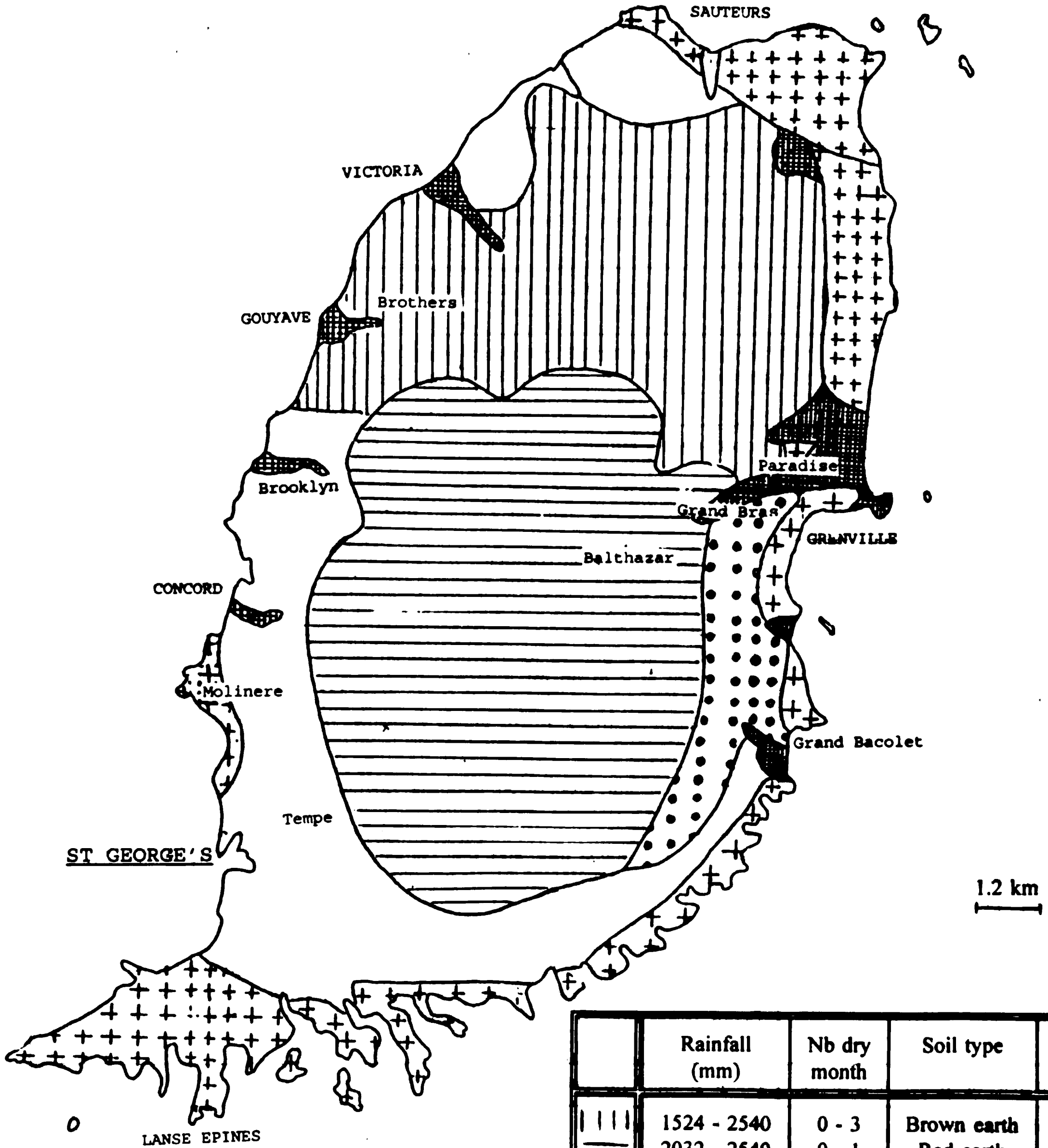
Farmers	Location	Tree code	Superior trees
Roy Bedeau	Bois congo	RB1	
Roy Bedeau	Bois congo	RB3	
Roy Bedeau	Bois congo	RB4	
Roy Bedeau	Bois congo	RB5	Large fruits
Roy Bedeau	Bois congo	RBX	
Chappy Petters	Bois congo	C1	
Chappy Peters	Bois congo	C4 ← C6	
Chappy Peters	Bois congo	SR1	
Sonny Robertson	Bois congo	KG1	
Kingsley Gustard	Bois congo	KG2	
Kingsley Gustard	Bois congo	KG3	
Kingsley Gustard	Bois congo	Bel1	
Belfon	Brooklyn	HR1	
Rodjeric Hector	Brooklyn	MN1	
May Noel	Brooklyn	EM2	
Eluta Mc Queen	Brooklyn	EM3	
Eluta Mc Queen	Brooklyn	SP1	High yeild
Matthew St Paul	Brothers	SP2	High yeild
Matthew St Paul	Brothers	WC1	
Warrial collier	Grand bacolet	Bau1	
Baudau	Balthazar	ET1	
Elma Teka	Brothers	VB1	
Verna Baldeo	Brothers	F1	
Frederiks	Tempe	JB1	
Joseph Brizen	Tempe	JM1	
Joseph Mitchell	Molinere	JO1	
Miller	Molinere	JO2	
Miller	Molinere	JO3	
Miller	Molinere	JO4	
Miller	Molinere	LL1	Early bearing
Larry Lohar	Paradise	LL2	
Larry Lohar	Paradise	GB	
	Grand bras		

ANNEX C2

MEASUREMENTS OF THE PARAMETERS ON GOLDEN APPLE TREES AND FRUITS

Table 21 Definition of the parameters measured on golden apple trees in Grenada (All the measurements were taken by two observers and the average taken)

Parameter	Method of measurement
Location	9 areas: Paradise, Brooklyn, Brothers, Grand Bacolet, Balthazar, Molinere, Vendome, Tempe, Grand Bras (reported on following map)
Climate	According to the location on the following agro-climatic map
pH, P, K, Na, Ca, Mg, OM	Samples taken at 30 cm depth were analysed by the Diagnostic Laboratory of the Ministry of Agriculture
Age	According to farmers interviews done by the former project (in years)
Tree height	Visual with a guide mark at 2 m (in m)
Tree shape	Visual, scale: round, slender
Trunk circumference	Measured 60 cm from the ground level (in cm)
Trunk height	Visual from the ground to the separation of the major brances with a guide mark at 2 m (in m)
Trunk colour	Visual, scale: brown / white; brown / yellow; brown / white / yellow
Canopy diameter	Measured on the ground on opposite diametrical trunk side (in m)
Quantity of foliage, splitted bark, gummosis, sooty mould, epiphytes, parasitic vines, algi, termites and ants	Visual on the entire tree and per comparison to other trees, scale: no, few, average and a lot
Pests problems	Attribution of a score calculated as the quantities of (gummosis + ants + sooty mould + termites + epiphytes + parasitic vines + algae) - 7 (Score going from 0 to 21 for severely infested)
Percentages of mites and fungi	Visual percentage occurring on the fruits (in %)
Time of bearing	Visual evaluation for 3 consecutive days. The percentages of the following were noted: flowers, fruits 0 - 2.5, 2.5 - 5, 5 - 8 cm in diameter respectively and then classified as: Early: 15% of fruits of 5 - 8 cm in diameter Normal: 80% of fruits of 2.5 cm in diameter Late: 40% of fruits of 0 - 2.5 cm in diameter Very late: flowers
Surrounding vegetation	Presence or absence of cocoa, banana, nutmeg, other fruit and secondary forest



	Rainfall (mm)	Nb dry month	Soil type	Elevation (m)
| | |	1524 - 2540	0 - 3	Brown earth	90 - 760
═	2032 - 2540	0 - 1	Red earth	90 - 760
▓	1524 - 2540	2 - 6	Alluvial	<30
+ +	<1524	6	Shoals	0 - 60
	1524 - 2540	3 - 5	Lithosols	0 - 180
• • •	1524 - 2032	1 - 2	Red earth	60 - 300

Figure 44 **Agro-climatic regions of Grenada Location of pre-selected trees**

ANNEX C2

Table 22 Methods of measurement of golden apple fruit characteristics

Parameter	Method of measurement
Shape	Visual observations, scale: round, oval, pear-shape
Fruit length	Measured from top to bottom with a tape (cm) (Fig 45 a)
Fruit diameter	Measured on the larger width with a tape (cm) (Fig 45 b)
Ratio length to diameter	Calculated, representative of the shape as a value of 1 can be attributed to round fruits
Skin colour	Visual observations on RHS colour charts: green fruits: green (GI38B, G144B) Ripe fruits: yellow orange (YO15A, YO15C, YO15D)
Taste	Appreciated on the pulp by 1 taster, scale: crispy, intermediate, soft
Texture	Estimated on the pulp by 1 taster, scale: crispy, intermediate, soft
Firmness	Measured with a penetrometer (Mc Cormick FT327) in 2 thinly peeled areas away from the main spines or fibres (lbs/cm)
Thickness of the pulp and skin	Measured on the fruit cut in half with a tape (cm) (Fig 45e)
Pulp colour	Visual observations on the fruit cut in half according to RHS colour chart: green: yellow orange (YO15A, YO15D, YO10D) ripe: yellow orange (YO15A, YO15C, YO15D, YO10D)
Smell	Estimated by 1 taster on the fruit cut in half, scale: none, mild, strong
Weight of fruit, skin, pulp and seed	Measured with a scale (Mettler) on the whole fruit and after separation of the different parts (g)
Yield of pulp	Calculated as: Pulp weight x 100 / Fruit weight
Yield of edible parts	Calculated as: (Fruit weight - Seed weight) x 100 / Fruit weight
Quantity of spines	Visual observations on the fruit cut in half, scale: few, average, abundant
Length of spines	Measured with a tape on fruit cut in half on the majority of the spines (cm) (Fig 45 f)
Total Soluble Solids (TTS)	Measured with a refractometer (Atago ATC-1) on pressed juice of mixed pulp in duplicate (°brix)
Titratable acidity (TTA)	37.5 g of pulp blended in 100 ml of distilled water was boiled for 1 h (evaporated water was replaced to keep volume constant). The contents adjusted to 250 ml was filtered through Whatmann filter paper. 25 ml of this sample was diluted to 250 ml. 100 ml of this solution were titrated with NaOH (0.1N) and 3 drops of phenolphthalein
Ratio, TTS/TTA	Calculated as °brix / % malic acid
Time to ripen and overripen	Measured after storage at ambient temperature (30°C) (days)

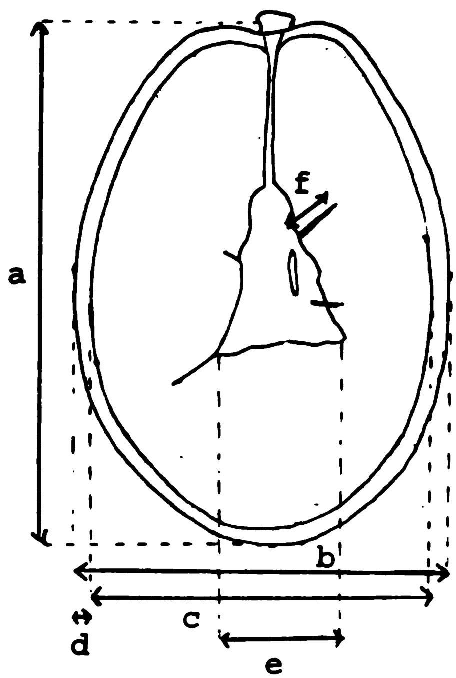


Figure 45 Measurements of length (a), diameter (b), pulp thickness (c), skin thickness (d), seed diameter (e) and length of spines (f), on golden apples

ANNEX C3

CORRELATIONS OF THE PARAMETERS

Table 23 Correlations between all the parameters measured

TREES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1- Tree shape																														
2- Tree height																														
3- Trunk height		***																												
4- Trunk circumference																														
5- canopy diameter		*																												
6- Tree age		*		***																										
7- Trunk colour						*																								
8- Bearing																							*							
9- Splitted bark				**		*																								
10- Phyto-sanitary problems																														
11- Ants																														
12- Termites																														
13- Sooty mould					*							**																		
14- Algi																														
15- Parasitic vines																														
16- Epiphytes																														
17- Gummosis																														
18- Mites																														
19- Fungus					*					**							***													
20- Rainfall								*						-**						***										
21- Number of dry month													-*																	
22- Elevation													*																	
23- Soil type								*																						
24- pH																														
25- P																	**		**											
26- K																	**		**											
27- Na																	**		**											
28- Ca																														
29- Mg																														
30- OM																														

*** = P<0.05, ** =P<0.01, *** = P<001; - = negative relation**

GREEN FRUITS

		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
TREE	1- Tree shape																							
	2- Tree height																							
	3- Trunk height																							
	4- Trunk circumference																							
	5- canopy diameter																.•							
	6- Tree age															••		.••	•					
	7- Trunk colour																							
	8- Bearing					.•					•												.••	
	9- Splitted bark																							
	10- Phyto-sanitary problems																							.•
	11- Ants																							.•
	12- Termites																							
	13- Sooty mould																							
	14- Algi																							
	15- Parasitic vines																						.•	
	16- Epiphytes													•										
	17- Gummosis													.•										
	18- Mites																							
	19- Fungus																							
	20- Rainfall		•••	.••		•••																		
	21- Number of dry month					.••																		
	22- Elevation			.••		•••																		
	23- Soil type																							
	24- pH			••													••							
	25- P																	•						.•
	26- K																							
	27- Na																							
	28- Ca		.••	••		.•	.•										.•••							
	29- Mg			••		.•																		
	30- OM			••										•										
GREEN FRUIT	31- Fruit length																							
	32- Fruit diameter	•••			••																			
	33- Length/diameter							.••																
	34- Fruit shape																			•				
	35- Pulp thickness	••	•••																					
	36- Skin thickness		•••			••																		
	37- Seed diameter		••			••																		
	38- Spines quantity				•••																			
	39- Spines length																							
	40- Fruit weight		•••	•••			•••	••																
	41- Seed weight						••		•		•													
	42- Pulp yield																							
	43- Edible parts yield														••									
	44- Firmness									••	.••													
	45- TTA																							
	46- TSS																							
	47- TSS/TTA			••																			••	
	48- Taste																							
	49- Scent																							
	50- Texture																							
	51- Skin colour																							
	52- Pulp colour																		•••					
	53- Time to ripen																							
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
RIPE FRUIT	54- Pulp thickness		•••			•••	••	•			•••			••										
	55- Skin thickness											••		.••										
	56- Seed diameter		••			•		•••		••														
	57- Spines quantity							••																
	58- Spines length									•••		•			•									
	59- Fruit weight	•••	•••		•	•••	••	••			.••													
	60- Seed weight											•••												
	61- Pulp yield																							
	62- Edible parts yield																							
	63- Firmness																							
	64- TTA	.•••				.•										•••			.••					
	65- TSS													••			•••							
	66- TSS/TTA																		•				•	
	67- Taste																							
	68- Scent													••						•				
	69- Texture																							
	70 Skin colour													••	.•				•					
	71- Pulp colour		•				•••				••			••	.•••									
	72- Time to overipen											.••		••										
LEAVE	73- Leaflets number													••										
	74- Leaflet width																		••					
	75- Leaflet lenght																							.••
	76- Leave width																							.••
	77- Leave length																							

ANNEX C

RIPE FRUITS

		54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
TREE	1- Tree shape																			
	2- Tree height																		-**	
	3- Trunk height																			
	4- Trunk circumference																		-*	
	5- canopy diameter																			
	6- Tree age																			
	7- Trunk colour																			
	8- Bearing			-**														**		
	9- Splitted bark																			
	10- Phyto-sanitary problems			**					**											
	11- Ants																			
	12- Termites																			
	13- Sooty mould																			
	14- Algi																			
	15- Parasitic vines																			
	16- Epiphytes																			
	17- Gummosis			***					***											
	18- Mites			*															-*	
	19- Fungus										*									
	20- Rainfall			**																
	21- Number of dry month		-**					***												*
	22- Elevation																			-**
	23- Soil type																			*
	24- pH																			
	25- P			*															-*	
	26- K			**															-*	
	27- Na			**																
	28- Ca		-**																	
	29- Mg																			
	30- OM																			
RIPE FRUIT	54- Pulp thickness																			
	55- Skin thickness								**											
	56- Seed diameter		**					**												
	57- Spines quantity				**															
	58- Spines length				**															
	59- Fruit weight																			
	60- Seed weight							*												
	61- Pulp yield																			
	62- Edible parts yield	*							-**					***						
	63- Firmness																			
	64- TTA																			
	65- TSS							***												
	66- TSS/TTA	**								**				***						
	67- Taste																			
	68- Scent																			
	69- Texture				***			**		***				**						
	70 Skin colour	**												***	***					
	71- Pulp colour	***						*		***				***	**				***	
	72- Time to overipen																			
LEAVE	73- Leaflets number																			
	74- Leaflet width																			
	75- Leaflet lenght																			
	76- Leave width																		-**	
	77- Leave length																			

ANNEX C4

TREE PROPAGATION

Samples taken with a cutter on the terminal branches of about a year's growth were collected. Scions, of similar diameter as the rootstock, were prepared with a clean knife as reported in Figure 46. The rootstocks used were golden apple seedlings from the Agricultural Station at Ashenden, Grenada.

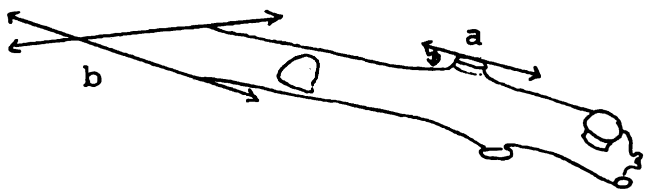


Figure 46 **A Golden apple scion (a = 1 mm of leaf petiole was left, b = wedge shape on the lower end)**

Side and top grafting were used. Some leaves were left on the plant to allow respiration and a grafting paste was placed on the wounded tissue to avoid water introduction and rotting. The inserted scions were then tied with a plastic strip and placed in a sealed plastic bag for 21 days to prevent any disease infestation. The grafted plants were kept outdoors under shade and humidity at Mirabeau Agricultural Propagation Station, Grenada. The first trial was conducted with rootstocks of about 6-8 months old (1 cm in diameter). This resulted in the death of the trees because the seedlings used had just been transplanted into new soil.

Another propagation was set up with the same recovering rootstocks because of problems of availability. The grafted trees were sprayed with an insecticide to avoid the scale problem observed in the first trial. This attempt was also a failure. The rootstocks used may have been too old (hard and woody).

The propagation was repeated with younger rootstocks (3 month old, green tissue, 0.5 cm of diameter). Scions were chosen younger for diameter compatibility (0.5 cm of diameter). The result was an improvement (40% of success) but was still unsatisfactory.

Trials looking for the ideal rootstock and scion size and stage should be conducted to increase the percentage of success of the grafting. *Spondias mombin* has been suggested by the Ministry of Agriculture, Grenada.

ANNEX D: POST-HARVEST TECHNOLOGY

ANNEX D1

HARVESTING TOOLS

- Polystyrene bags 50 cm x 90 cm in size that can hold 50 kg of fruits. They are reused and cleaned every 2 or 3 days and are quickly destroyed lasting only 1 or 2 weeks; but they are obtained at no cost.

- Fruit picker belonging to and made by the harvester of reused materials. It is composed of a bag attached at the end of a bamboo pole (Figure 47). There are two sizes of bamboo rod: a long one (4 m) used for the top of the tree or in difficult areas, and a short one (3 m) used for the lower branches of the tree and preferred because it is easier to handle. The bag is fixed onto a piece of wire shaped in the middle like a comb (Figure 47). The fruits are placed in the bag under the teeth, where the branches pass, plucking the fruits which falls into the bag.

- Long cotton strings.

- A hand weighing machine which is owned by the team or the exporter.

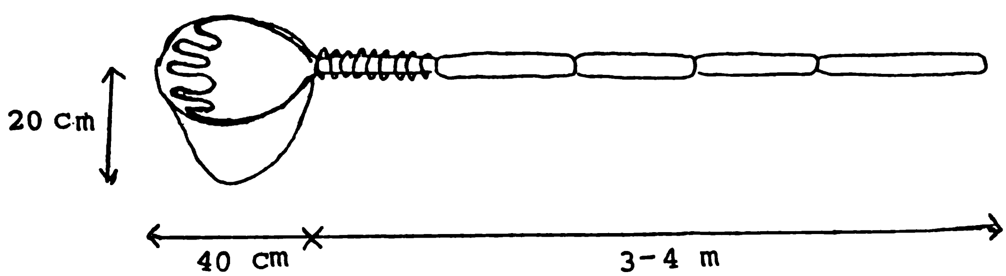
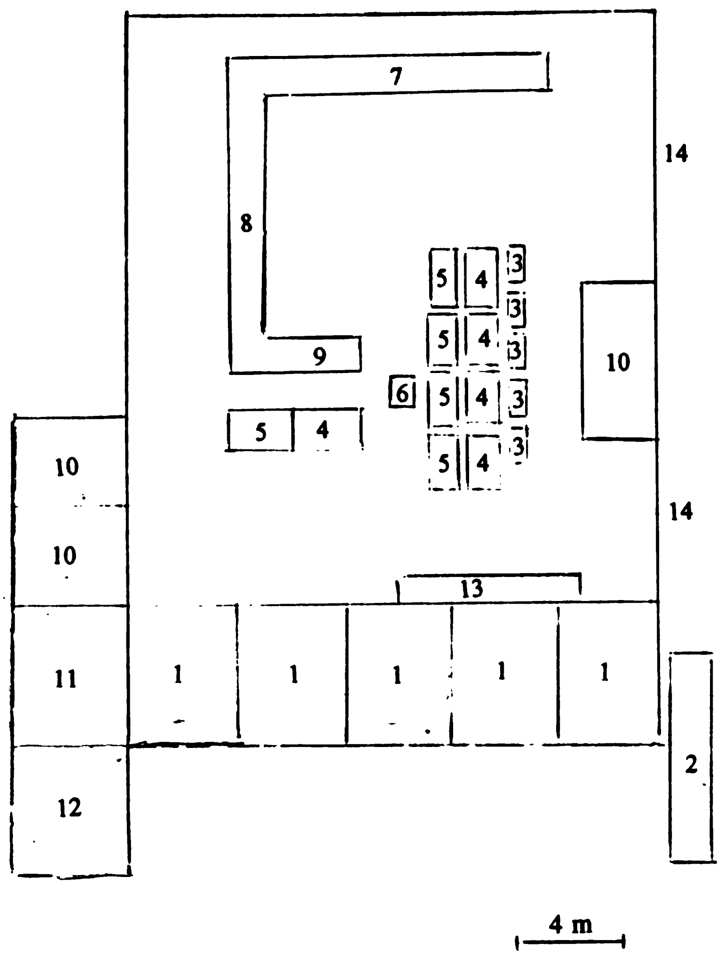


Figure 47 **Fruit picker used to harvest golden apple fruits in Grenada**

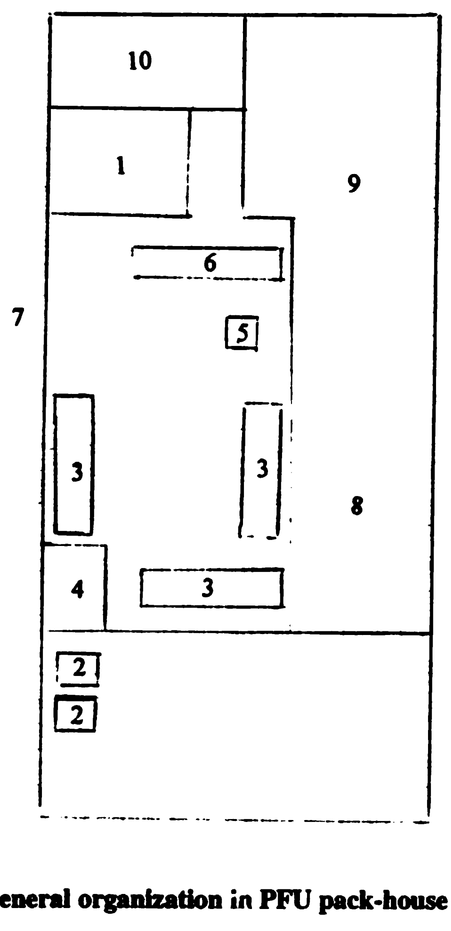
ANNEX D2

EXPORTERS' INSTALLATIONS



1 = Chill-room, self-regulated
2 = Refrigeration machines
3 = Baths
4 = Sorting tables with metallic or wooden tops and removable side stoppers
5 = Packing table
6 = Weighing machine
7 = Washing machine
8 = Mechanical sorting table
9 = Mechanical packing table
10 = Offices
11 = Stock of boxes
12 = Ladies/gents
13 = Stocks of rejects
14 = Embarkation/disembarkation

Figure 48 **General organization at the MNIB pack-house**



1 = Storage of fresh fruits
2 = Baths (used containers)
3 = Sorting tables
4 = Pile of rejects
5 = Bathroom scale
6 = Storage of full boxes to ship
7 = Embarkation/disembarkation
8 = Storage of empty boxes
9 = Storage of equipment for chillroom
10 = Office

1 m

Figure 49 **General organization in PFU pack-house**

ANNEX D3

RESPIRATION TRIALS

Plate 13 **Equipment used for respiration measurements (see plate on page 61).**

1 = CO_2 analyser
2 = H_2O trapper
3 = Sealed cover
4 = Glass jar

Table 24 **Ripening behaviour of golden apple fruits at ambient temperature**

Time (days)	Stage of ripeness				
	Green	Traces	Half-ripe	Ripe	Overripe
0	+++++				
1	++++	+			
2	+++	++			
3	++	++			
4	++	+	+		
5	+	+	++	+	
6	+	+	+	++	
7	-	+	+	++	
8			+	++	-
9			+	+++	+
10				+++	++
11			-	+	+++

The no. of + indicates the relative quantity of fruits at that stage of ripeness.

ANNEX D4

REFRIGERATED STORAGE MEASUREMENTS

a) Weight loss, volume loss and specific gravity

After unwrapping, five specially studied fruits were weighed (Sartorius 1216MP) and the weight loss was calculated as follows:

$$\frac{\text{Initial weight - Weight at sampling time}}{\text{Initial weight}} \times 100 \quad (\%)$$

The fruits were then placed in water (contained in a bucket) and the weight of the fruit in the water was measured on a bottom balance. The fruits were then dried, rewrapped and placed back again in the chamber. The volume was calculated as follows:

$$\frac{\text{Weight in air at sampling time - Weight in water at sampling time}}{\text{Density of water } (=1\ g/cm^3)} \quad (cm^3)$$

And the volume loss calculated by:

$$\frac{\text{Initial volume - Volume at sampling time}}{\text{Initial volume}} \times 100 \quad (\%)$$

The specific gravity was calculated as follows :

$$\frac{\text{Weight in air - Weight in water}}{\text{Weight in air}}$$

b) Firmness

With a penetrometer

The whole fruit was placed under the pointed edge of a cone (of 50 g) of a penetrometer (Stanhope Seta Ltd). The cone, adjusted to just touch the skin, was released for 5 seconds and the depth of its penetration into the fruit was noted in tenths of a millimetre.

With a compression tester

A slice of golden apple 1 cm thick (cut with a mechanical slicer Hobart 612E) was stamped out with a punch of 2.2 cm in diameter. This disc was placed with the skin uppermost between the metallic compression plates of the compression tester (Comten Industries C400). The boards were then adjusted to just touch both sides of the fruit.

The force of resistance of the fruit to an applied pressure was measured against the deformation undergone until non-elasticity of the fruit (Figure 50). The fruit, after becoming elastic, ruptures. The linear coefficient of the first part of the curve, representative of the elasticity of the fruit, was calculated for each fruit.

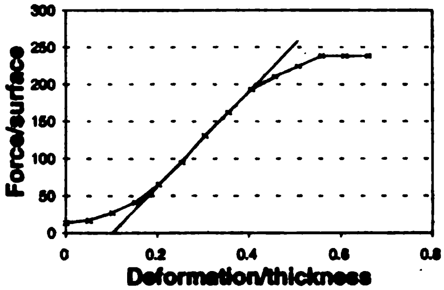


Figure 50 Example of the general shape of the curve obtained for the measure of fruit compression

c) Chlorophyll

1 g of fruit sample was reduced to a smooth paste in a mortar (Ohaus Galaxy TM110) with 30 ml of solvent (acetone 80%) and purified sand. The mixture was left to stand overnight at 10°C to extract the pigment. The mixture was filtered through Whatmann no. 4 filter paper and adjusted to 50 ml with the solvent. The absorbance of this coloured solution was read at 642 and 663 nm (Milton Roy Company Spectronic 20D spectrophotometer). With the dilution factor, the quantity of chlorophyll was calculated as follows (Helrich 1990):

$$\frac{20.2 \times D_{645} + 8.02\, D_{663} \times 5}{\text{Weight of sample}} \quad \text{(mg/100 g)}$$

d) Total carotenoids

A sample of 1 g was reduced to paste in a mortar with purified sand and 30 ml solvent (cold acetone/hexane; 75 : 60 v/v). The mixture was left to stand at 10°C overnight to extract the pigment. The mixture was then filtered under suction with a cotton micro-funnel glass (AG IX2). The extract was rinsed with solvent until it was colourless.

The volume was adjusted with the solvent in a volumetric flask to 50 ml and transferred in a centered funnel to be freed of acetone by repeated washing with distilled water. The hexane layer containing the carotenoids was dried over anhydrous sodium sulphate and its absorbance read on the spectrophotometer at 436 nm (Thomas 1975). The amount of carotenoid was calculated with reference to a standard curve based on ß-carotene as shown in Figure 51.

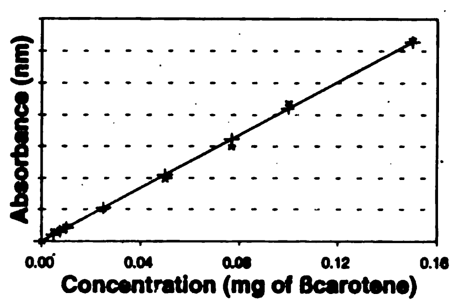


Figure 51 Carotenoid standard curve based on ßcarotene

The linear coefficient obtained was 8369.975, therefore the amount of total carotenoids in the fruit was calculated as follows:

$$\frac{\text{Absorbance of 1 g sample} \times 1.10^5}{\text{Weight of sample} \times 8369.975} \quad \text{(mg ß-carotene/100 g of sample)}$$

e) Total soluble solids (TSS), ratio TSS/TTA, pH

The TSS of the 1/1 puree was measured with an Atago hand refractometer (Helrich 1990). The ratio TSS/TTA was calculated as °brix/% malic acid. The pH of the 1/1 puree was measured with a pH meter.

f) Total phenols

The 1/1 puree was filtered using a Buckner funnel with Whatmann no. 4. filter paper and 5 ml of Folin and Ciocalteu's 2N reagent diluted 1 : 10 was added to 1 ml of the 1 : 10 diluted juice. After 30 seconds and before 8 minutes, 1.5 ml of 20% saturated sodium carbonate solution and 2.5 ml of water were added. After 2 hours at 24°C, the absorbance was read at 765 nm against a blank made with water (Singleton 1965). A standard curve using gallic acid is shown in Figure 52.

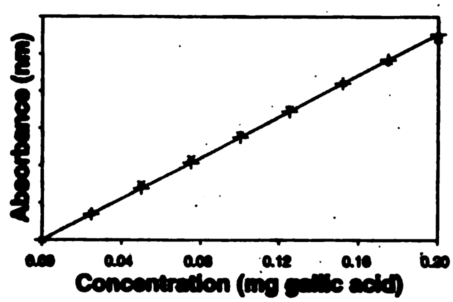


Figure 52 **Phenol standard curve based on gallic acid**

The linear coefficient obtained was 5541, therefore the amount of phenols according to the dilution factor was calculated as follows:

$$\frac{\text{Absorbance} \times 1.10^5}{5541} \text{ (mg gallic acid/100 g of sample 1/1)}$$

g) Titratable acidity (TTA)

A sample of 20 g of 1/1 pulp or 10 g of 1/1 skin was passed through a strainer and rinsed with distilled water. The volume was adjusted to 150 ml and the solution titrated against 0.1N sodium hydroxide until pH 8.2 (Helrich 1990).

$$\frac{\text{Titre} \times \text{N NaOH} \times \text{Vol. made up} \times \text{Equiv. weight of acid (64)} \times 100}{\text{Vol of sample taken} \times \text{Weight of sample taken} \times 1000} \text{ (\% malic acid)}$$

h) Observations

The percentage of the visible shrivelling on the skin was noted as well as the number of days taken to ripen out of the chamber. The pulp and skin colours were measured visually by one observer according to the RHS scales described in Table 25.

Table 25 **Scheme for colour determination**

Score	Green skin colour	Ripe skin and pulp colour
8	Brown	-
7	Yellow orange (YO15A)	Brown
6	Yellow orange (YO15C)	Yellow orange (YO23B)
5	1/4 green	Yellow orange (YO15A)
4	1/2 green	Yellow orange (YO15C)
3	3/4 green	Yellow orange (YO10C)
2	Traces of yellow	Yellow orange (YO15D)
1	Green	Yellow orange (YO10D)
0	-	Green

The taste of the puree and aroma of the green and ripe fruits were sampled by one observer and a score was given as shown in Table 26.

Table 26 **Scheme for scent evaluation**

Score	Taste	Aroma
4	Sweet	-
3	Mild sweet	Average
2	Mild acidic	Light
1	Acidic	None
0	-	Alcoholic

ANNEX D5

CHLORINE DOSAGE

The method used was an iodometric titration of chlorine: chlorine reacts with excess acid and the iodide is oxidized to iodine which is then titrated against thiosulphate (Mohammed 1993):

- Transfer 100 ml of the chlorine solution to be titrated into a 250 ml Erlenmeyer flask. Add 2 ml of 1N sulfuric acid, 2 ml of 1N potassium iodine solution. If chlorine is present a yellow orange colour will appear.

- Add 2 ml of starch solution (2 g starch + 10 mg mercuric iodide in 1 l distilled water). Since the yellow colour fades slowly as the titration proceeds, the end point would be difficult to see without the starch indicator which forms a blue complex with iodine.

- Add the 0.1N thiosulphate carefully drop by drop, counting the number of drops required to make the blue colour disappear. Calculate the concentration as (thiosulphate in ppm = 71,000 x N thiosulphate):

$$\frac{71{,}000 \times 2 \times \text{N thiosulphate} \times \text{Vol thiosulphate in ml}}{100}$$

However, this procedure in the pack-house was of low efficiency due to dust interference with the colour and inhomogeneous dilution of the chemical. Complementary trials should be done to define an accurate procedure.

Standardization of the thiosulphate solution:

- Add 1 ml (10 ppm) of potassium iodate standard solution (1 g KIO_3 in 1 l = 0.0467M IO_3^-) diluted to 100 ml with distilled water. Follow the titration procedure and calculate the concentration of the thiosulphate as follows:

$$\frac{0.467 \times 10^{-5} \times 6}{\text{Vol.} \times 10^{-3}} \quad \text{(mol/l)}$$

ANNEX E1

EQUIPMENT USED

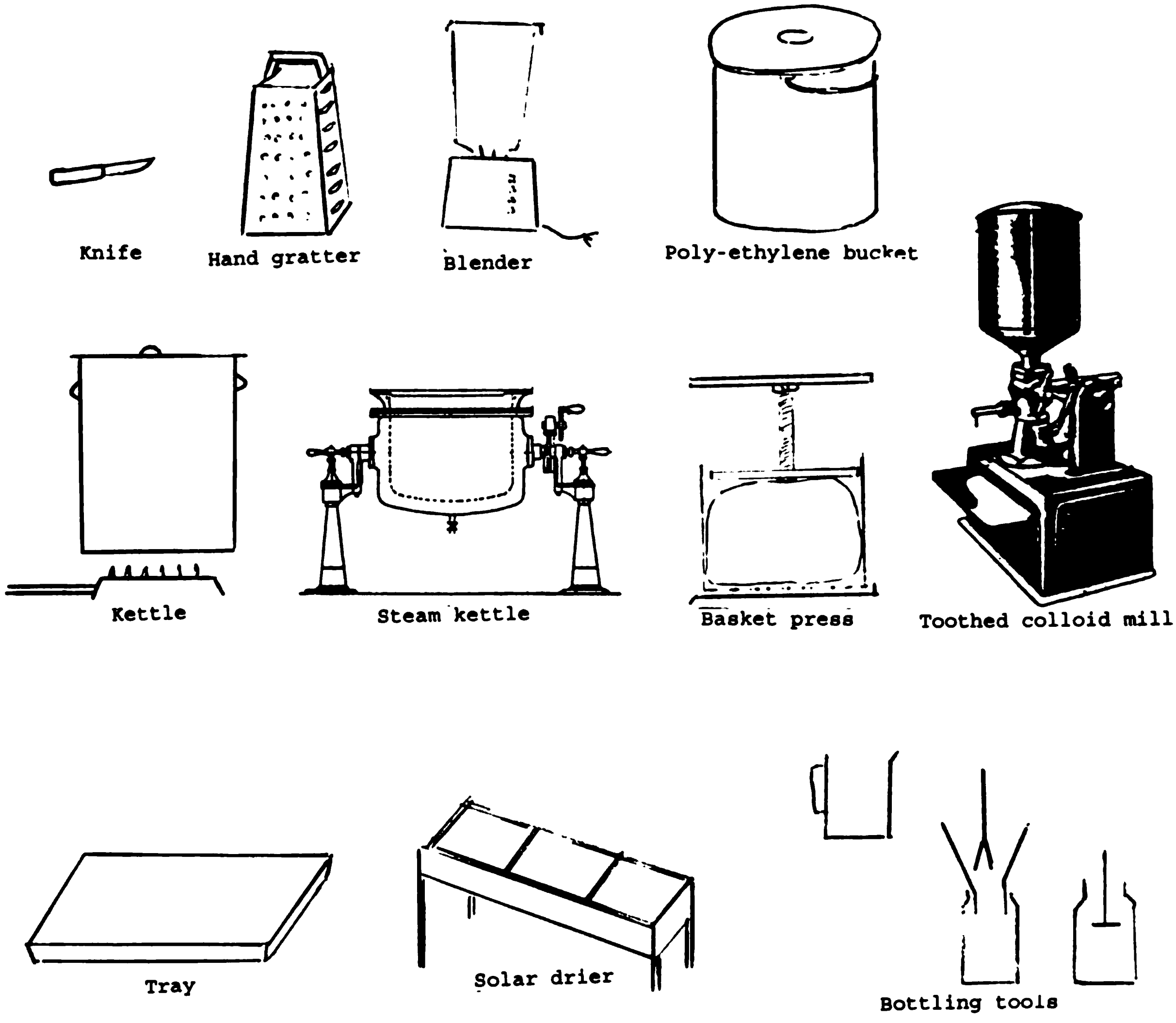


Figure 53 **Equipment used for processing golden apple**

ANNEX E2

Table 27 Methods of measurement for the parameters in the beverages trials

Parameter	Method of measurement
Colour	Evaluated with a tintometer Lavibond Model E
TSS	Measured with a hand refractometer (AOAC 932-12) (Helrich (1990)
TTA	Measured according to the AOAC procedure 942-15B described previously
pH	Measured with a pH meter
Dry Matter (DM)	Samples of 2 to 5 g were dried to constant weight at 70 °C overnight and placed in a desiccator to cool down for 45 minutes then weighted and the DM was calculated as Weight (box+sample) - Weight (box+dried sample) ________________________________x100 (%) Weight (box+sample) - Weight (box)
Viscosity	Measured with a viscosimeter (Brookfield DVI+) with with spindle 2 and a speed of 2 RPM with the following precautions to avoid interference: 30 °C, 1 min of standing then 2 min of rotation before the measurement, identical location in the container
Pectin	Evaluated by an alcohol test (1 vol. ethanol and 1 vol. product). A precipitation indicates a significant amount of pectins. Measured according to the procedure of Ruck (1963): 50 g of homogenized sample added to 400 ml of water were boiled 1 hour with replacement of the water lost by evaporation. The level was adjusted at 500 ml in a volumetric flask at 20 °C. After shaking, the solution was filtered throught filter paper Whatmann no. 4 in an erlenmeyer flask. The latter was shaken and two 100 ml aliquots were pipetted into 800 ml beakers. 300 ml of water and 10 ml of Na OH were added with constant stirring. The solution was left to stand overnight. 50 ml of 1N acetic acid was added and stirred then allowed to stand for 5 min, 25 ml of 1N CaCl2 solution was added and stirred and left to stand for a further hour. It was heated to boiling and boiled for 1 min and then filtered through Whatmann no. 41 filter paper washed with hot water, oven dried for 2 hours at 100 °C, cooled in a desiccator and weighed in a covered weighing dish. The precipitate was washed with almost boiling water until chloride free (silver nitrate test) The filter paper was transferred to the original weighing dish and dried overnight at 100 °C, cooled in a desiccator and weighed. The quantity of pectin is reported as the percentage of calcium pectate according to the following formula: % calcium pectate = Weight of precipitate x 100 ________________ Weight of sample Interference in the measurements did not allow an exact quantification

ANNEX E3

QUESTIONNAIRES FOR CONSUMER EVALUATION

In Grenada

1. Product tasted: dried fruit / jam / chutney / pickles / **kuchela** / sauce

2. Date: 3. Location: 4. Questionnaire number:

5. How do you find the colour?: excellent, good, fair, poor, very poor

6. How do you find the smell?: excellent, good, fair, poor, very poor

7. How do you like the taste?: excellent, good, fair, poor, very poor

8. General comment on the quality of the product

9. Is the hot pepper level: too high, high, just good, low, very low

10. How is the spice flavour?: too strong, strong, just good, low, very low

11. How is the sugar level: too high, high, just good, low, very low

12. How is the acid taste?: too high, high, just good, low, very low

13. How do you find the texture?: excellent, good, fair, poor, very poor

14. Do you prefer jam and chutney: with entire pieces, smooth

15. Do the fibers bother you?: Yes / No

16. What size of package do you like most?: 1, 2, 3

17. What do you think is a right price for number 1 package?: ____

18. Would you buy such product made in Grenada in the shops?: Yes / No

19. If no, why?: ______________________________

20. How often do you use it?: once a day, a week, a month, never

21. Sex: male, female 22. Age: 0 to 15, 15 to 25, 25 to 40, 40 to 60, + 60

23. Occupation: ____________ 24. Are you?: Grenadian, Foreigner living here , tourist

Juices and nectars for panel evaluation in Trinidad

❑ **Taste the 2 coded samples in the following order: 225, 317**

Which of these 2 samples do you prefer?: _______

Reasons:

❑ **Evaluate these 2 samples for thickness (draw a circle over the rating chosen on the scale):**

225:

too thick 9 — 8 — 7 — 6 — 5 — 4 — 3 — 2 — 1 **too liquid**

317:

too thick 9 — 8 — 7 — 6 — 5 — 4 — 3 — 2 — 1 **too liquid**

❑ **Taste the 2 coded samples in the order 249, 572 and tick how much you like or dislike them.**

	249	572
Like extremely Like moderately Neither like or dislike Dislike moderately Dislike extremely		

Reasons:

ANNEX E4

TECHNICAL NOTE ON THE DRIED FRUIT

Sensory evaluation

The colour satisfied the panel as 72% regarded the dried fruits as of good colour with the same range of excellent or fair (12%). The aroma has to be preserved by using appropriate technology. The scent was regarded as good (67%) but also as fair (24%). The scent is correlated with sex ($P<0.05$), women appreciate it less.

The amount of sugar used represents the right compromise as there were no replies of 'too much' or 'very low', and a similar percentage for 'much' or 'low'; the majority being 'just good' (85%). All the tasters have answered 'just good' (98%) for the acidity level.

ANNEX E5

TECHNICAL NOTE ON THE JAM

Table 28 Ingredients used in golden apple jam

Item	Weight (kg)	% total	% / kg fruit
Fruit pulp	5.6	45	100
White sugar	6.8	55	121.4
Citric acid	0.035	0.3	0.6
Pectin	0.075	0.6	1.4
Total	12.51	100	223.4

Sensory evaluation

The colour was highly appreciated with answers of 'good' (67%) and 'excellent' (29%). The scent could be improved by reducing the time of cooking to avoid the volatilization of the aroma. However the respondents regarded the scent as good (65%) or excellent (25%).

The panel was satisfied with the texture as 56% regarded it as good and 23% as excellent which is due to the fact that Grenadians like hard jams. However, it was the only characteristic for which the jam was regarded as poor (6%) or fair (15%). Therefore the level of pectin has to be reduced.

The level of sugar was 66 °brix which is the normal level used in jams therefore the main response was 'just good' (73%). However, some tasters answered 'high' (23%). A large majority of the surveyed population regarded the acidity as the right level (87%), however 12% regarded it as high or too high. Therefore there should be a slight decrease in the citric acid added.

The main general spontaneous comment was 'it is good' (19%) which emphasizes the good acceptability of the jam. There were also a lot of various answers (12%) and the other remarks were: hard or thick (4% and 2%), too acid (4%) or too sweet (2%). With small changes in the consistency, acidity and sugar content, all the comments should become positive.

ANNEX E6

TECHNICAL NOTE ON THE GOLDEN APPLE SAUCE

Table 29 Composition of spiced vinegar

Ingredient	Quantity
5% Acetic acid	5.5 L
Hot pepper	0.080 kg
Pimento	0.046 kg
Coriander	0.095 kg
Clove	0.070 kg
Mace	0.020 kg
Ginger	0.050 kg
Mustard	0.025 kg
Black pepper	0.025 kg

Table 30 Ingredient proportions for golden apple sauce

Item	Quantity (kg)	% total	%/kg fruit
Pulp	3.75	57.93	100.00
Citric acid	0.0093	0.14	0.24
White sugar	2.61	40.32	69.6
Spiced vinegar	0.1	1.56	2.68
Sodium benzoate	0.0035	0.06	0.1
Total	6.4728	100	172.62

Sensory evaluation

The surveyed population appreciated the scent (good, 68%; excellent, 21%). Although some tasters regarded the golden apple sauce as baby food, the colour was appreciated (good, 66% and excellent, 25%). The texture was regarded as good (60%) and excellent (23%). However this was due to the fact that this kind of product is unknown and is taken for a jam. As a golden apple sauce the product is too thick (as too long a pasteurization gelatinized the pectins). The main response of the panel indicated that it contains the right amount of sugar (83%). However, there was also a tendency for too much sugar which could therefore be slightly reduced.

The tasters regarded the acid content as 'right' (92%) and as 'too high' (8%). The acidity could be slightly decreased by adding less citric acid or by not adding the vinegar but only the spices. The golden apple sauce showed the highest percentage of no general comment expressed (59%) compared to the other products which shows it was appreciated. This was confirmed by the other answers which were 25% of various and 15% of good.

ANNEX E7

TECHNICAL NOTE ON THE CHUTNEY

Table 31 Ingredient proportions in golden apple chutney

	Quantity	% / Total	% / kg Fruit
Fruits in brine	7.4 kg	47.27	100
Vinegar Acetic acid	1.41 0.31	8.94 1.92	18.9
Sugar (55 °brix)	6.1	38.97	82
Spices (1% of the total) Turmeric Black pepper Seasoning pepper Cinnamon Pimento Clove Nutmeg Mace Ginger	 0.005 kg 0.01 kg 0.05 kg 0.05 kg 0.25 kg 0.01 kg 0.007 kg 0.007 kg 0.007 kg	 0.032 0.064 0.32 0.32 0.165 0.064 0.045 0.045 0.045	 0.07 0.14 0.68 0.68 0.34 0.14 0.095 0.095 0.095
Hot pepper puree	0.07 kg	0.45	0.95
Starch diluted in water	0.063 kg 0.150 l	0.40 0.96	0.85 2
Total	15.654 kg	100	210.2

After tasting the product, a second batch was made with onions (3%), more ginger (0.085%) and more starch (0.7%). The first batch was more spicy and the second had a seasoned flavour. The first recipe was chosen after a laboratory panel sampling.

Sensory evaluation

The colour was found to be quite attractive (70% good and 20% excellent), probably because the consumers do not have any product for comparison. The surveyed population enjoyed the scent (5% good). However, there was also a significant percentage who regarded it as fair (16%), some as poor or even very poor. This was the only product rated as very poor for this criteria. This was due to the strong scent of the product which has to be improved.

The texture was rated good (54%), however there were also respondents who regard it as fair (2%) or poor (12%). Fibres did not bother 71% of the respondents. However, the deficiency in the texture was partially due to the presence of the fibres ($P<0.05$). It is difficult to have a good consistency and no fibres in a commercial chutney. The tolerance of fibres was negatively correlated to nationality ($P<0.01$). Foreigners accepted them less than Grenadians and tourists not at all. This shows that people who knew the fruit tolerated them but exporting these products to markets unaccustomed to the fruit may be a problem.

'Just good' was the main response obtained from the tasters on the hot pepper content (59%), but then they also said 'too hot' (22%). The hot pepper content can be decreased, as Grenadians are not used to hot pepper. The taste was negatively correlated to the evaluation of the hot pepper content ($P<0.05$). Tasters of low income level found the chutney better than those of other levels ($P<0.01$). For the local market the amount of hot pepper could be reduced, however for the export market to Trinidad another sort of chutney could be produced with more hot pepper.

The amount of spice seems to be right as 84% of the respondents regarded it as 'just good' and a equal percentage of them as 'high or 'low'. The average response for the sugar content was 'just good' (85%) with the same amount for 'high or 'low'. The sugar evaluation was correlated to the taste of the product ($P<0.02$) which confirmed that tasters appreciated sweet chutney. Foreigners regarded it as 'just good' to 'low' and Grenadians 'just good' to 'high' ($P<0.01$).

Even if the main answer expressed by the panel on the judgement of acidity was 'just good' (62%), there were a few 'low' (2%) but a lot of 'high' (30%) or even 'too high (7%) which clearly indicates that the acetic acid has to be reduced which will contribute to a decrease in the unappreciated scent and flavour ($P<0.001$).

The surveyed population did not express any spontaneous comment (44%) or gave various responses (21%) which is a sign that people do not know the product. About 12% of the sample said that it was too acidic which confirm that that is the main change needed. Eight per cent said 'it is good' which suggested an appreciation of the chutney; then they also said too hot (5%) and 5% were bothered by the fibres.

ANNEX E8

TECHNICAL NOTE ON THE KUCHELA

Table 32 Ingredient proportions in golden apple kuchela

	Quantity (kg)	% total	% / kg fruit
Dry fruit	3.75	63.2	100
Spice mix	0.317	5.3	8.6
Turmeric	0.01	0.2	0.3
White vinegar	0.2	3.4	5.4
Vegetable oil	1.5	25.3	40.5
Potassium sorbate	0.002	0.03	0.05
Hot pepper puree	0.150	2.5	4.1
Total	5.929	100	158.95

Sensory evaluation

Only 12% of the surveyed population regarded the colour as 'fair' or 'poor', with the majority of the responses being 'good' (60%). The scent was very much appreciated as only 10% of the panel had a negative reaction. The percentage of 'excellent' was 35 which can be considered as very high due to the strong scent of the product. The major response to the texture was 'good' (73%). However, there was a 15% positive response.

The main response for the hot pepper content was 'just good' (67%), but also quite surprisingly 21% of the tasters found it too low. Therefore a small quantity of hot pepper should be added. The hot pepper content was correlated to the nationality of the tasters ($P<0.01$). The main result for the spice content was 'just good' (81%). However, as the other main answer was 'low' (10%) the level can also be increased a little.

The main spontaneous remark was 'no comment' (56%) or various answers (19%) which is also linked to the lack of knowledge of the product which led to the inability of the tasters to comment as they had no basis of comparison. Responses obtained were good (8%) and oily (8%). It is not possible to reduce the amount of oil as it is the preservative used for this type of product, but instructions on straining the product, before eating it, could be provided.

Fibres usually did not bother the tasters (79%) (apart from tourists) as the fruits were grated and the fibres were less apparent.

ANNEX E9

TECHNICAL NOTE ON THE PICKLES

Sensory evaluation

The colour was acceptable but not highly so as about 68% rated it good and 17% found it fair. The brownish colour of the vinegar solution in the bottle and the greyish colour of the skin seemed to cause this response. Men appreciated the colour more ($P<0.02$). The response for the scent was quite similar to that for the colour (66% of good and 15% of fair). The aroma was quite acidic which may be the reason for the average acceptance.

A majority of tasters (93%) said that the sweetness was appropriate. However no one said it was too high and 6% of the population said it was not enough. Eventually, by adding a little more sugar one might be able to satisfy those who found it sour without changing the minds of those who found it just good. The majority of the tasters found the acidity just good (80%). This is a good result, but as 15% of the population found it was too acidic and only 6% not acidic enough it is probably possible to decrease the concentration of vinegar which will decrease the acidic scent ($P<0.02$) and increase the sensation of sweetness ($P<0.02$).

With the spontaneous comments, the texture problem was confirmed with 51% of the panel finding the pickles too hard. Thirteen per cent of the sample simply answered that it was good which shows an appreciation of this new product. Eight per cent regarded it as too acidic which confirms the previous remark. A majority (79%) of the respondents were not bothered by the fibres which is quite a good result. On the other hand, the tasters were not eating the longer fibres but throwing them away. However, they are used to the fruit and do not pay much attention to this.

ANNEX E10

TECHNICAL NOTE ON THE NECTAR ENZYMATION OF THE PULP

The 1/1 pulp obtained was brownish and very thick, therefore an enzyme treatment was attempted to diminish the thickness. A trial was conducted to determine an adequate concentration and time of enzyme action in golden apple pulp.

Pulp samples (400 g) diluted to 70% water – as advised by Gomez (1991) for making a sparkling beverage with golden apple – were seeded with different enzyme concentrations, homogenized and stored at 30°C. This ambient temperature was chosen because of its convenient use by the local processors. The kinetics of the viscosity were analysed by variance analysis (Figure 54).

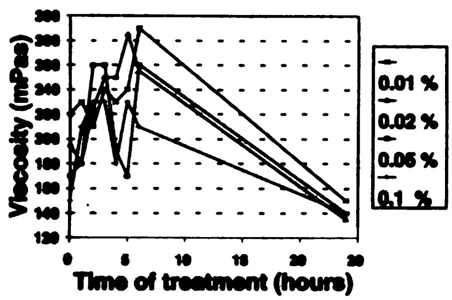


Figure 54 **Kinetics of the viscosity of enzyme-treated golden apple pulp**

The trend observed in the first hours was an increase of the thickness probably due to interference of the dilution with water without previous maceration. However, there was a significant effect of the enzyme after 24 hours ($P<0.01$). The enzyme concentration used did not significantly influence the treatment.

The time of treatment can be reduced by using a water-bath at 45°C for 3 hours. However, as the process is designed for small processors, ambient temperature is more appropriate. After such a treatment, the viscosity was 1500 mPas, similar to a commercial nectar (mango; Eve, Jamaica) used as a standard (1560 mPas). An alcohol test was carried out after the enzymation; no precipitation was observed as opposed to the untreated pulp, therefore the pectin content was significantly reduced.

ANNEX E11

TECHNICAL NOTE ON THE DRINKS: CLARIFICATION

A natural clarification with a 1 : 2 dilution was used. The filtered juice was placed in a volumetric cylinder at 4°C and the quantity of juice separated was measured (Figure 55). One day was necessary to obtain a satisfactory yield (88.5%).

The 1 : 2 filtered juice was treated with 0.02% of enzyme at 30°C; the kinetics are shown in Figure 55. An hour's treatment was effective but 24 hours were needed to obtain a juice of quality; but then it was fermented. This enzymation did not improve the procedure.

The 1/1 filtered juice was filtered again through a filter bag of 20 µm for 16 h at 4°C. Eight per cent of residues were obtained which was a yield comparable to natural clarification. Therefore natural clarification is advised.

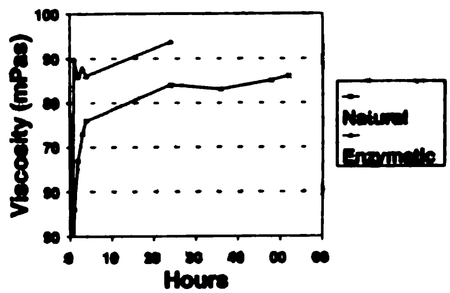


Figure 55 **Kinetics of clarification of golden apple pulp**

An alcohol test was conducted on the clarified juice and a precipitate was instantly formed showing a high level of residual pectin. Therefore trials were carried out to make a further clarification of the juice by enzymation (0.05 and 0.03% enzyme; 30°C 16 h), by natural standing (3 days at 4°C) and by use of gelatin (1 and 2.5% kept 24 h at 4°C). No additional clarification was possible. The juice obtained was cloudy due to the residual pectin which had a positive action on the stabilization.

ANNEX E12

COMPOSITION OF THE BEVERAGES

Table 33 Composition of golden apple drinks and nectars submitted for panel evaluation

	TSS (°brix)	pH	TTS (% malic acid)	TSS/TTA
Nectar 12 °brix	12	3.0	0.489	24.5
Nectar 14 °brix	14	3.0	0.479	29.2
Clarified drink	16	2.9	0.591	27.1
Pressed drink	12	3	0.586	20.5

Table 34 Composition of intermediary products during the processing of golden apple beverages

	Colour red	Colour yellow	Viscosity (mPas)	TSS (brix)	TTA (% ac malic)	pH	DM (%)
Fruits	2.2	7.1		13.6	0.875	2.9	17.4
Pressed juice	0.6	2.4	60	10	0.939	3.1	11.3
Pressed residue 0.1%	0.2	1.4	0	10.9	1.313	3	11
Pressed residue 0.2%	0.2	1.3	0	9.6	1.194	3.05	11.9
Pressed fruits 0.1%	0.2	1	0	9.8	1.109	3	11.4
Pressed fruits 0.2%	0.4	1.3	0	10.4	1.157	3	11.4
Cooked pulp 1/1	2.4	8.0	3860	7	0.590	2.9	7.7
Enzymed cooked pulp 1/1	2.1	7.2	1500	6.8	0.617	3.0	7.33
Fresh pulp 1/2	1.2	6.0	130	4.1	0.357	3	4.5
Residue 500 µm 1/2	1.3	3.2		3.6	0.303	3.15	6.1
Residue 177 µm 1/2	2.5	5.7		5	0.321	3.2	6.3
Filtrated juice 1/2	0.2	0.9	70	4.2	0.273	3.1	4.02
Clarified residue	2	6.2	50.3	0.808		3.05	3.8
Clarified juice 1/2	0.1	0.6	60	3.8	0.275	3.0	3.7

ANNEX E13

PROCESSING IN THE OECS COUNTRIES

In 1994, the institutions CIRAD, CRITT, CARIRI and IICA, realised a study on the fruit processing industries in the Caribbean region. The conduction of the survey by the author in the OECS countries lead to a characterization of the processing units; there are two types: small home cottage industries and medium size factories.

Home cottage

An important amount of individuals have developed a small business on fruit processing mainly of pepper sauce and guava jelly and cheese, but also some jams and a few wines for the tourisim market. These businesses are mainly part time or spare time activities as well as full time for a couple of days per week. However, a few individuals try to develop their activities as a full time job. This processing is usually manual with home equipments (no technological knowledge but cooking experience). They follow the proportions of recipes without any quality control tests (only spoon or water test to judge the degree of cooking of the jam).

They do not have problems to find the required quantity of fruits, even if they have to pick them themselves or contact farmers. But they have difficulties with the seasonality of the fruit as they do not have storage facilities.

Their main problem is usually the availability and cost of the jars and to some extent the equipments. It increases a lot their production costs or simply diminish the final quality of the product which are less marketable. They also have scarcely access to duty free concession which also contributes to increase the cost of jars or equipments. Therefore, their market is limited. Moreover those island are small, and the internal market is highly saturated by other local products, as well as American, Canadian or Trinidadian products. Their attitude are usually of "wait for market to develop".

Medium size industries

Two or three main processors exist in each island employing ten to forty persons each. They are also mainly manual but have very attractive packaging and labels. They need advice on how to choose the right equipments and sourcing cheap ones to be able to continue to develop their business. Fillers and pulpers of medium capacity are mainly needed. They usually develop a few quality control points and send regularly samples to local PCL or foreign laboratories. A few processors have small machinery but in such cases they are less marketing aggressive.

Coordinator: Mr Gérard Barbeau
Editor: Don Walmsley
Layout: Camille Samuel
Printing: MacPrint Promotions Ltd

INTER-AMERICAN INSTITUTE FOR COOPERATION ON AGRICULTURE
OFFICE IN TRINIDAD AND TOBAGO
AERO SERVICES CREDIT UNION BUILDING, Orange Grove Road, Trincity, Trinidad and Tobago
P.O. Box 1318 Cable: IICAPOS. Telephone: (809) 645-3023/3031/6481 Fax: (809) 645-3070
Internet E-mail <iicatt@opus-networx.com>