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Postharvest Institute for Perishables

HANDLING AND PACKAGING

FRESH TROPICAL FRUITS FOR EXPORT

Report to the Royal Thai Government
Ministry of Agriculture

and

the U.S. Agency for International Development/Thailand

by

Dr. Julian June-Ling Lee

for the
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TABLE OF CONTENTS

PAGE

I. Executive Summary and Recommendations.....1

II. Prerequisites of Packaging Design.....3

III. Visits, Observations and Discussions.....9

IV. Recommendations.....12

V. Miscellaneous.....15

I. Executive Summary

The U.S. Agency for International Development Mission in Bangkok requested in cable Bangkok 01412 that the Postharvest Institute for Perishables (PIP) provide a packaging specialist to assist the Royal Thai Government (RTG) with handling and packaging problems in tropical fresh fruit exports. In respons to this request PIP obtained the services of Dr. Julian Lee from the Michigan State University School of Packaging. Dr. Lee spent the period of March 14 to April 1, 1983 in Thailand working on the project.

While in Thailand Dr. Lee visited orchards, packaging sheds, container handling at the Bangkok seaport, the Bangkok air cargo terminal, different departments and laboratories at the Thailand Institute for Scientific and Technical Research (TISTR), and the Ministry of Agriculture.

As a result of his visits, discussions and observations, he made the following recommendations in order to improve postharvest handling and packaging of fresh tropical fruits for export:

1. Establish a permanent research organization for the advancement of packaging technology.
2. Initiate long-term research topics
   a. Compile statistics on postharvest losses to provide basis for improvements in packaging systems.
   b. Qualify and quantify damaging factors in distribution system so that packaging can be designed to reduce the effects.
   c. Study maturity indices of fresh fruits.
   d. Compile data on known optimum conditions for fresh produce quality retention that will identify needed research areas.
3. Initiate short-term research topics
   a. Develop a rapid, practical method for removal of field heat from produce.
   b. Development of use of wire-bound crates for higher-priced fruits.

c. Develop bamboo baskets for better stacking strength.

d. Develop a suitable stacking pattern for produce in refrigerated trucks in order to ensure uniform cooling during transit.

4. Initiate a training program

a. Short-term training in packaging could be met by short courses offered in universities or industries abroad, or by short-term training in-country by teams of experts.

b. Long-term training in packaging should involve formal education to provide a steady supply of packaging engineers.

5. Develop the Packaging Technology Laboratory at TISTR into a modern packaging laboratory to measure and evaluate vibrational forces, vibration fragility, packaging materials, and shock fragility.

II. Prerequisites of Packaging Design

This section describes the information needed prior to the establishment of design procedures for any product with the emphasis on tropical fruits. It also serves the purpose of defining the scope of packaging, and to lay the foundation for the recommendations made in this report.

The prerequisites of designing a proper packaging system for any product are the following:

1. Qualitative and quantitative knowledge of the hazards present in the distribution environment of the product.
2. Knowledge of the fragility of the product.
3. Knowledge of the properties of available packaging material and packaging systems.

To improve or alter the currently employed packaging system for a product, the cost of improvement or alteration should be weighed against the potential profit resulting from reduction in product loss.

Distribution environment can be defined as the physical environment the product has to go through from its site of production to its site of consumption. There are five different types of hazards in the distribution environment of fresh produce - namely: shock, compression, vibration, temperature, and humidity.

Shock is a result of an accidental drop of the package. The severity of the shock is related to both the drop height and the nature of the surface the package impacted onto. Severe bruising and breakage of the produce are the usual consequences of unacceptable amounts of shock. The attenuation of shock to the product is achieved by incorporating proper type and amount of cushion material in the packaging system. The knowledge of cushion design is a separate discipline in the field of packaging. In my opinion, the profit margin of fresh produce does not justify the use of proper cushion material as part of the packaging system. The most economical method of reducing the shock to fresh produce is careful handling during shipment.

The vibrational force affects the product during transportation with vehicles. The vertical vibration of the vehicle can be described, in simplified terms, as sine wave motion with certain frequency and amplitude. The prominent frequencies for trucks are 2-7 Hertz, 10-20 Hertz, and 50-70 Hertz with an average peak amplitude of 0.5 g. The amplitude can be higher if the condition of the road is poor. Instantaneous amplitude of 3 g's is not uncommon. All products vibrate at their characteristic frequencies, nature frequencies, upon excitation by external forces. The amplitude of product vibration depends on the ratio of the product's nature frequency and the external excitation frequency (forcing frequency), and on the amplitude of the forcing frequency. When the ratio of forcing frequency to nature frequency is in the range of 0.4 to 1.3, the amplitude of the external vibration is amplified. In other words, the product may vibrate at several times the amplitude of the external vibration.

There are several manifestations of the damaging vibrational force to fresh produce. If not tightly packed, the produce tends to rotate inside the package. This rotation may cause severe surface abrasion on the produce. Vertical vibration of the fruits in clusters may cause separation of individual fruit from the clusters. If the nature frequency of the fleshy fruit comes close to the forcing frequency, internal bruising or cell rupture may be the result. It is possible to make applesauce without breaking the skin of the fruit by applying the proper vibrational force. The rotation and vibration of fresh produce inside the package may be suppressed by incorporating loose fill material to restrict their possible movement.

When the vibration amplitude of the vehicle bed exceeds one g, the lading inside the vehicle will jump off the bed momentarily and then drop down onto the bed, and the product is affected by shock. The severity of one such shock is small compared to the shock resulting from dropping. But repetitive shock can cause structural failure of protective packaging systems, and hence damage to the product.

The natural frequency of a stack of corrugated boxes usually is in the range of vehicle vibration frequency. The boxes at the top of the stack usually receive more than one g vibrational force, and are subjected to repetitive shocks. This problem can be alleviated by strapping the stack of boxes vertically together and somehow anchor the stack onto the bed of the vehicle.

The bottom of a stack of boxes support the weight of all the boxes on top of it. The weight carried by the bottom box is called compression load. The minimum requirement of a corrugated box is to have enough compression strength to withstand the static load for the required or intended stacking height. During vibration, the apparent weight of the top boxes increases proportionally to the amplitude of the vibration measured in g values. The minimum strength of corrugated boxes should be increased accordingly to withstand the dynamic compression load. With properly designed corrugated boxes, in terms of both static and dynamic compression load, the produce inside the package should not be damaged by the compression force.

The temperature and variation of temperature throughout the distribution environment, especially the temperature inside the transportation vehicles, should be known. As a rule, the retention of quality of fresh produce increases with decreasing temperature surrounding the produce. Obviously, the temperature of fresh produce can be controlled to the desired degree by proper refrigeration and ventilation if it is commercially feasible.

The humidity in the distribution environment affects the movement of water in or out of fresh produce. The development of certain diseases on fresh produce is related to the humidity of the environment. Among other methods, humidity can be controlled by proper ventilation coupled with refrigeration. The effect of humidity on the properties of packaging material cannot be ignored. One of the well-recognized effects of humidity is that the strength of corrugated boxes decreases with increasing humidity.

The fragility of fresh produce can be discussed in two categories - namely: resistance to external mechanical force and the requirements for sustaining the living process.

For industrial products, e.g. television sets, the mechanical fragility consists of shock fragility and vibration fragility. Shock fragility is defined as the minimum g force that can cause product damage. The vibration fragility is determined by identifying all the natural frequencies of a produce. The quantitative analysis of a product's mechanical fragility requires expensive and sophisticated modern testing equipments. The profit margin of fresh produce probably does not justify such capital investment.

The knowledge of the requirements of sustaining and prolonging the living process of fresh produce is a distinctive discipline of plant science, i.e. postharvest physiology. It takes years of formal training to achieve a beginning level of appreciation of this discipline. The shelf life of fresh produce can be prolonged by proper manipulation of factors such as temperature, humidity, respiration rate, disease and physiological disorder control measurements, and chemical or physical treatments. The optimal quantitative values for these factors should be studied for any given variety produced at a given location.

The physiological fragility of fresh produce may be discussed in terms of:

A. Temperature
B. Respiration rate
C. Physiological disorders
D. The natural maturation and ripening processes
E. Moisture retention

Each type of produce has its own optimal temperature for obtaining maximum possible shelf life. This temperature should be provided to the produce as early as possible after its harvest and throughout its distribution cycle. The removal of field heat of fresh produce in the tropical regions is of vital importance for extending its shelf life. For example, loss of strawberries may be up to 60% if the removal of field heat is delayed by as little as 8 hours after harvest, compared to a 10% loss if field heat is removed within 2 hours after harvest.

In general, the shelf life of any produce is inversely related to its respiration rate. Lowering the temperature is one of the most effective means of suppressing respiration rate. Modifying the atmosphere composition surrounding the produce is another method. Reduced concentration of O_2 and elevated CO_2 prolong shelf life. The optimum concentration of CO_2 and O_2 vary with different crops and should be studied in the laboratory. The desired atmosphere can be achieved by using atmosphere generators for the storage facilities or by using plastic bags with the suitable permeation constant. An added benefit of controlled atmosphere is controlling the insects in fresh produce.

The development of physiological disorders of fresh tropical produce seems to be a rare case. The occurence of pitted spots in the flesh of a certain

variety of mango after harvest may be the only example. Most of the known physiological disorders of fresh produce seem to be related to the lack of an adequate concentration of calcium in the produce or improper ratio of calcium in relationship to magnesium or potassium. Preharvest spray and postharvest dip treatment of a calcium salt with a surfactant are the practical cures for this problem.

The best packaging and handling system does not improve the quality of any fresh produce, it only delays its deterioration process. High quality produce for the consumer should start with produce harvested at its maturation stage. Maturation stage is defined as the stage that the produce has acquired the capability of achieving satisfactory ripening following harvest. The identification of reliable maturation index should be studied for each of the important fresh products. A delay of ripening of a mature crop is also effective in prolonging its shelf life. Lowering the temperature, reducing respiration rate, removal of ethylene and other gases that mimic the action of ethylene increasing the concentration of calcium in the fruits and r-ray radiation are some of the means employed for the purpose of delaying ripening.

The pathological fragility of fresh produce can be studied by identifying the bacteria, fungi or insects that cause the deterioration of fresh produce. Various preharvest and postharvest measures are available for controlling this type of loss.

Most of the weight of fresh produce is water. Loss of water not only reduces the salable produce but also gives the produce an unattractive appearance. Moisture loss can be reduced by high humidity, waxing or wrapping the produce with high moisture barrier material. But high humidity in the immediate environment of the produce promotes the growth of rot causing microorganisms. A happy median should be found to maximize the profit for each crop.

The major packaging materials available today can be classified into five groups - namely: paper, wood, plastics, metal, and glass. The mechanical strength (both compression and tensile), the cushioning capability, thermal conductivity and gas permeability (oxygen, carbon dioxide, water, ethylene) may be among the more important properties related to the protection of fresh produce. One of the purposes of packaging is to provide protection for the

vulnerable aspect(s) (fragility) of the product from being compromised by the hazards existing in the distribution environment. The protective functions of packaging systems can be studied by beginning with the understanding of mechanical and chemical properties of packaging materials.

Armed with three categories of knowledge, the proper criteria and procedure for designing a packaging system for fresh produce can then be developed. Packaging is an integrated science, not the single act of constructing protective packages. Through continuing effort in packaging research, education and promotion, the advancement of economic activities as a whole is insured.

III. Visits, Observations and Discussions

A. Site of Fruit Production

Most fruit is produced in small orchards and/or the backyards of farmers. Relatively small amounts of fruits are transported by various means to the wholesalers who, usually, do packaging and exporting. I visited one of the larger mango orchards in Sing Buri, 180 km north of Bangkok. This particular orchard had not produced this season due to insect problems.

B. Site of Packaging Operation

Packaging of fruits is mostly done manually under sheds built with wooden posts and canvas tops; obviously with no temperature control. Packages of fruit are loaded manually into refrigerated trucks. To minimize transportation cost, the trucks are fully stacked with boxes of fruits, with no pallet, strapping, and no room for cold air to circulate about individual boxes. Lading destined for Singapore is transferred at the Thai-Malaysia border to another truck. Thailand trucks are not allowed to be operated in Malaysia.

C. Seaport at Bangkok

The seaport is fully equipped with modern handling equipment for containerized shipments. Refrigerated containers are available, too. Most of the loading and unloading of shipping containers is done at the seaport. Currently, no fresh perishables are shipped by sea for export purposes.

D. Bangkok Air Cargo Terminal

Some of the perishables destined for Hong Kong, Singapore, Arabian and European countries are shipped via air cargo. The Bangkok air cargo terminal is an excellent modern facility. Fresh produce is packaged in either corrugated boxes or bamboo baskets, and loaded into airplanes in pallets, containers or bulk loads. The shipper has no prior knowledge or choice of the method of loading. Palletizing and containerization are done at the terminal.

E. Postharvest Technology Lab of TISTR

Mrs. Sing Ching Tongdee is the Chief of the Postharvest Technology Lab, Agricultural Products Development Division, Thailand Institute of Scientific and Technological Research, a government operated research institute. The lab is ill-equipped to carry out its responsibility due to lack of adequate research facilities and experienced research staff. For example, the lab is having difficulty in designing any equipment to pre-cool fresh produce.

F. Packaging Technology Lab of TISTR

Dr. Amornrat Swatditat is the Chief of Packaging Technology Lab of TISTR. This lab has the same problem as the Postharvest Lab. The following is a list of equipment and some brief comments:

a. Mullen tester

b. Compression tester for small samples

c. Puncture tester

These instruments are used for quality control and for property testing of paper products.

d. Micrometer. Measures thickness of material in 1/1000 in.

e. Conditional room. Small; used to condition test samples at $73^{o}F$ and 50% RH.

f. Free fall drop tester. In theory this tester is of little value, if any, in package testing.

g. Vibration table. 60-250 kpm; 1 inch fixed displacement mechanical drive; this is outdated equipment no longer used in the USA for package testing.

h. Compression tester. Up to 50,000 kg load; variable drive speed; test sample size is limited to 20 inches x 30 inches (approximate); converted from a matel press machine; cannot register deformation of sample.

G. Department of Packaging Technology

Dr. Thanong Pukkarushpon is the temporary chairman of the Department of Packaging Technology, Agro-Industry Faculty, Kasetsart University. The University started the investigation into the possibility of forming the

packaging department. Limited teaching equipment had been bought and a proposed four-year curriculum was developed. The University is not favoring the establishment of this department at the present. No firm decision has been made.

H. Quarantine Office

All the fresh produce for export is examined by the quarantine office which is located inside the Kasetsart University. For large shipments, the examination is done at the site of packaging; for small shipments, it is done at the quarantine office. A wide variety of packaging for vegetables was observed. Fruits for export were not in season at the time.

I. Seed and Postharvest Pathology Branch

Mrs. Dara Buangsuwon is Chief of Seed and Postharvest Pathology Branch, Plant Pathology and Microbiology Division, Dept. of Agriculture, Ministry of Agriculture. She was my host and all the visits were arranged by her. Most of the researchers in this branch have a background in plant pathology. Three of these researchers - Ms. Pakinee Akkaravessapong, Mrs. Supha Suckaseam, and Ms. Mallapa Dhirabhava - were assigned to work closely with me.

IV. Recommendations

The recommendations are not prioritized because they are equally important and should be implemented simultaneously to achieve the goal of the Thailand government with the least amount of delay.

A. Research

1. A permanent organization should be established to be charged with the responsibility for the advancement of packaging technology. The Interministry Project on Improvement of Producing and Handling of Fresh Fruits, Vegetables, Cut Flowers and Ornamental Plants for export is an excellent means of solving short term problems. Its role should be carried on by a permanent organization to accommodate the changes in the marketing, produce requirements, packaging materials and design criteria in the future.

2. Long-term research topics.

   a. Investigation and compilation of statistics regarding the volume, monetary value, and percentage of loss of fresh produce during postharvest handling, storage (if any) and transportation. Above all, packaging is a method of increasing profit. Without data on the losses, there is no solid ground to improve any packaging system.

   b. Qualification and quantification of the potentially damaging factors in the local distribution environment. These data can also be very useful in designing packaging for industrial products.

   c. Studies of maturity indexes of important fresh fruits.

   d. Compiling the available data on the known optimal conditions for quality retention in locally grown produce for easy reference and identification of needed research in this area.

3. Short-term research topics.

   a. Development of a practical method for rapid removal of field heat from harvested produce before or after packaging.

   b. The use of wire-bound crates to replace corrugated boxes for fruits commanding higher retail prices.

   c. Develop a bamboo basket of cylindrical shape, equal diameter for the top and bottom, with supporting members in both the lid and the periphery for better stacking strength.

   d. Develop suitable stacking pattern for produce in corrugated boxes shipped in refrigerated trucks to insure proper and uniform cooling during transit.

B. Education

1. Short Term. To meet the immediate need of specialists in fresh produce packaging system design, postharvest physiologists are the best candidates. The essence of packaging can be acquired by sending qualified personnel to attend short courses offered by industries and universities abroad. Or a team of experts can be brought to Thailand to give a short-term training program.

2. Long Term. Formal college level academic programs in packaging should be made available. Technology of packaging is a growing and continuous need demanded by the industry. Formal education is one of the best methods of providing a steady supply of packaging engineers to meet this need. The proposed curriculum by the Department of Packaging Technology at the Kasetsart University is excellent.

C. Packaging Laboratory

The Packaging Technology Laboratory in the Agricultural Products Development Division of Thailand Institute of Scientific and Technological Research is a good place to be expanded into a modern packaging laboratory. The following additional equipment should be obtained:

1. Study of distribution environment. Equipment and instrumentation for acquiring and analyzing vibrational forces. (i.e. accelerometers, recording devices capable of frequency response in the range of 2 to 200 Hz, wave form analyzer, storage oscilloscope, etc.)

2. Shock fragility determination. Programmable shock machine.

3. Vibration fragility determination. Electro-hydraulic vibration table capable of 2-200 Hz with fixed acceleration up to 1 g.

4. Package material and system property testing. Additional testing equipment; such as compression tester equipped with recording device for deformation, tensile tester, permeation cell, gas chromatography and optical comparator.

5. Performance testing of packaging systems. The ultimate test for the protective function of a newly designed package system is, of course, the field test. Field tests are, in general, difficult to conduct, expensive and time consuming. The next best alternative is simulation testing, done in a laboratory. Close simulation of the hazards in the distribution environment is not easy to achieve either. For this reason, certain selected tests, so-called performance tests, are done to packaged products as a means of evaluating the packaging system. Shock machines, vibration tables, and incline plane testers are the major equipments employed.

The primary functions of the packaging laboratory are those defined by TISTR. If possible, the facility of this laboratory may also serve as a training tool for the students in the Department of Packaging Technology.

V. Miscellaneous

A. Most of the local publications pertaining to handling, storage, and packaging of tropical fresh fruits for export are in the Thai language. Verbal translation into English was made to me by Ms. Pakinee. Comments on the experimental design, data analysis, and parameters to be studied in the future were communicated to researchers of Mrs. Dara B.

B. Informal lectures on the following topics were delivered to researchers of Mrs. Dara B.

   a. Design Considerations of Corrugated Boxes for Packaging of Tropical Fruits.

   b. Fundamentals of Theory and Applications of Shock and Vibration Related to Shipping Container Design.

   c. Hazardous Element in the Local Fruit Distribution Environment.

   d. Available Methods for Precooling of Fruits and Possible Methods to be Applied in Thailand.

   e. The Use of Wire-bound Crates as Shipping Containers for Fruits.

C. Detailed discussions involved the parameters to be considered, possible new packaging systems and methods of evaluation for the trial shipments of tropical fruits to Hong Kong, Singapore, and Paris this coming season to be carried out by the lab of Mrs. Dara B.

D. A new type of corrugated box for the shipment of mangos was designed and constructed.

E. Suggestions were made on the improvement of bamboo baskets as containers for shipping tropical fruits.

F. Part of this report was communicated to the interested personnel in the government, university, and industry communities in a two-hour oral presentation.

G. There was no existing mechanism (procedure) for the design and testing of suitable packing containers for the nine fruits listed in my job description for the Thailand mission. The fruits were mango, papaya, guava, rambutan, sapote, strawberry, longan, lychee and grape.

H. No firm mechanism (procedure) for the design and testing of suitable packing containers could be suggested for the nine fruits listed due to lack of information on product fragility and testing equipment.