This is to certify that the

dissertation entitled

A QUALITY CONTROL MODEL FOR OIL PALM
FRESH FRUIT BUNCHES (FFB)

presented by

Ernest Meshack-Hart

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Agricultural Engineering Technology

Ajit K. Srivastava
Major professor

Date Oct 11, 1984

A QUALITY CONTROL MODEL FOR OIL PALM FRESH FRUIT BUNCHES (FFB)

By

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A DISSERTATION

Submitted to
Michigan State University
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ABSTRACT

A QUALITY CONTROL MODEL FOR OIL PALM FRESH FRUIT BUNCHES (FFB)

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The purpose of oil palm quality control is to make it possible for management to take the right action at the right time, so that the objective of the enterprise, to get the highest quality of oil yield may be attained as well as maintained. This is very important because negligence of this matter may result in a financial loss.

Normally, harvesting is carried out in a cycle of several days. Therefore, bunches of different stages of ripeness will be found in the harvest. The harvest composition, that is the proportion of the number of bunches in each class of ripeness, will depend on the minimum ripeness criterion and the harvesting cycle in force. The appropriate criterion and harvesting cycle will depend, among other things, on the rate of ripening, which itself is

influenced by climate. Therefore, the criterion and harvesting cycle should always be adjusted. To make the right adjustment it is very helpful to analyze the crop composition regularly, by sorting a number of harvest samples using the model developed for this purpose.

This research focused on the quality of fresh fruit bunches (ffb) as affected by field factors (harvesting). There were three specific objectives:

1. To investigate the possibility of establishing a ripeness criterion by color based on ffa content.
2. Evaluate field factors that affect oil quality with ffa content as a primary assessment factor.
3. Develop an oil palm harvest analysis model which can aid producers and processors to improve oil quality.

A systems analysis approach was used as the analytical and problem evaluation technique. The resulting generalized data were used for verification of the computer simulation model.

The significant conclusions derived from the statistical and computer simulation analysis were as follows:

The control of percentage detached fruit alone, does not affect the choice of appropriate premium substantially and, therefore, has little or no effect on the revenue accruing to the farmer. The world market price of ₦800 per ton of oil and the quality premium award of 1 percent for every percent below 5 percent are not enough to encourage Nigerian growers to produce high quality oil. To recapture world market share, Nigeria must offer artificial incentives, not based on world market premiums. The color of the outer fruit should be at least 70% ripe color for Tenera and Pisifera variety. However, color alone cannot be used as a ripeness criterion, especially by inexperienced harvesters because of the variations in color within bunches in the same class of ripeness.

To obtain oil of low free fatty acid content from ripe fruit, it is an important requirement to avoid bruising and damage as far as possible at all stages from the time of harvesting to the time of fruit sterilization. It is of paramount importance to ensure that unripe and very ripe bunches are kept to a minimum and that all loose fruit are collected.

Approved Ajit K. Srivastava
Major Professor

Approved Donald M. Edwards
Department Chairman

ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to his major professor, Dr. Ajit Srivastava for his guidance and help throughout the course of this study. His continual interest in this project during the problem formulation, data collection and analysis provided the vital catalyst which insured the successful completion of the research.

The helpful comments and guidance of Prof. Merle L. Esmay, Prof. John B. Gerrish, Prof. Fred W. Bakker-Arkema, Prof. R.D. Stevens, Prof. James H. Stapleton who served on the author's graduate advisory committee are appreciated.

The research was possible due to the financial assistance of the Thoman Fellowship. Special appreciation is also extended to Nigeria Institute for Oil Palm Research (NIFOR) for providing accommodation during the data collection. The cooperation of the staff of the Institute facilitated the process of data cllection. The author feels deeply indebted to Dr. Onochie, the Director of the Institute who made all this possible.

Thankful acknowledgement is also due to my wife Constance whose mult-dimensional support has contributed immensely to the success of this program.

The understanding and patience of the author's parents, Chief Peter Meshack-Hart and his wife, Ellen, are highly appreciated. Their moral support and parental guidance during the years have been invaluable.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols	Description	Units
FFB	Fresh Fruit Bunches	Kilograms, pounds
FFA	Free Fatty Acid	Percentage
MSTD	Minimum Harvesting Standard	Decimal
LF	Loose Fruit	Kilogram
BW	Bunch Weight	Kilogram
AG	Age	Years
UR	Bunches Classified as Unripe	--
RF	Bunches Classified as Ripe	--
VR	Bunches Classified as Over-Ripe	--
W	Weight	Kilogram
NPV	Net Present Value	Naira
IRR	Internal Rate of Return	Percentage
Pm′	Free Fatty Acid Correction Factor	--
NAAC	National Agricultural Advisory Committee	--
Estate	A Plantation of Palm Trees with Integrated Farm Settlement	--
TD	Time Delay	Days
Pm	Standard Premium	Decimal
DF	Average Percentage Detached Fruit	Percentage
₦	Nigerian Currency - Naira	--
P	Original Loan or Principal	Naira
r	Interest Rate	Percentage
n	Time Duration	Years
V	Principal Plus Interest After Time Duration	Naira
A	Equivalent Annual Cash Flow	Naira
P_{an}	Equivalent Annual Loan	Naira
B_n	Benefits in Each Year	Naira
C_n	Costs in Each Year	Naira
M_n	Margin Obtained at the End of the Year	Naira
R	% Detached Fruit	Percentage
OPM	% Oil Per Mesocarp Weight	Percentage
Pmt	Payment in Nigerian Currency Called Naira (₦)	

CHAPTER 1

Introduction

The Portugese explorers Ca'da Mosto in 1455-1467, and Duarte Pacheco Pereira in 1506-1508, made mention of oil palm (Elaeis guineensis Jacq.) and its products in the reports of their visits to the West African Coast (Crone, 1937; Mauny, 1956). In 1588 and 1590, small quantities of palm oil were imported to England, but it was not until 1790 that the first import of about 130 tons of palm oil was made from Nigeria to England (Mauny, 1956).

As a result of the dominance of the slave trade and method of trading, the importance of palm products into Europe did not attain much significance in the late eighteenth and early nineteenth centuries. Even when the slave trade was abolished in 1807, it was only from 1830 that the future trade of oil palm was assured by the implementation of active measures to suppress the trade in slaves, and by the encouragement given to the oil trade by the British Government.

The fact that the oil palm has played an important part in the Nigerian economy is reflected in the relatively high value of exports of palm produce to the total national exports. In 1900, when the total agricultural commodities amounted to 95.6% of total exports, the contribution made by palm oil and palm kernel alone was 81.6% or £1,514,900 ($2,242,052.00). This continued to be the pattern of export trade until the mid 1920's, when increasing contributions began to be made by cocoa and groundnuts. At this time oil palm products accounted for 53.7% of export earning. The relative importance of the crop in the economy dropped to about 30% during the period 1925-1955 and from 1960-1965 it varied from about 15 to 24% of total export revenue (Oyenuga, 1967).

During the period 1959-65, commercial exports of palm oil and palm kernels averaged 163,000 and 414,000 tons per annum, respectively. Exports of palm produce from Nigeria, therefore, constitute nearly 30% (palm oil) and 50% (palm kernel) of the world trade in these commodities. Since the exports of palm kernels greatly exceed those of palm oil, the indication was that internal consumption per annum must account for a large part of the palm oil produced. Estimates have placed the amount utilized locally at 150,000 to 200,000 tons of oil annually (Oyenuga, 1967).

Palm oil contains large amounts of carotene from which vitamin A is derived. Since it is used extensively in food preparations in Nigeria as well as in other parts of West Africa, where it is used in stews or eaten raw with yams, plantains or other starchy foods, it is of great dietic importance in reducing the incidence of diseases due to vitamin A deficiency. In addition, palm oil and palm kernel continue to be used in the manufacture of margarine, compound cooking fats, soap, candles, cosmetics, confectionaries and as a lubricant in the tin-plating industry. Palm kernelcake, which is a byproduct from the extraction of palm kernel oil, is a useful source of protein (about 20%) and is widely used in the rations of dairy and beef cattle, pigs and horses (Oyenuga, 1959).

Further uses of the oil palm include the production of palm wine which is an industry of considerable economic and nutritional importance. The wine which is obtained by tapping excised male inflorescences is an important source of vitamin B Complex. The leaves are used as thatch for covering houses; the leaf rachises provide material for fences and for reinforcing buildings; the midribs of the leaflets can be made into brooms; the bunch refuse is used locally for soap making and the fibre and shell produced after oil and kernel production, are a source of fuel as well as aggregate material for flooring.

1.1 Oil Palm Development in Nigeria

The production of palm oil in Nigeria reached its lowest ebb during the Nigerian civil war (1966-70). As a matter of fact, it was estimated in 1978 that Nigeria had become a net importer of palm oil, to the tune of 30,000 metric tons worth ₦11 million ($16 million). The forecast for 1980 was 200,000 metric tons of oil and fat imports for Nigeria.

The prediction by (The Standard Chartered Review, 1978) about the decline in the production of palm oil was not taken seriously because the past performance of Nigeria in the world trade for palm oil had been excellent. (See Table 1.1) In 1961, Nigeria's percentage share in world production was the highest (39.9%). Nigeria continued to be the world's largest exporter of palm products till the inception of the civil war in 1966 when she lost the leadership to Malaysia. Surprisingly, Ivory Coast, which in the past was unknown in palm oil international trade, became a net-exporter owing to a well organized modern oil palm plantation system, for example, "Sodepalm Palmivoire Abidjam Coted'lvoire."

The development of oil palm industry in Nigeria has made some progress but very slow in making the desired impact. The trade in palm produce started in the Eastern Nigeria as "Oil Rivers Protectorate," extending along the southern part of the country, covering cross river, Rivers, Anambra, Imo, Bendel and Ondo states. (Figure 1.1)

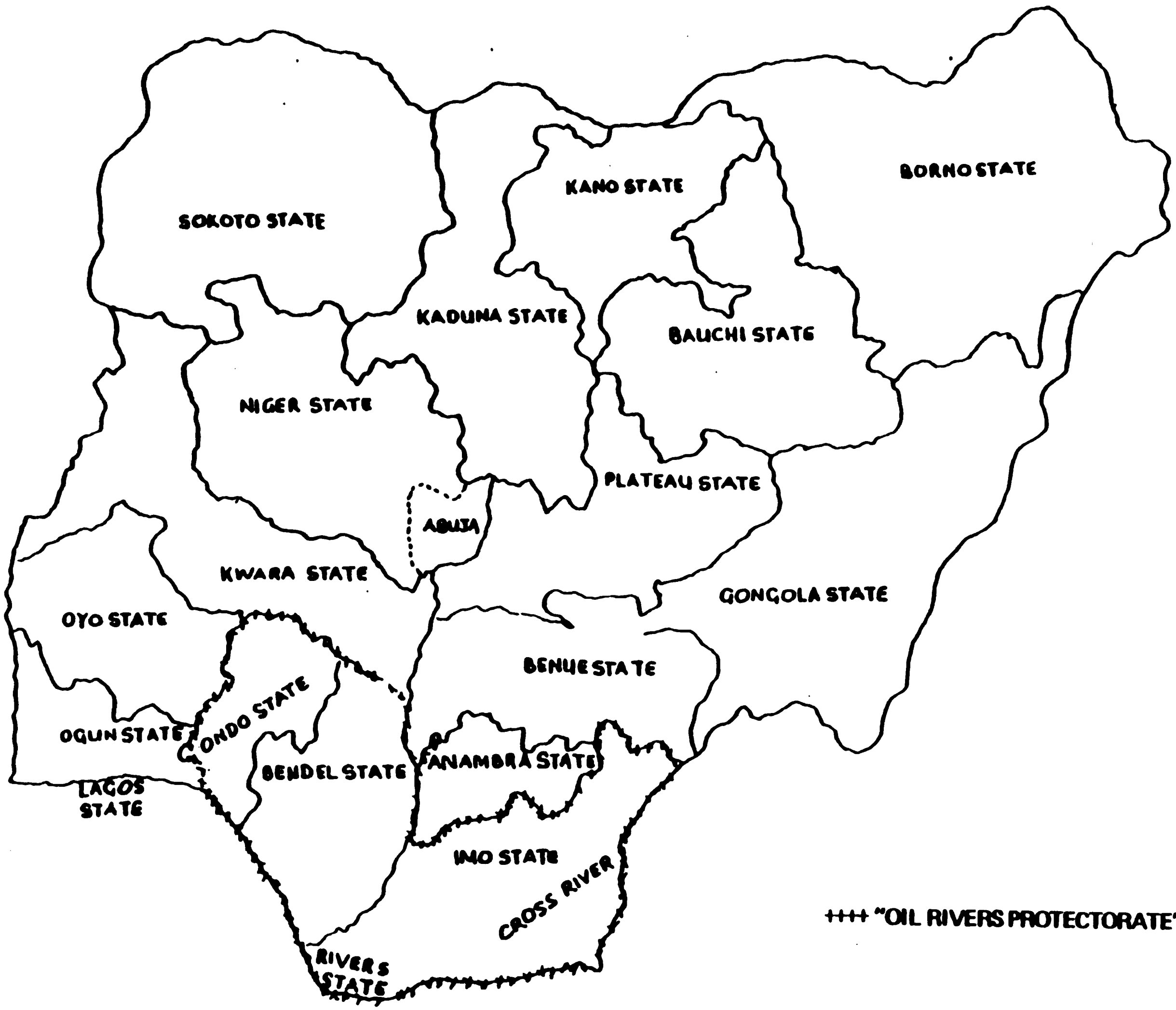
At the initial stage, the exportable palm produce depended on wild oil palm groves. The "Oil Palm Belt" developed with particular abundance in the Eastern region of Nigeria, stretching from Calabar to the bank of the Niger

Table 1.1 Nigeria's Percentage Share in World Production of Palm Kernel 1961-65, 1969-71 & 1978-80

Producing Region/Country	Percentage Share of World Total		
	1961-65	1969-71	1978-80
Nigeria	39.9	24.4	18.5
Zaire	10.4	8.4	4.3
Sierra Leone	5.3	5.1	1.7
Benin	3.5	3.5	2.7
Cameroon	3.5	3.5	2.7
Ivory Coast	1.7	1.6	1.7
Indonesia	3.2	4.2	6.7
Malaysia	2.8	8.4	28.0
Africa	76.0	62.0	41.1
Asia	6.0	15.1	37.6
South America	15.2	21.1	19.2
North Central America	2.8	1.8	1.1
Oceania	0.0*	---	1.0
World Average Annual Production (Metric Tons)	1,050,400	1,178,651	1,658,345

*NOTE: Insignificant share in world total product tone.

SOURCE: Computed from F.A.O. Production Yearbook



++++ "OIL RIVERS PROTECTORATE" BOUNDARY

FIGURE 1.1 MAP OF NIGERIA SHOWING THE NINETEEN STATES

AND "OIL RIVERS PROTECTORATE"

and to the forest areas of Western Nigeria. It was the oil palm development in the Belgian Congo, Malaya, and the Netherland East Indies Java and Sumatra in the Far East that made it mandatory that if Nigeria's oil palm produce was to survive, immediate steps must be taken to rehabilitate the wild oil palm groves. The first oil palm replacement scheme was launched in 1926. This started effective operation in 1928 and by 1935 only 21 acres (about 13 hectares) were planted by six farmers.

It is important to note that during 1948/52, all the revenue from oil palm products came predominantly from exploitation of the uncultivated wild oil palm trees. Therefore there has been the need for better quality product and price differentials in order to sustain Nigeria's revenue from oil palm produce.

The department of agriculture in the early 1920's and 1930's established demonstration oil palm plots to study the yield potentials of selected oil palm trees. After the West African Agricultural Conferences of 1920 and 1927, the Oil Palm Research Station (OPRS) near Benin was established in 1939. In 1951, the station was transformed into the West African Institute for Oil Palm Research (WAIFOR) and in 1964, to the Nigerian Institute for Oil Palm Research (NIFOR).

The United African Company was in the forefront in the palm produce trade in Nigeria. This company provided the bulk oil plants set up at Portharcourt, Burutu, Abonema, Koko, Opobo and Calabar where palm oil was refined before shipment. (Figure 1.2) In addition, the U.A.C. established two large oil palm plantations, the Pamol Ltd., at Ikot Mbo near Calabar and Cowan Estate at Ajagbodudu near Sapele. The company also introduced hydraulic stork mills to process palm oil and kernels at these planations.

In 1945, the colonial Government of Nigeria requested the UAC to design Pioneer Oil Mills, for it had become evident that the crude local method of processing could not compete with the product of modern oil palm plantation of Belgian-Congo and Malaysia.

Before this request, the hand Screw Press (Dutscher Press) was introduced to Nigeria in 1932 in order to improve the quality of palm oil produced in the country (Hartley, 1965). By 1938, about 834 farmers had purchased the Hand Press for their operation. It must be noted that by the native method the oil extraction is about 45% while the Hand Screw Press has 65% extraction of palm oil.

Eventually, the Government introduced the Pioneer Oil Mills in 1946. By this Pioneer Oil Mill process, the fibre and nuts are separated by hand as well as the separation of shell and kernels. The reason for not completely mechanizing the process was to adopt an appropriate technology that would provide employment for men, women, and children in the oil palm belt area. The Pioneer Mill

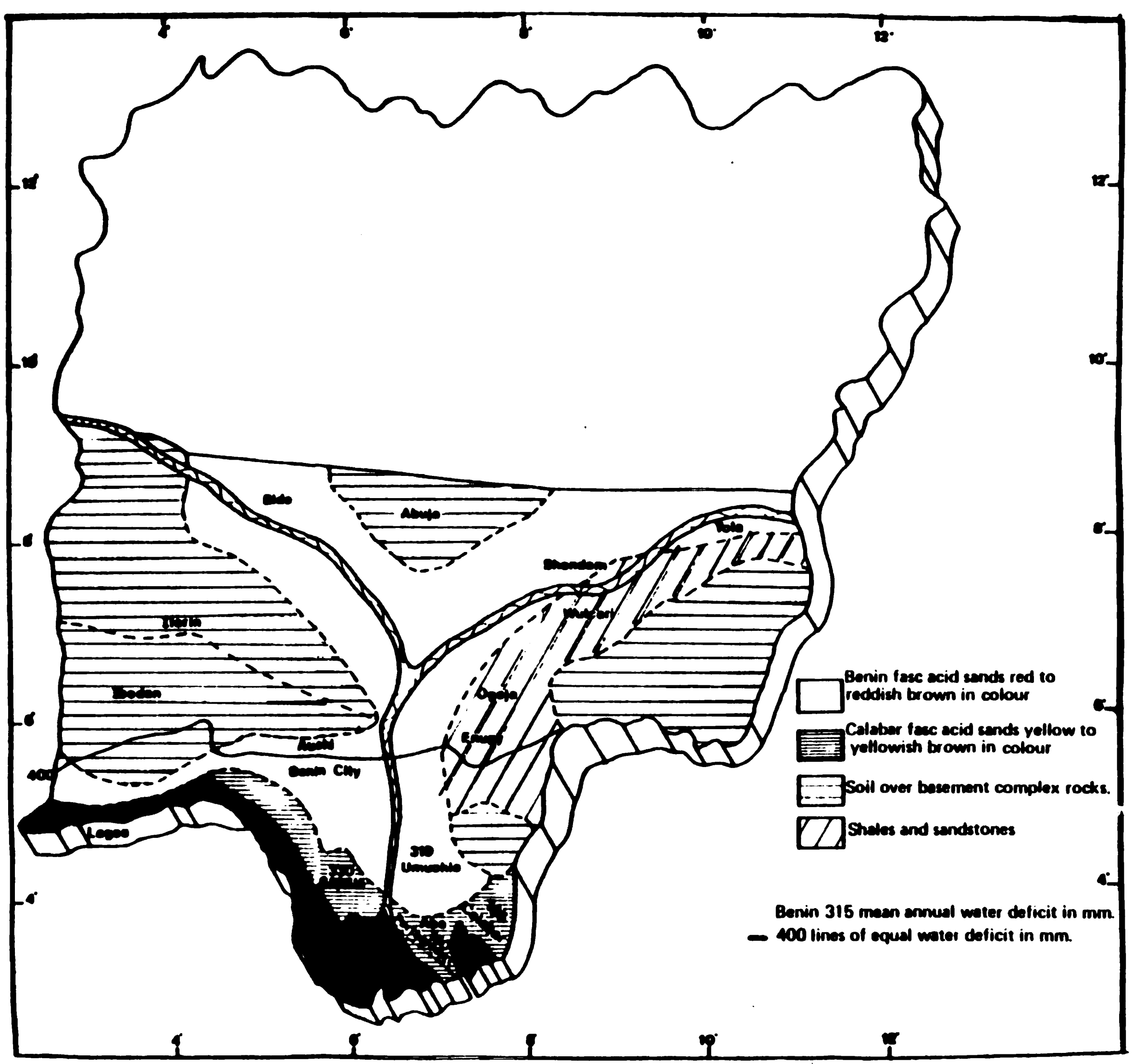


FIG. 1.2 MAP OF NIGERIA SHOWING SOIL TYPE WHERE OIL PALM CAN BE GROWN AND ALSO IHE OIL MILL LOCATIONS AND TWO LARGE PLANTATIONS ESTABLISHED BY THE UNITED AFRICAN COMPANY(UAC).

required a staff of about 30 persons to run. It could process 100 tons of fruit per month in 8 hour shifts. The extraction rate of oil by the Pioneer Mill was about 85%, whereas the UAC owned automatic stork mills at Ikot and Ajagbodudu had 95% extraction of oil.

At the end of the Nigerian civil war in 1970, there were 26 of these mills salvaged in the former East Central State. Of these, four are located in Cross River and River States. Many of these mills have since been in a state of disrepair, although the agricultural development authority did reactivate 26. In Orlu areas of Imo State, the Dutscher Press (Hand Screw Press) is still very popular. This is also the case in many palm oil producing areas.

The stork hydraulic hand press developed by the Nigerian Institute for Oil Palm Research (NIFOR) was introduced to increase palm oil extraction by small-scale producers but this has not gained as much universal acceptance as the Hand Screw Press. The oil extraction of the stork hydraulic press is estimated at 90 percent.

By 1956, the grades of palm oil for export were: (1) Special Palm Oil, 5% ffa or over but not more than 9% ffa; (2) Technical Palm Oil Grade II over 9% but not more than 18% ffa; (3) Technical Oil Grade III over 18% but not more than 30% ffa.

By 1980, the grades of palm oil for export were: (1) Special Palm Oil; not more than 3.5% ffa, (2) Technical Palm

Oil Grade I over 3.5% to not more than 18%. Technical Palm Oil Grade III was eliminated.

Palm oil and palm kernel of "first quality" are the exportable palm oil and palm kernel. A "first quality" palm kernel is that which is dry and hard while a "first quality" palm oil is that which contains not more than 5% ffa, less than 2% by weight of dirt and water, and is not adulterated. The concept of the "first quality" is to have palm produce which is safe for human consumption and which can compete favorably in the world market.

Historically, palm oil has been considered less attractive than many other oils. This, however, dates from a period when palm oil reached Europe with a free fatty acid (ffa) of 20-25% while also highly oxidized. Modern cultivation and processing have improved the image of palm oil for shortenings, deep frying and production of margarine (Hartley, 1967).

The future growth of the use of palm oil in fat blends and cooking oil will depend on how well Nigerian growers can meet the need of the edible oil refining industry. In this direction, this project highlights criteria and other various field factors which will promote the production of high quality palm oil with low content of ffa and a low content of moisture, impurities, and of heavy metals, low oxidation value and excellent bleachability.

There is need for Nigerian producers of palm oil to become aware that a low ffa is the first characteristic to which edible oil refiners pay attention and hopefully it will be a good ambition to create a special Nigerian identity for its palm oil so that it will hold great attraction for edible oil refiners not only in Nigeria but even more in the overseas market.

1.1.1 Policies and Programmes for Oil Palm Development in Nigeria

The special importance of the oil palm as a crop lies in the fact that palm oil is the main source of fat for the Nigerian population. Palm produce provides raw materials for industries, plays a vital part in exports, can absorb a large number of the working population and can provide a substantial share of the capital necessary for development. In view of the role of palm produce, recent policies have been re-orientated towards an increase in productivity and area. The report of NAAC (National Agricultural Advisory Committee) contains a table of production to match the estimated value of ₦600 million ($882 million) of export-earning schedules for 1980. The NAAC admits that because of probable falling prices, it is necessary to more than double the present area to meet the required export goals.

The projected figure for palm produce is given in (Table 1.1.1). In the table, it is assumed that the areas planted in 1975-80 will produce by 1985 while 1980-85

Table 1.1.1 Projected Figures for Palm Produce

Production	Area (ha.)	Bunch Yield (tons/ha.)	Bunch Production (tons)	Oil Production** (tons)	Kernel Production (tons)
A. Estates					
Established prior to 1971*	26,077	11.3	294,382	41,213	13,267
Established 1971-74	20,655	6.8	139,382	19,586	6,295
Established 1975-80	35,369	6.8	239,564	32,522	10,780
B. Smallholder Schemes and Other Settlements					
Established 1971	39,858	6.3	249,972	34,956	11,249
Established 1971-74	49,100	7.3	357,204	50,009	16,074
Established 1975-80	166,271	6.3	1042,784	145,989	46,925
C. Wild Palm Groves	235,913	2.5	591,820	627,329	414,274
Total Production			2,915,108	951,644	518,864

* Includes Ministry farm
** Extraction rates for palm oil (14%) and kernel (4.5%)
Adapted from NAAC report

plantings will not contribute yield worthy of inclusion in the total yield figures. By 1985, a total of 951,644 tons of oil and 518,864 tons of kernel will be produced.

Although the production has dropped over the past few years as a result of the Nigerian civil war and the world market situations, there are major oil palm plantations in the following states, Anambora, Bendel, Cross River, River, etc. (Table 1.1.2) The Western, Bendel, and Lagos States account for 30%; the remaining 5% is being produced in the Northern States by Kwara, North-Western and Benue-Plateau States.

About 90% of the total production of palm produce was from semi-wild groves of which there was an estimated area of 6 million hectares. These wild groves were either in smallholdings or free. The remaining proportion was obtained mainly from estates and from settlements. The country has improved in her "Tenera" hybrid palm which can produce at least six tons of bunches per hectare as against three tonnes per hectare of wild groves. The improved Tenera hybrid palms were adopted in the 1950's by the former West African Institute for Oil Palm Research (WAIFOR) now NIFOR. The Institute has also advanced in agronomic practices for producing palm seedlings and established fertilizer response coefficients under field conditions. Processing of palm oil is accomplished through mechanized mills and traditional processes. Marketing of produce for

Table 1.1.2 Areas Under Major Oil Palm Plantations, 1982

State	Area Under Major Oil Palm Plantation (ha.)
Anambora	2,572
Bendel	13,786
Cross River	15,888
Rivers	8,814
Imo	5,811
Lagos	108
Ogun	1,667
Ondo	11,593
Oyo	60
	60,299 ha.

Source: NIFOR, Progress Report on the 1982 Annual Research Programme -- Oil Palm Programme export is carried out by the State marketing Board through licensed buying agents. Local markets for palm produce are concentrated in the hands of middlemen and palm produce dealers.

Most of the programs are carried out on a State level. The State programs involve expansions in output through an increase in area. The increase in area takes the form of rehabilitation of wild palm groves as output per hectare of an estate or rehabilitated grove is assumed to be higher than that of wild grove. It was estimated that by 1985, the field of all palm areas will be improved by approximately 13%, equivalent to an area estimated at 337,000 ha. out of which the Smallholders Development Scheme will account for 70 percent.

The States mainly affected are Imo and Anambra States, Cross River State, Rivers, Oyo, Ondo States, and Bendel State. However, Kwara and Niger States proposed to develop Smallholder Development Schemes of 166 and 42 hectares, respectively.

The consortium for the study of Nigeria's Rural Development (CSNRD) suggested: (i) priority to be given to Smallholders in the expansion of oil palm production, (ii) development of State governments oil palm campaign for 1970-75 period through subsidy and loan components; and (iii) loan program for 1975-80 for the financing of oil palm expansion after eliminating marketing Board and exporting taxes on oil palm.

1.1.2 Smallholders Scheme

This is one of the programs geared towards increasing oil palm production. In all the oil palm producing states, the program is emphasized.

1.1.3 Smallholder's Unit - Ahoada

A good example of the Smallholders' Scheme is located in Ahoada, Rivers State of Nigeria. Similar schemes are scattered all over oil palm producing areas. For a farmer to be eligible to participate in Ahoada Scheme, the farmer must own a minimum of one hectare. The State government makes a cash advance of ₦300.00 ($441.00) in four installments. The first year, ₦180.00, the second year, ₦50.00, third year, ₦40.00 and fourth year, ₦30.00. This loan is repaid with a 9.5% interest and has a 7 year grace period.

The government further supports the farmers with free fertilizer, seedlings, transportation of seedlings and fertilizer and protection of the plantings. When the palm fruit mature and are harvested, the fresh fruit bunches (ffb) are bought by the government for processing into palm oil. The current (1984) rate is ₦75.00/ton ($110.215) of ffb.

1.1.4 Smallholders' Problems

The main problems of the Smallholders in Rivers State are very much common to other Smallholders in the other

States. These are:

i. Poor funding - whereby the loans are not paid at regular or stipulated periods.

ii. The farmers feel cheated - the government clerks use faulty scales in weighing their palm produce.

iii. The payment for the supply of fresh fruit bunches is unduly delayed.

iv. Lack of good access roads to the plantations and also inadequate transportation system to move the palm produce to the mill for processing.

v. Lack of incentives for the growers.

vi. Shortage of labor, especially harvesters, when the tree is tall.

All of these problems, coupled with poor field supervision, are responsible for the low productivity and poor quality oil. (Table 1.1.4, 1.1.5)

1.2 Objectives of the Study

The general objective is to obtain information on the changes in ffa content with fruit bunch ripeness and color and then translate this information into practical use to improve oil quality. The specific objectives were:

(i) To investigate the possibility of establishing a ripeness criterion by color based on ffa content.

(ii) Evaluate field factors that affect oil quality

Table 1.1.4 Oil Palm Planting Targets and Achievements, 1975-1980 Smallholders' Oil Palm Development Projects

Smallholders Project	1975-80 Planting Target Hectares	Annual Planting Achievements (Hectares) 1975	1976	1977	1978	1979	1980	1975-80 Total Planting (Hectares)	1975-80 Planting Achievement as Percent of Target
SMU Owerri	16,000	--	415	853	1588	1899	2320	7,075	44.2
TCU Bennin	8,000	--	262	267	532	633	860	2,554	31.2
SMU Okitipupa	4,000	--	124	238	251	301	256	1,170	29.2
SMU Ahoada	3,400	--	--	--	183	744	1475	2,402	70.6
ODS Calabar	20,000	3410	1014	2432	3203	2548	1745	14,335	71.7
Total	51,400	3410	1818	3790	5757	6105	6656	27,536	53.5

Source: NIFOR, Progress Report on the 1982 Annual Report Research Programme

Table 1.1.5 Oil Palm Targets and Achievements, 1975-1980
Estate Oil Palm Development Projects

Projects	1975-80 Planting Target (Hectares)	1975	1976	1977	1978	1979	1980	1975-80 Total Planting (Hectares)	1975-80 Planting Achievement as Percent of Target
Risom Palm (Rivers State)	6,000	--	--	--	125	925	1900	2,950	49.2
OPC (Bendel State)	6,240	597	1505	1125	120	382	1089	4,818	77.2
O.O.P.C. (Ondo State)	6,000	320	85	400	257	502	--	1,564	26.1
Okumu Federal Oil Project	5,300	--	--	200	500	300	200	1,200	22.6
Ore-Irela Federal Oil Palm Project	5,300	--	--	346	754	517	837	2,454	46.3
Aiyip-Eku Federal Oil Palm Project	5,300	--	--	--	500	1000	600	2,100	39.6
Total	34,140	917	1590	2071	2256	3626	4626	15,080	44.2

Source: World Bank Nigeria Oil Sub-Sector Review, July 1981 with ffa content as a primary assessment factor.

(iii) Develop an oil palm harvest analysis model which can aid producers and processors to improve oil quality.

1.2.1 Present Method of Evaluating Fresh Fruit Bunch Supply by Farmers

In the past, there was no standard method of evaluating the quality of ffb supplied by the farmers or delivered at the Mill for processing. The general method common to all the major processing mills was evaluation by visual inspection. The payment for bunches was based on distance only, in which case it was assumed that all the bunches were in optimum condition, except the green and rotten bunches which were rejected.

The NIFOR Mill Company has the following rates for ffb:

From 0 to 50 km, a metric ton is ₦67.00

55 to 100 km, a metric ton is ₦70.00

greater than 100 km, a metric ton is 75.00

The farmgate price for locations within 50 km from the Mill is ₦50.00/ton.

1.2.2 Problems Associated with the Present Method

Some of the problems associated with the present method of assessing fresh fruit bunches were:

(i) It was based on distance only. The majority of the farmers have acute transportation problems. When the bunches were collected by the Mill Company, they were purchased at farmgate price.

(ii) The quality of the bunches was not given a serious consideration during the evaluation process, except the green and rotten bunches were discarded. No thought was given to the fact that the most efficient processing facility cannot guarantee high quality oil, if the quality of the fruit arriving at the factory was poor. Therefore, quality control begins in the field.

(iii) The use of visual inspection is not only unreliable but also deceptive. If a black or green immature fruit bunch is harvested and left on the ground, it will show symptoms of ripeness after a few days (Arokiasamy, M., 1969) but its oil content will be low. This phenomenon could be exploited by dishonest farmers.

(iv) The small farmers who constitute the bulk of the producers are exploited and incapacitated in the repayment of their loans because the present method tends to be arbitrary and subjective. The fate and future of the farmers, therefore, lie in the hands of the unscrupulous assessment officers.

(v) The present method breeds malpractice and corruption because there are no set procedures and standards for assessing the quality of the fresh fruit bunches. As a result of these malpractices, rotten and severely bruised bunches are passed as good and paid for. This results in poor quality oil.

CHAPTER 2

Literature Review

2.1 Field Factors Affecting Oil Palm Quality

Knowledge of the field factors which affect oil quality is inadequate (Gray and Bewan, 1969). The fact remains, that efforts to improve processing, storage and shipment of oil are to no avail if the quality of the fruit arriving at the mill is poor. Some of the factors which may influence oil quality are genetical, agronomic, environmental, palm age and are due to improper harvesting techniques.

2.1.1 Effects of Age and Environment

A general field observation has been that the age of the palm is of some significance because fruit ripening seems to be faster on young palms just coming into bearing. Age also affects ffa level through the height factor, with falling fruit being damaged to a greater extent in older, taller palms (Gray and Bevan, 1969). In addition, visual assessment of ripeness becomes more difficult as the palms grow taller.

There is little evidence that the chemical composition of palm oil may be influenced by environment. Geographical variations have been noted in the content of unsaturated acids (Eckey, 1954) and Jacobsberg, 1969). The soil characteristics affect the chemical composition of palm fruit and the oil palm quality (Arokiasamy, 1969). The observations made so far have been totally subjective (Richards, 1969).

2.1.2 Agronomic and Seasonal Effects

There are no published data concerning the effects of agronomic factors, such as the effect of fertilizer type and amount on oil quality. Since bunches with poor fruit set tend to be partly rotten at harvest time, assisted pollination may have a beneficial effect on oil quality (Gray and Bevan 1969).

The rate of ripening is known to be affected by seasonal variations (Broekmans, 1957), (Hartley, 1967) and differences have been noted in composition and plasticity where wet and dry seasons are sharply distinct (Loncin, and Jacobsberg, 1965). Sunshine may influence carotene levels, whilst rainfall may cause bruising where the exocarp has become soft with ripening (Bunting, et al., 1934) although this is probably not of considerable practical significance where climate is reasonably constant (Hartley and Nwanze, 1965). Low temperatures have also been implicated in high ffa levels (Wolvesperges, 1969).

2.1.3 Genetical Factors

Little is known of any variations in oil quality which might be related to particular types of planting materials. Differences both between and within progenies have been recorded in carotene content by Ames, Raymond, and Ward, (1960) and Arnott, (1966) and Purvis, (1957), although this appears to have little effect on bleaching. Bleaching is significantly impaired only when high temperatures have resulted in the formation of oxy-carotenes (Hiscocks and Raymond, 1964).

2.2 Harvesting Standards and Quality

No matter how good the processing or shipping, these are immaterial if the quality of the fruit arriving at the factory is poor. Hence, quality control begins while the fruit is still on the palm and is very closely connected with harvesting standards and practice (Gray and Bevan, 1969). This aspect of quality control cannot be over-emphasized, especially since oil quality and ffa content are affected (Hartley, 1967) and Gebr, Stork and Co. 1960). One week before ripening, the oil content may have reached 80% of the final amount (Arnott, 1966, Bunting, Georgi, and Milsum, 1934; Crombie, 1956). During periods of low oil content, palmitic and linoleic acids predominate, with oleic acid occurring only in very small quantities. During the final week of ripening all oils increase in amount, but that of oleic acid shows the greatest increase to become second to palmitic acid in quantity (Crombie, and Hardman, 1958). The final oil change occurs simultaneously with color change and the exocarp becomes softer on ripening (Arncott, 1966), (Bunting, et al., 1934).

The objective of harvesting is to combine maximum oil yield with an acceptable ffa level. At an estate where the annual crop is 50,000 tons of fresh fruit bunches (ffb), harvesting under-ripe fruit has been estimated to result in an oil loss of 900 tons (Speldewinde, H.V. 1968). Under-ripe fruit contains less ffa but also less oil; overripe fruit has a much higher ffa content and bleachability is also impaired (Jacobsberg, 1969). In addition to oil quantity, changes occur in the chemical composition of the oil during the final phase of ripening.

2.2.1 Determination of ripeness

There is little experimental evidence on which to base an exact criterion of ripeness (Bevan and Gray, 1969) and this one aspect of quality control which is urgently in need of full and accurate investigation. One of the major difficulties in this determination is the interval between the time when the first fruit ripens on a bunch and the last, which can be as long as 16-20 days (Bevan, Fleming, and Gray, 1966), Gebr, Stork and Co. (1960), Grut (1966).

The commonly used determining factor of bunch ripeness is the percentage of detached fruit from a bunch. This measure of ripeness is used by harvesters and also applied by supervisors in the control of harvesting, but the true test of its validity as a ripeness indicator is whether or not it relates to oil quality and quantity (Southworth 1976). Southworth further elaborated on the best definition of a detached fruit, as one that can easily be removed from the bunch by hand, this is not the same as a fallen fruit, though it is closely related.

Studies in the Congo showed that the maximum oil percentage occurred at 50% loose fruit, but the increased oil must be balanced against a reduction in price due to higher ffa content (Dufrane and Berger, 1957). Other criteria have been suggested (Gerard, Renault, and Chaillard, 1968). With the close relationship between ffa level and loose fruit number under normal conditions of estate practice, it could well be preferable to collect and process loose fruit separately. Harvesting interval is of obvious importance in quality control since the larger the interval the greater will be the number of loose fruit and hence a higher ffa level. An interval of 7 days and certainly not exceeding 10 days would seem desirable (Turner and Gilbanks, 1974).

2.2.2 The Effect of Degree of Ripeness on Quality and Quantity

The number of detached fruit and the ffa content of oil have been correlated. Dufrane and Berger (1957) showed a linear relation between ffa and percentage detached fruit. Ng. and Southworth (1973) confirmed a linear relationship with a slope of 0.1262. Thus, for every 1% change in percentage detached fruit, ffa increases by .13%. There have been many studies of changes in oil content with time. For example, studies by Rajaratnam and Williams (1970) and Thomas Phang Sew, Chan, Easua and Ng. (1971). Figure 2.1 shows a typical curve of oil content against time after anthesis.

According to study, by Rajaratnam and others, oil content as measured by percent oil/dry mesocarp starts to accumulate rapidly 110 days after anthesis. At 150 days after anthesis (which corresponds to the first fruit becoming detached) oil content levels off to some extent although it still continues to increase until all the fruit are detached.

The important period of time with respect to harvesting is the time from the first fruit detachment onwards. Unfortunately, evidence in the literature on oil accumulation during this period conflicts. Dufrane and Berger (1957) showed that percent oil/mesocarp increases linearly until at least 50% of the total fruit are detached. They used oil fresh mesocarp as a measure of oil accumulation, but with a different sampling procedure as that of Desassis (1957). They analyzed 400 Tenera bunches, at different stages of ripeness, at Bokonje in the Congo.

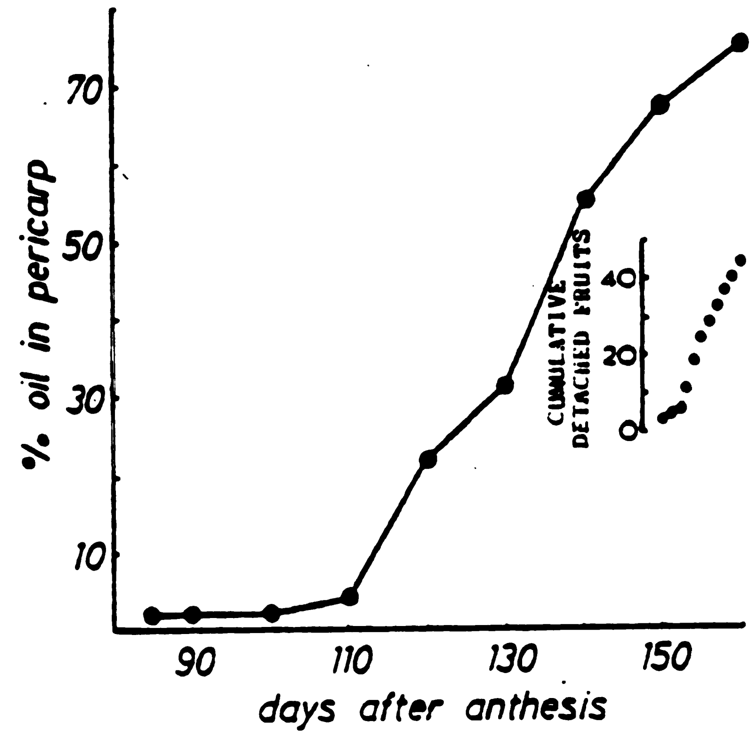


FIGURE 2.1 OIL SYNTHESIS IN FRUITS OF TENERA PALMS IN MALAYSIA.
(AFTER RAJARATNAM & WILLIAMS 1970)

After normal harvesting each bunch and its loose fruit were analyzed separately.

Ng. and Southworth (1973), however, demonstrated a curvilinear increase in percent oil/mesocarp; the rate of increase slowing down after 20% of the fruit has become detached from the bunch. Maximum percent oil/mesocarp occurs at about 30% detached fruit to total fruit.

Wuidhart (1973) showed that percent oil/mesocarp and percent oil/dry mesocarp increase up to 6% detached fruit/ffb. This corresponds to approximately 9-11% detached fruit to total fruit. The reasons for the apparently contradicting evidence in past studies are either in the methods of sampling or in the method of expressing oil yield or both.

2.2.3 The Effect of Collection and or Transportation on Quality

Rapid movement of fruit to the loading points as early as possible is very important for efficient factory operation as well as for quality control. It is well recognized that collection and transportation of fruit must take place as quickly as possible (Bevan, Fleming, and Gray, 1966), (Coursey, 1965), (Olie, 1969). Mechanized means of picking up loose fruit would greatly accelerate collection and if properly designed, could also reduce both damage and dirt contamination.

Roadside collection points also need to be arranged so as to stop dirt collection, and apparent increase in ffa content of fruit kept in the sun for a long time. (Bek-Nielsen, 1969) Considerable interest has been generated in Malaysia in the use of containers for fruit transport (Cunningham, 1969) which could reduce both dirt and damage. After the initial sharp rise in ffa levels following damage, later increase is comparatively slow but still significant. For this reason every effort should be made to process all fruit harvested on the same day.

2.3 Delay on Processing and Quality

There is not enough evidence to show that there is a relationship between speed of fruit transport to the Mill and processing (Gray and Bevan, 1969) although there are strong indications that rapid collection and transport are necessary for the production of high quality oils.

It is still doubtful if oil with very low ffa content can be obtained where fruit is processed on the same day as bunch cutting. A plantation trial in Malaysia, concerning the relationship between delay in processing and ffa level gave the following results:

Table 2.1 Rate of Acidification - Tenera

No. of days between harvesting and processing	ffa levels (percent) Batch 1	Batch 2	Batch 3
0	1.80	1.96	2.04
1	2.32	--	--
2	--	2.89	2.13
4	3.31	3.46	2.23

Source: Gray and Bevan (1969)

Rapid processing of fresh fruit bunches is necessary in order to eliminate the delay factor in quality deterioration and this requires close coordination between field and factory operations or growers and processor (Fleming, 1969 and McCulloch, and Anderson, 1969). In peak seasons it is preferable to leave fruit on the palms rather than harvest it and leave it lying around, since there will be a slower rise in ffa content in unharvested fruit (Bevan, Fleming, and Gray, 1966 and Hartley, 1967).

2.4 Fruit Damage and Quality

The amount of bruising or damage to fruit influences quality, especially in the amount of ffa and perhaps oxidation in the oil. Some damage is unavoidable, but much could be reduced, both during handling in the field and transport to the Mill (Wolvesperges, 1969). The palm fruit contain an enzyme, lipase, which causes the breakdown of oil into fatty acids and glycerol after the vacuolar membrane around the oil constituents in the cell has been broken, either through damage or decay (Gray and Bewan, 1969). The rate of enzymic conversion of fats into fatty acids is very high and it has been shown that the ffa content of fruit rises from below one percent to over six percent within 20 minutes of bruising (Bek-Nielsen, 1969), with slower but steady and significant rise with time after this. (Figure 2.2) This is of considerable practical significance. It is not practically possible to stop the enzymic reaction until this is brought about by high temperature during the sterilizing process. Therefore, it is apparent from these basic considerations that the most important requirements for obtaining oil of low ffa content from ripe fruit is to avoid bruising and damage as far as possible at all stages from the time of harvesting to the time of fruit sterilization.

Damage occurs at various stages during harvesting and mill handling and some of the sources of damage are listed below: (Gray and Bewan, 1969)

(i) The fall of loose fruit to the ground. The level of ffa in this connection will be related to the number of loose fruit used as the harvesting criterion.

(ii) The fall of fruit bunches after harvesting, with much depending on palm height.

(iii) The way fruit and bunches are handled prior to collection; fruit thrown into baskets and onto the ground.

(iv) Transfer of fruit from collection points. Rough handling (long-distance throwing into trucks with associated misses, etc.).

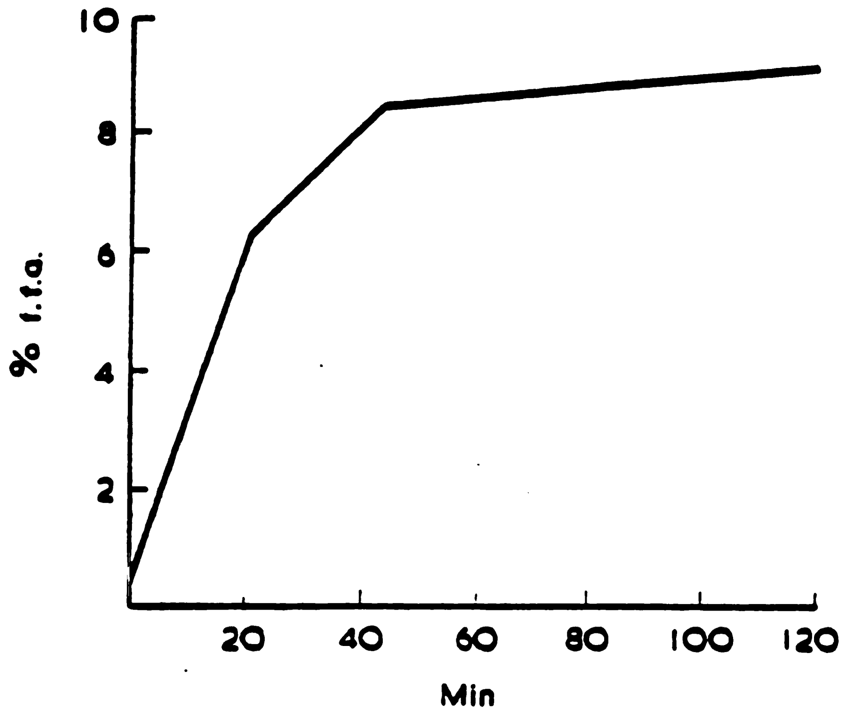


FIGURE 2.2 PRODUCTION OF FREE FATTY ACIDS IN THE MESOCARP OF OIL PALM FRUIT FOLLOWING BRUISING (Bek-Nielsen, 1969)

(v) Dirt ground into the fruit surface, damages tissues, influencing both dirt and ffa content.

(vi) Rough roads over which fruit is transported.

(vii) Tipping from transport onto ramps and into storage compartments or sterilizer cages.

(viii) Vehicles run over loose fruit on ramps, etc. and also labor tread onto piles of loose fruit. This would seem to be a particularly bad source of ffa increase.

Mechanized harvesting and interrow collection could well be of value in reducing damage.

2.5 The Color of the Palm Fruit

The varieties of oil palm distinguished by the color of the fruit have long been recognized by Chevalier (1910), and Vanderweyen (1952). The later listed the following types:

Nigrescens
Albo-Nigrescens
Virescens
Albo-Virescens

In Vanderweyen system, the term Poissoni is prefixed if a 'mantle' (a ring of supplementary carpets) is present, and the terms Dura, Tenera, or Pisifera may be added to designate the internal form of the fruit. At full maturity, Nigrescens has been described to have a reddish orange color of varying intensity. While Virescens is green before ripening, but at full maturity the color is light reddish orange (Figure 2.3).

Some studies (Purvis, 1957) at NIFOR have shown that both the Nigrescens and Virescens types can be divided into subtypes. In Ghana, West Africa, a clear distinction is made in the Nigrescens types, 'Abepa' typically red fruited and "Abetuntum" typically orange fruited but in Nigeria no such distinctions are made (Purvis, 1957).

2.6 Economic Evaluation of Tree Crops

The returns from tree crops are best evaluated by using discounting techniques (Upton, 1973). In discounting, tree crops are treated as a long term investment involving deferred returns. The delay between the input of capital and the receipt of its products complicates the estimation of return on capital. The trace of the pattern of capital values over the life of a project, an asset or an enterprise is known as 'Capital Profile' (Harrison, 1956). The total capital requirement is determined by the peak requirement.

In the use of the discounting technique, the determination of the discounting rate is very important because the profitability of any project or investment is highly dependent on the interest rate.

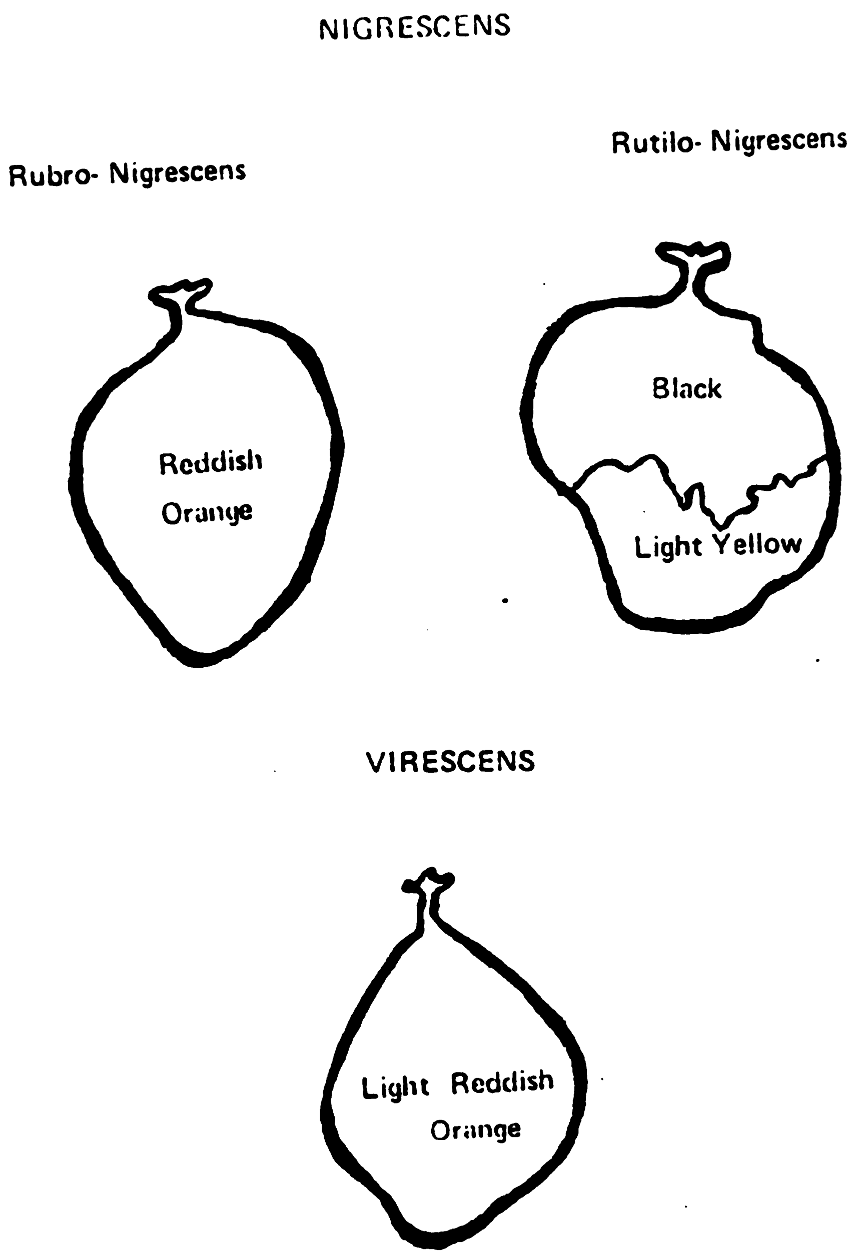


FIGURE 2.3 OIL PALM FRUIT COLOR

Chapter 3

Oil Palm Harvesting Operations

Harvesting operations can be classified under three broad headings:

(a) finding and cutting ripe bunches,

(b) collecting the bunches and loose fruit and carrying them to the collection point, and

(c) loading into vehicles for transport to the mill.

The methods by which fruit bunches are harvested and their organization have been subject of some study (Turner and Gillbanks, 1974). In Malaysia, there are some data available on the time required for each section of the harvesting process mentioned above. The time for each component varies, depending on such factors as age, yield, the harvesters' experience, etc. Such information is very relevant both for estimating potential work output per harvester and in determining where possible changes can be made to improve efficiency, economy, and quality control.

3.1 Present Harvesting Methods

A palm bunch is ready to be harvested when it has just a few loose fruit. It is essential that each palm be inspected at regular intervals for ripe bunches since over-ripe fruit produces low quality palm oil.

There are three methods of harvesting palm bunches recommended by the Nigerian Institute for Oil Palm Research (NIFOR). In each method, it is essential that only the fresh leaves which hinder removal of the bunch should be cut off.

3.1.1 Harvesting with Chisel

This method involves the use of a piece of flat iron 23 cm long, with one end rounded off and well sharpened (Figure 3.1). The other end is bolted to one end of a metal water pipe 23 cm long. Inside the hole at the other end of the water pipe is fixed a wooden handle up to 3/4 meters long after fixing. This implement, called a harvesting chisel, can be made by a village blacksmith. The harvesting chisel is used for harvesting bunches from young low palms. A good harvester needs only one strike and by careful manipulation of the implement can have the stalk cut and the bunch pushed out (Figure 3.2). To avoid inflicting injury on the stem of the palm, much care is required in the use of the harvesting chisel.

3.1.2 The Pole-Knife Method

This implement usually referred to as the harvesting

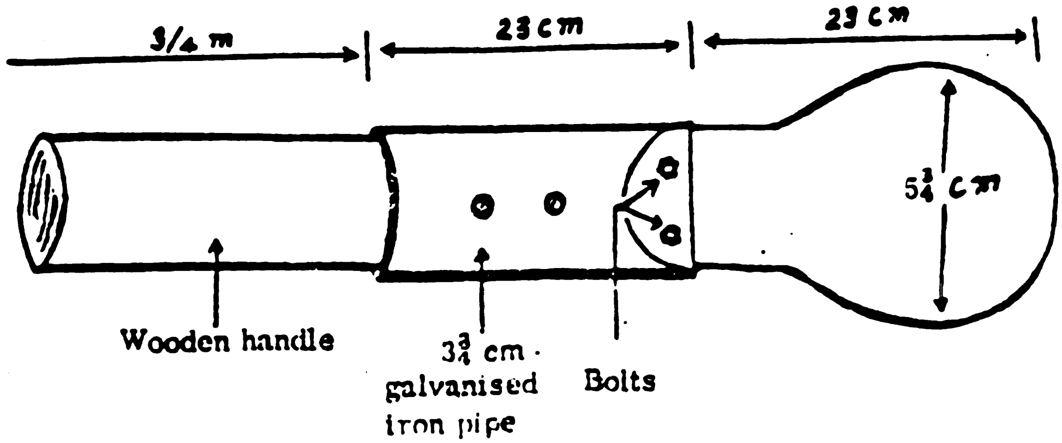


FIGURE 3.1 HARVESTING CHISEL

FIGURE 3.2 HARVESTING WITH THE CHISEL

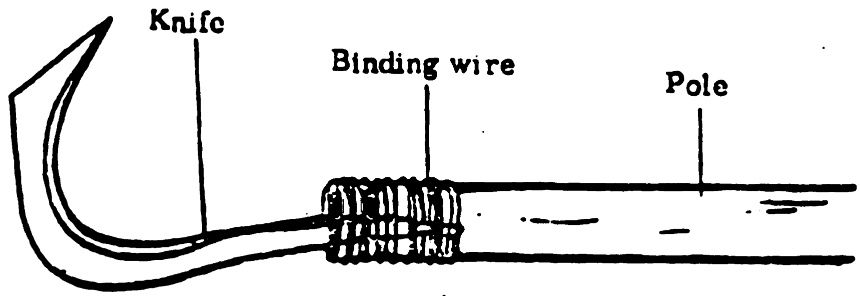


FIGURE 3.3 HARVESTING HOOK

hook or the Malaysian Knife, (Figure 3.3) is used in harvesting bunches from palms which have become too tall to be harvested with the chisel. The Malaysian Knife, is sickle-shaped, and is firmly tied on to a pole (Indian bamboo or any strong "bush" pole) with binding wire. The length of the pole depends on the height of the palms to be harvested. The knife is usually well sharpened, and a sheath is provided to cover the knife when the implement is carried along the road.

When harvesting with a harvesting hook, the harvester stands at a convenient spot to enable him get at the stalk of the bunch (Figure 3.4). If the bunch to be harvested is subtended by one or more leaves, which prevent access to the stalk, the leaves are cut off close to the trunk with the knife. The harvester with the use of the harvesting hook severes the bunch from the crown with a downward pull. A good harvester usually succeeds in getting the bunch down with one pull. Sometimes he may, after the cut, hook the top of the bunch and then pull downwards so that the bunch falls to the ground. A well trained operator using the pole-knife method can harvest palms of about 8 meters height.

3.1.3 Harvesting with Climbing Ropes (single and double)

The method of harvesting palm bunches by climbing the palm tree with a rope (single or double) is very popular in

FIGURE 3.4 HARVESTING WITH KNIFE ATTACHED TO THE POLE

Nigeria, especially in the Eastern States -- Rivers, Cross River and Imo State.

The rope system (see Figure 3.5) has the advantage of placing the harvester very close to the bunch but it is a very dangerous and slow method. It does not only expose the harvester to the hazards of being attacked by snakes and other harmful insects, but the harvester also runs the risk of falling from the top of the tree. The usual advice and practice is to cut excessively tall palms and replant the area.

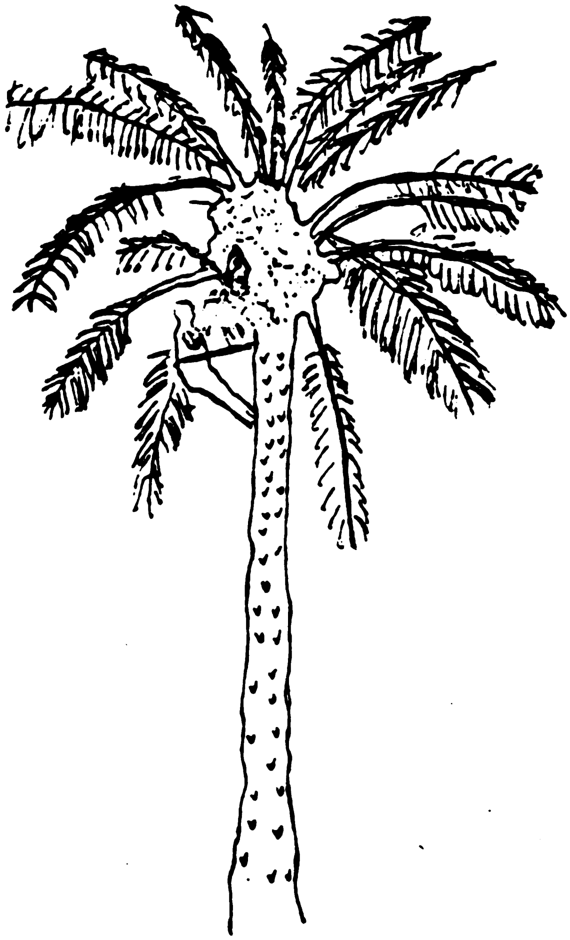


FIGURE 3.5 HARVESTING BY CLIMBING

Chapter 4

Methodology, Data Collection and Analysis

The basic factor that determines the quality of oil from an oil palm fruit bunch is the degree of ripeness at the time of harvest. For good quality oil, the fresh fruit bunches must be harvested in good time and with as little damage as possible to the fruit in order to keep the free fatty acid (ffa) to a minimum.

4.1 Methodology and Data Collection

A three month field investigation and data collection was undertaken in Nigeria to determine the influence of harvest operations on oil quality. Data and information regarding quality control measures were collected with reference to their relevance to the research objectives. There were three sources of data and information. (1) Direct field measurements during the harvesting operation. (2) Interviews with oil palm farmers participating in smallholders' scheme. (3) Documentation available at the research institute, eg. Nigeria Institute for oil palm research for supplemental data.

Random samples of fruits from bunches at different degrees of ripeness were obtained from the field and subjected to ffa analysis. Three locations within the oil palm belt region were selected (Figure 4.1). The data were more concentrated on Tenera, the popular variety, than on Dura and Pisifera. The fresh fruit bunch classification was based on the number of detached fruit. No special harvesting was organized for this purpose. Rather the usual harvesters were accompanied and numbers of detached fruit before and after cutting the bunches were recorded. The harvesters cut the bunches as 'ripe' according to the harvesting standards laid down by the management. The bunches were examined and classified based on the number of detached fruit. For the purpose of this study, detached fruit were the total of those that had dropped out of the bunch or could be detached by hand. The ripeness classification on which the study was based is as follows:

Code	% Detached Fruit	Degree of Ripeness
0	None	Very Unripe
1	One loose fruit to 10%	Unripe
2	10% to 20% of outer fruit	Under ripe
3	20% to 40% of outer fruit	Just ripe
4	40% to 60% of outer fruit	Ripe
5	60% to 80% of outer fruit	Over ripe
6	80% to 100% of outer fruit	Very over ripe

Very Unripe: No loose fruit before and after cutting the bunch. It is impossible to loosen any of the outer fruits by hand.

Unripe: One loose fruit to 10% of the outer fruits

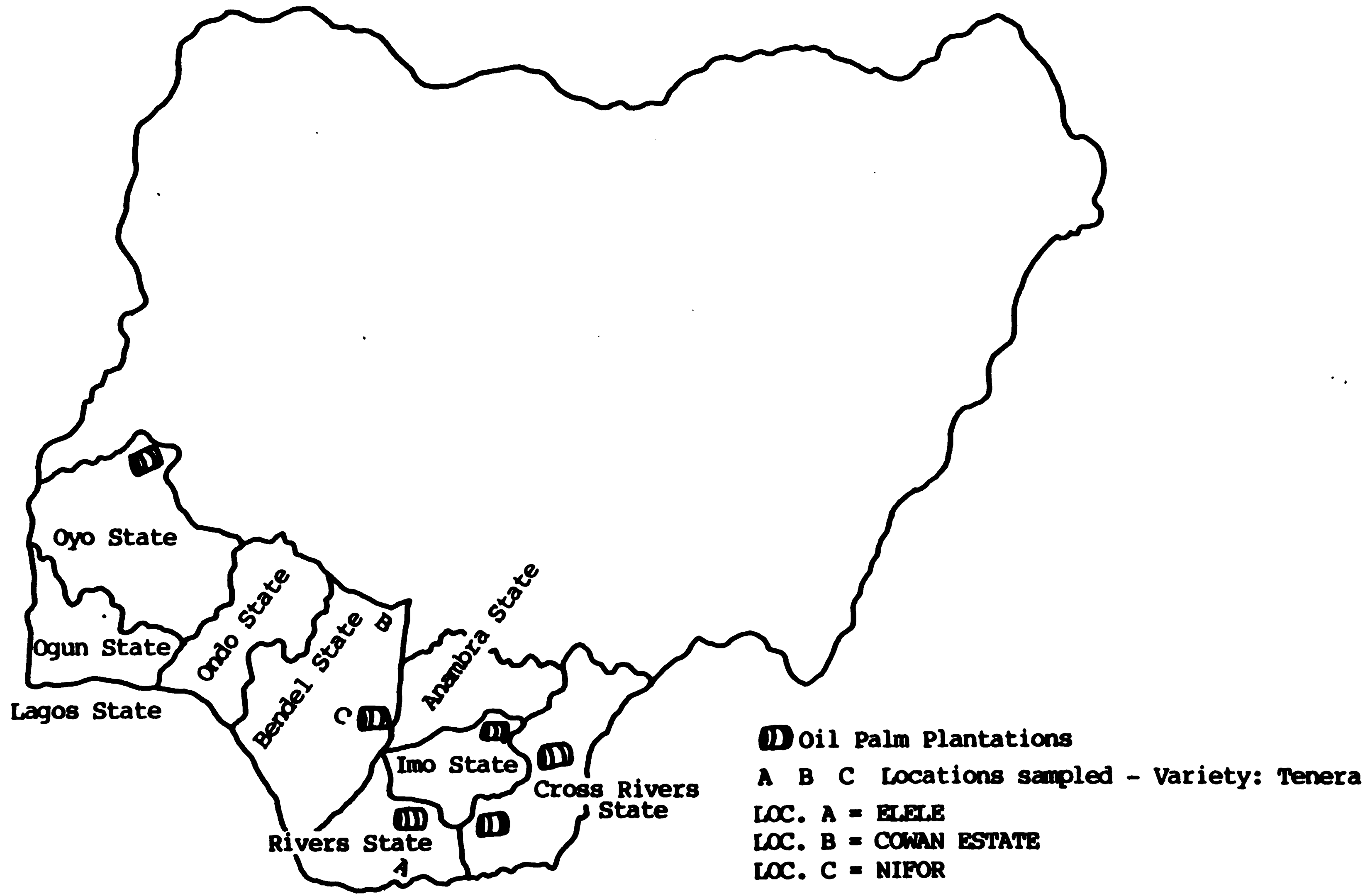


Figure 4.1 Map of Nigeria showing "oil palm belt" and the sampling locations A, B, and C.

detached or detachable by hand.

Under-ripe: 10% to 20% of the outer fruit detached or detachable by hand.

Just ripe: 20% to 40% of the outer fruit are detached or detachable by hand. A large proportion of the fruits could be detached by hand with little difficulty.

Ripe: 40% to 60% of the outer fruits are detached or detachable by hand. A large proportion of the fruits could be detached by hand with little or no difficulty.

Over-ripe: 60% to 80% of the outer fruit detached or detachable by hand. A large proportion of the fruit could be detached by hand with no difficulty.

Very over-ripe: 80% to 100% of the outer fruit detached or detached by hand. Some inner fruit are also detachable by hand at this stage.

One hundred and thirty-two tests were carried out in (NIFOR) Nigeria Institute for Oil Palm Research, using fruit harvested from mature Tenera palms on three estates. The mean values of (1) number of loose fruit, (2) percentage ripe color, (3) percentage free fatty acid and (4) percentage detached fruit for the seven classes of bunches from the three estates are presented in Appendix 3.

The data obtained were analyzed using the SPSS Statistical Package. The analyses of variance, linear regression and correlation analyses were carried out. A systems analysis approach was used as the analytical and problem evaluation technique. The resulting generalized data were used for verification of the computer simulation model. Details of the statistical analysis are discussed in the next section and the model development is presented in Chapter 5.

4.2 Statistical Analysis

The SPSS statistical package was used in the analaysis of the data. A forward (stepwise) inclusion multiple regression analysis was used. This is essentially a search method which computes a sequence of regression equations, at each step adding or deleting an independent variable until a reasonably good "best" set of independent variables are obtained. The criterion for adding or deleting an independent variable can be stated equivalently in terms of error sum of squares reduction, coefficient of partial correlation or F-statistic.

An investigation of the relationship between the dependent variable and other independent variables by means of graphs was made. The plots of mean free fatty acid with the corresponding means of number of loose fruit, percentage ripe color and percentage detached fruit for bunches of the same class were made. The plots for the three locations were found to be linear and highly correlated (Figures 4.2, 4.3, 4.4).

The percentage detached fruit explains 99% of the change in percent free fatty acid (ffa) content with degree of ripeness. Table 4.1 summarizes the regression analysis of the three varieties, with respect to free fatty acid and ripeness (percent weight of detached fruit at 95% confidence

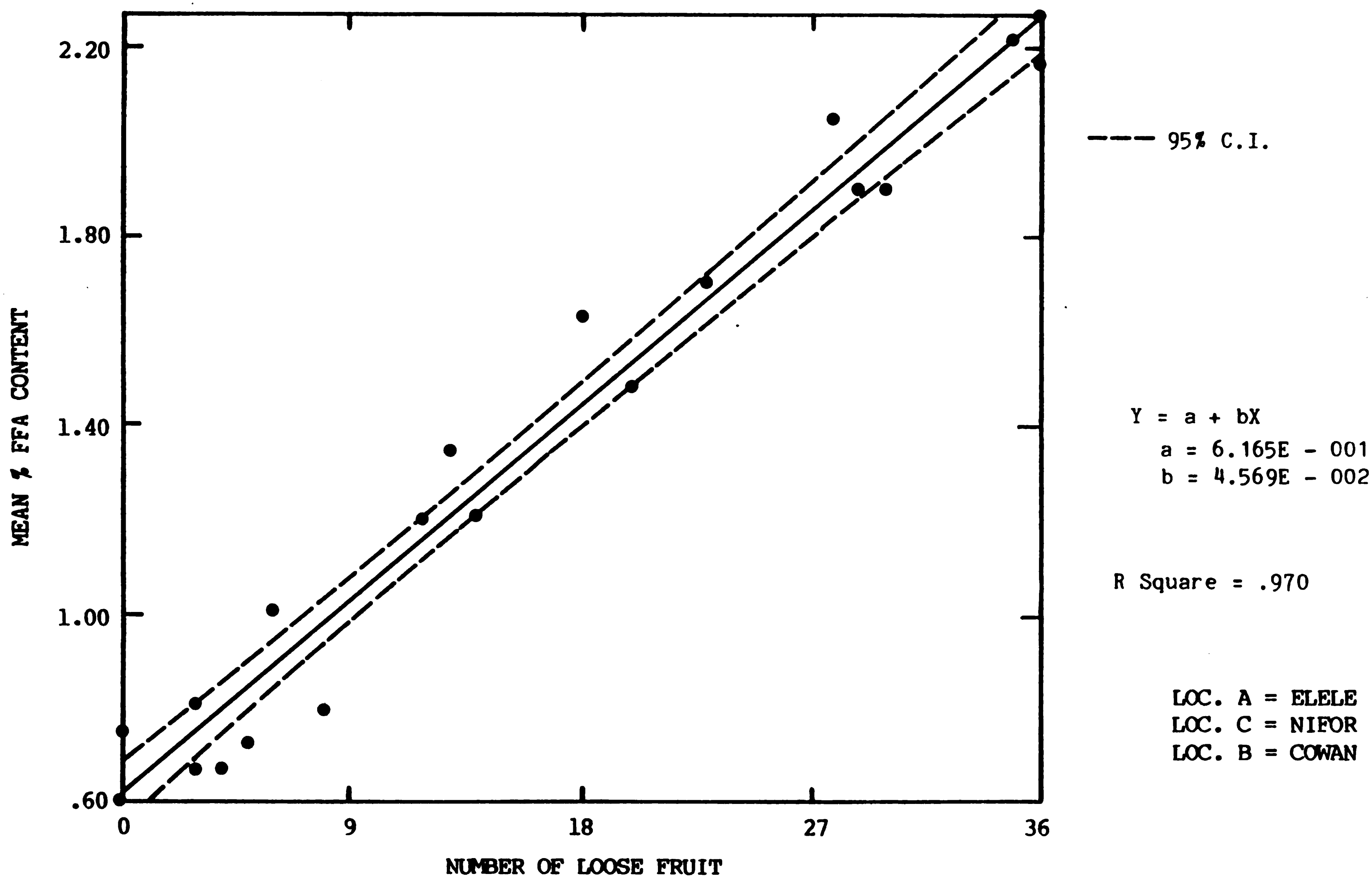


Figure 4.2 Tenera: % FFA vs. LOOSE FRUIT ABC

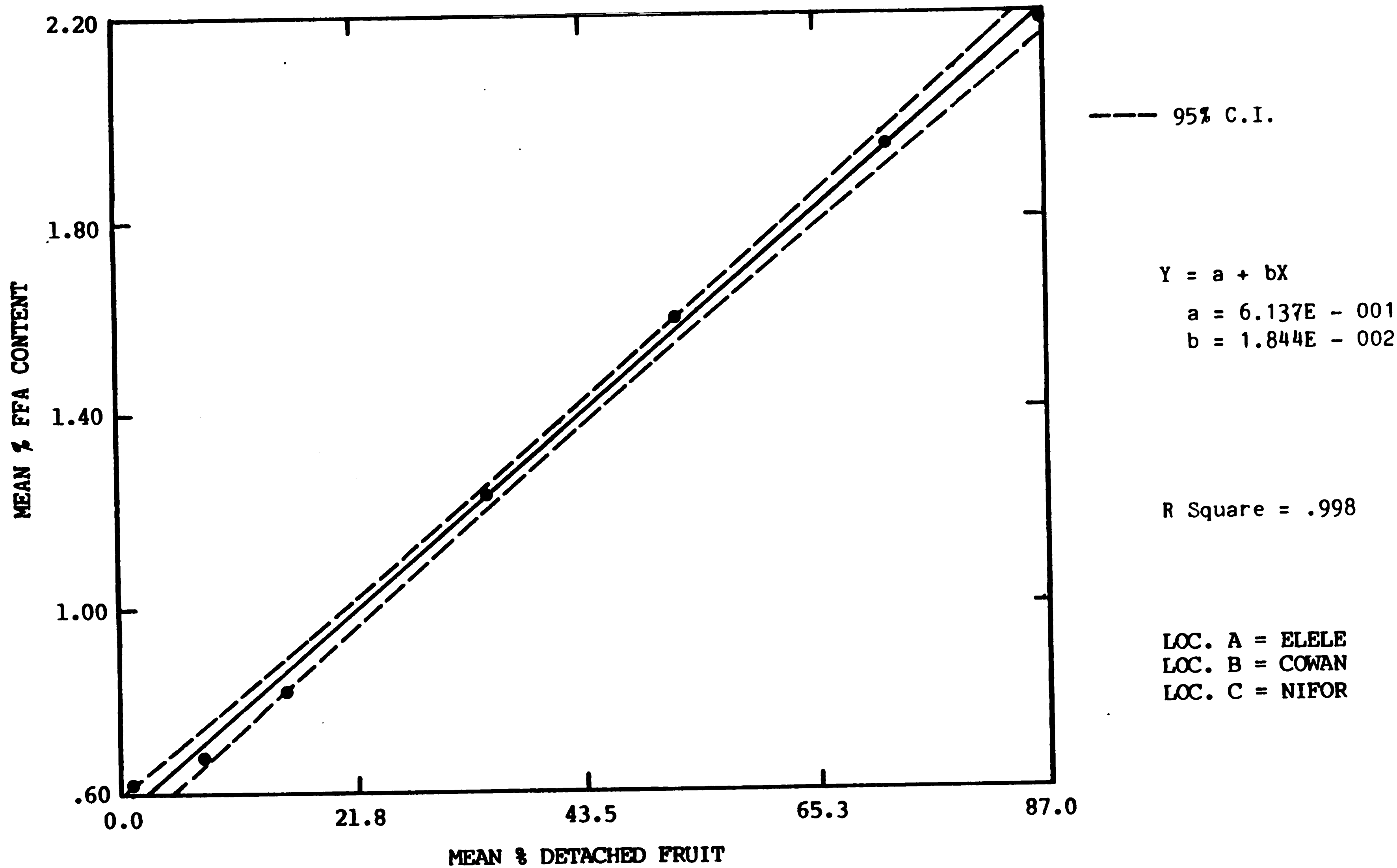


Figure 4.3 Tenera: % FFA vs. % Detached fruit - Location ABC

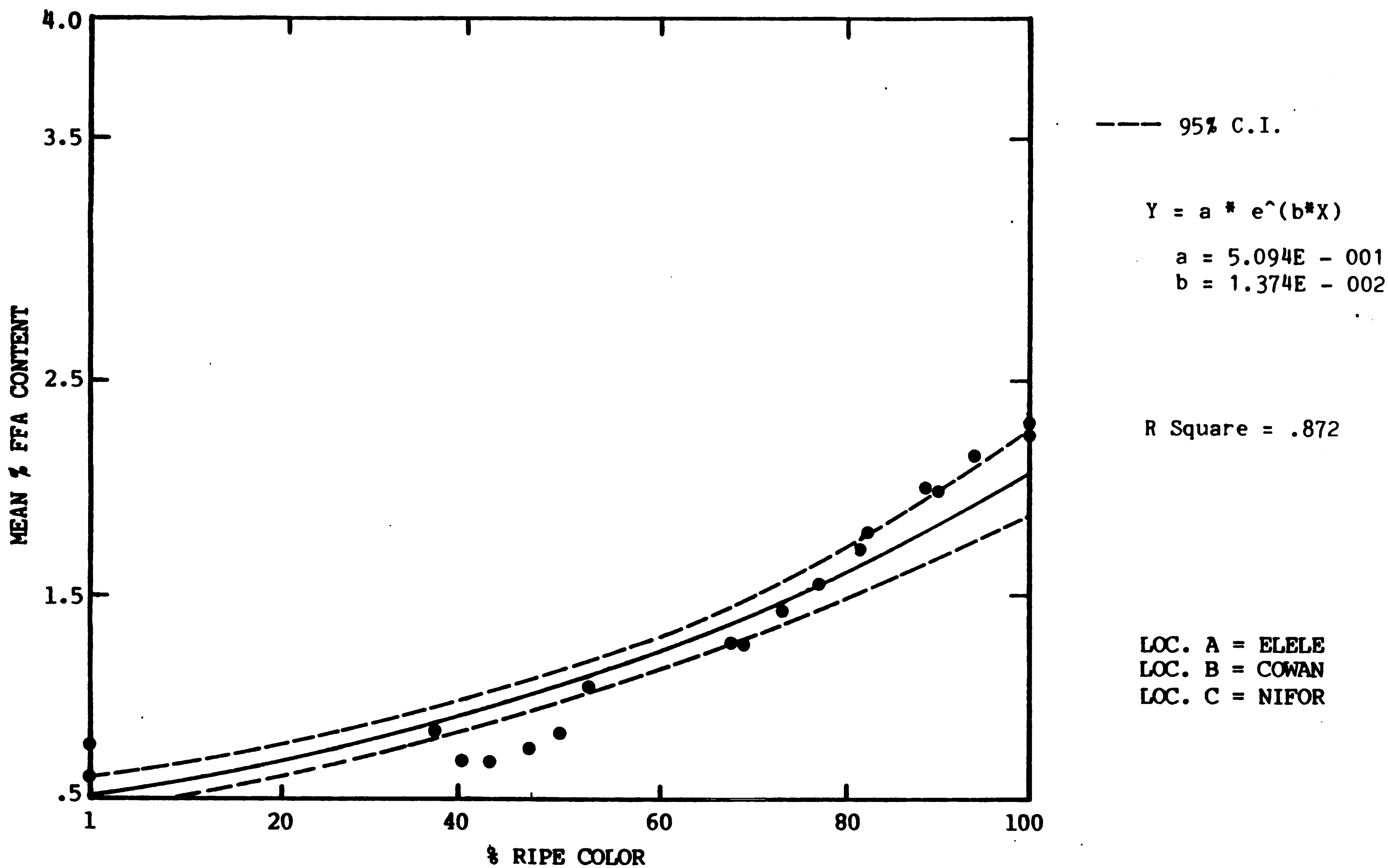


Figure 4.4 Tenera: % FFA vs. % Ripe colour - Location ABC

Table 4.1 Linear Regression Analysis: Free Fatty Acid and Ripeness (% wt. of detached fruit)

Variety	Regression Coefficient	Intercept	R^2	C.1
Tenera	.0184	.613	.998	95%
Dura	.0194	.601	.953	95%
Pisifera	.0173	.601	.997	95%

C.1 = Confidence Interval

Table 4.2 Variation of Bunch Characteristics with Ripeness (after Dufrane and Berger, 1957)

									Correlation with % detached fruit
Detached fruit %	2.2	7.1	11.7	18.6	21.5	34.9	35.1	45.8	--
Mean bunch wt. (kg)	4.8	5.4	4.7	4.5	4.8	4.2	4.0	3.7	-0.91**
Fruit/ bunch (%)	68.8	66.4	67.4	63.6	62.6	58.8	62.4	55.0	-0.95***
Oil/fresh mesocarp (%)	45.7	47.5	46.1	48.0	48.1	50.7	50.7	51.0	0.90***
Number of bunches analyzed	94	70	80	63	46	22	19	6	--

Table 4.3 Rate of Acidification for Tenera, Pisifera and Dura

No. of Days Between Harvesting and Processing	% FFA Tenera	Pisifera	Dura
0	.69	.67	.71
1	1.39	1.34	1.37
2	2.09	2.00	2.08
3	2.76	--	--
4	3.32	2.77	3.32

level.

In the analysis, one of the independent variables that has an insignificant effect on free fatty acid was the tree height. This is contrary to the bunch damage analysis by Clegg (1973). He related damage entirely to the height of the drop and reported that a drop of 20 feet resulted in an ffa rise of .26%. A possible explanation for the difference in the effect of height, might be due to the cushioning effect from the soil texture and probably the weeds around the tree. This explanation seems very obvious because if a bunch drops 20 feet on a bed of cotton wool it would have a different amount of damage and effect on ffa than if it dropped 10 feet on a hard surface, stones or ground.

In the analysis of the effect of delay in processing fresh fruit bunches (ffb) after harvesting, on an oil quality was found to be linearly correlated (Figures 4.5, 4.6, 4.7). This means that the longer the delay the more the deterioration of the oil quality because of the increase in the free fatty acid. The mean bunch weight is highly correlated with the age of the palm (Figures 4.8, 4.9, 4.10).

The results of the analysis of samples from the three different locations, - NIFOR, Cowan Estate, Elele Estate were not remarkably different. The slight difference might be due to the environmental factors, such as soil type and climate (Tables 4.4 and 4.5).

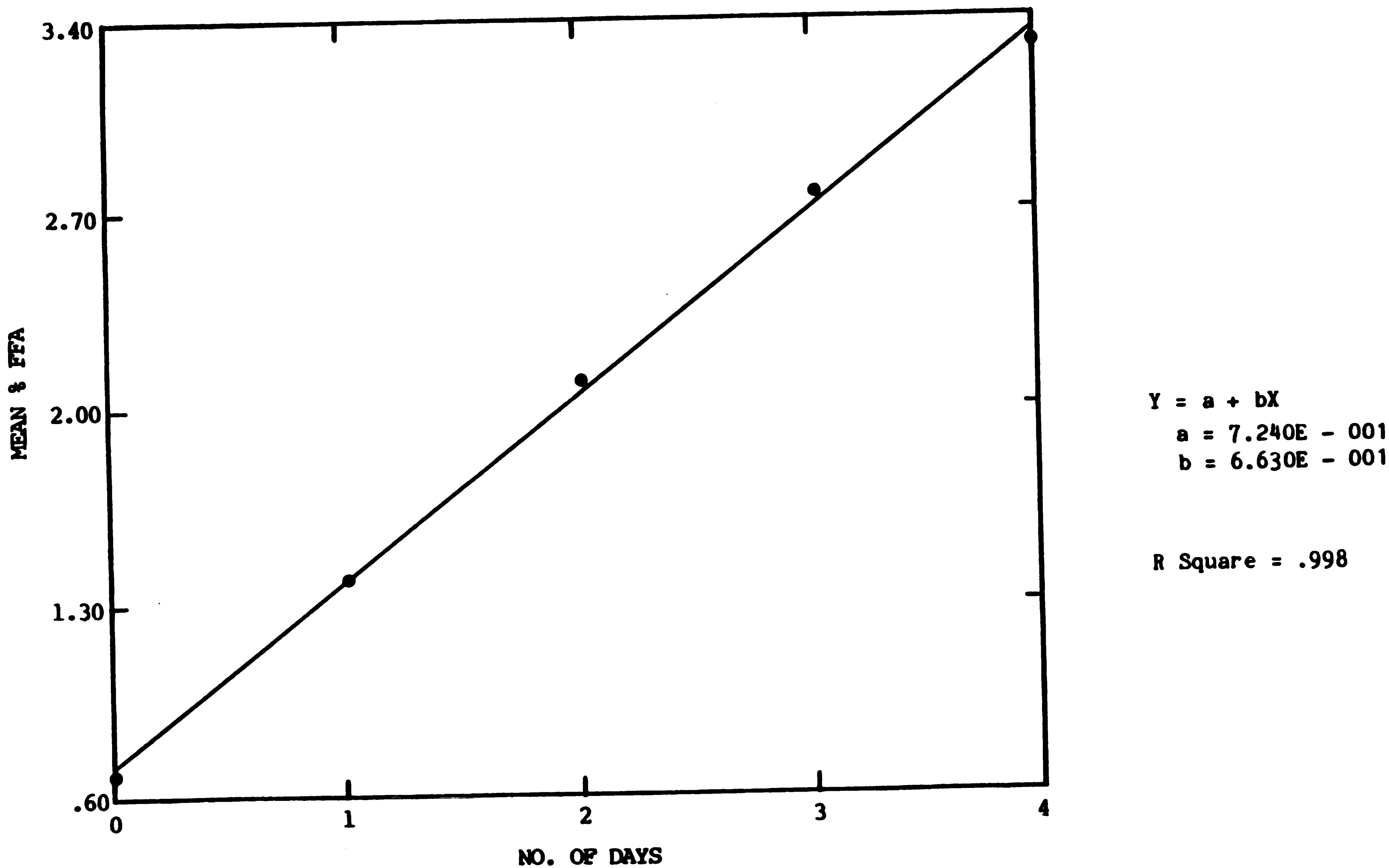


Figure 4.5 Rate of acidification - Tenera

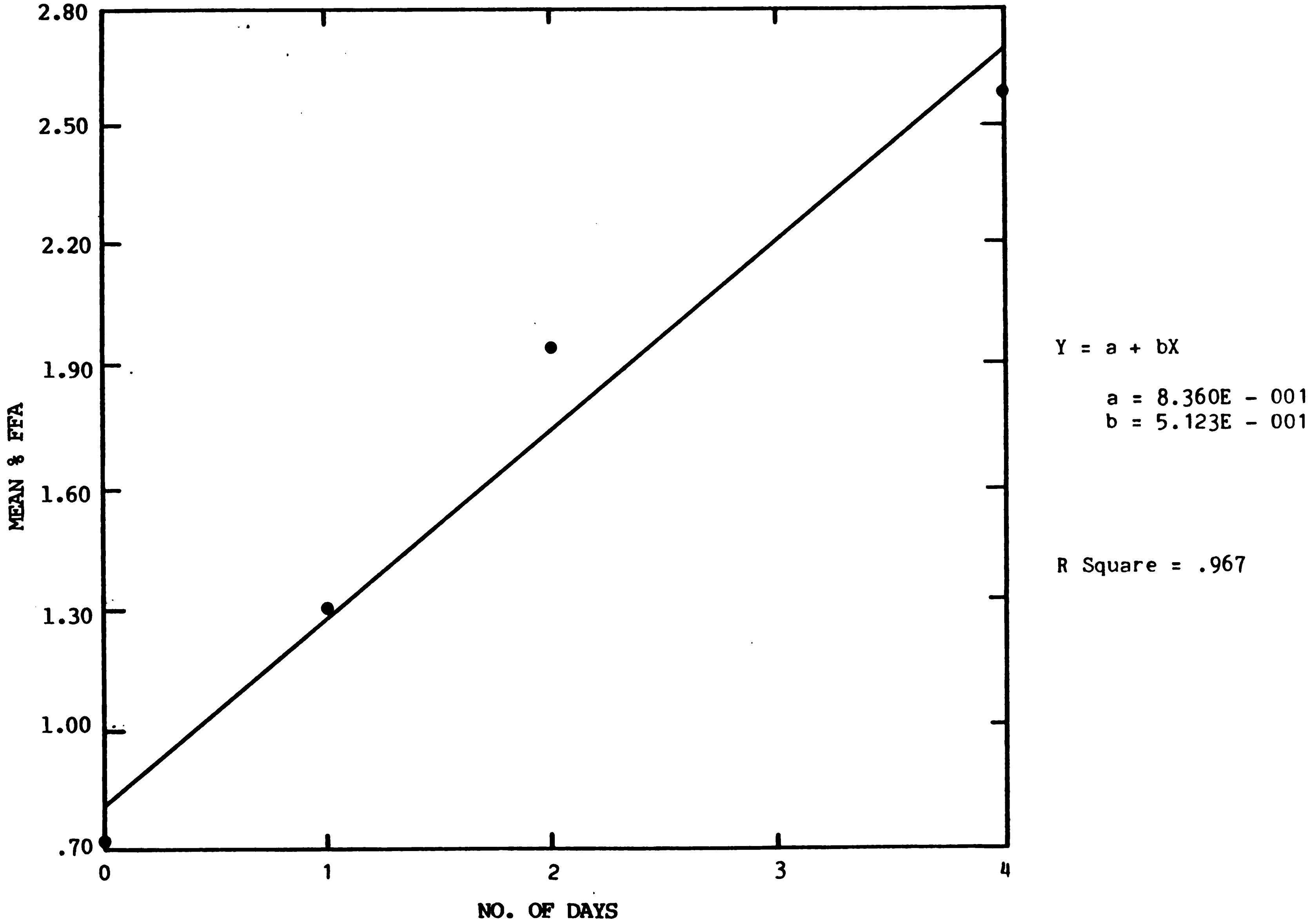
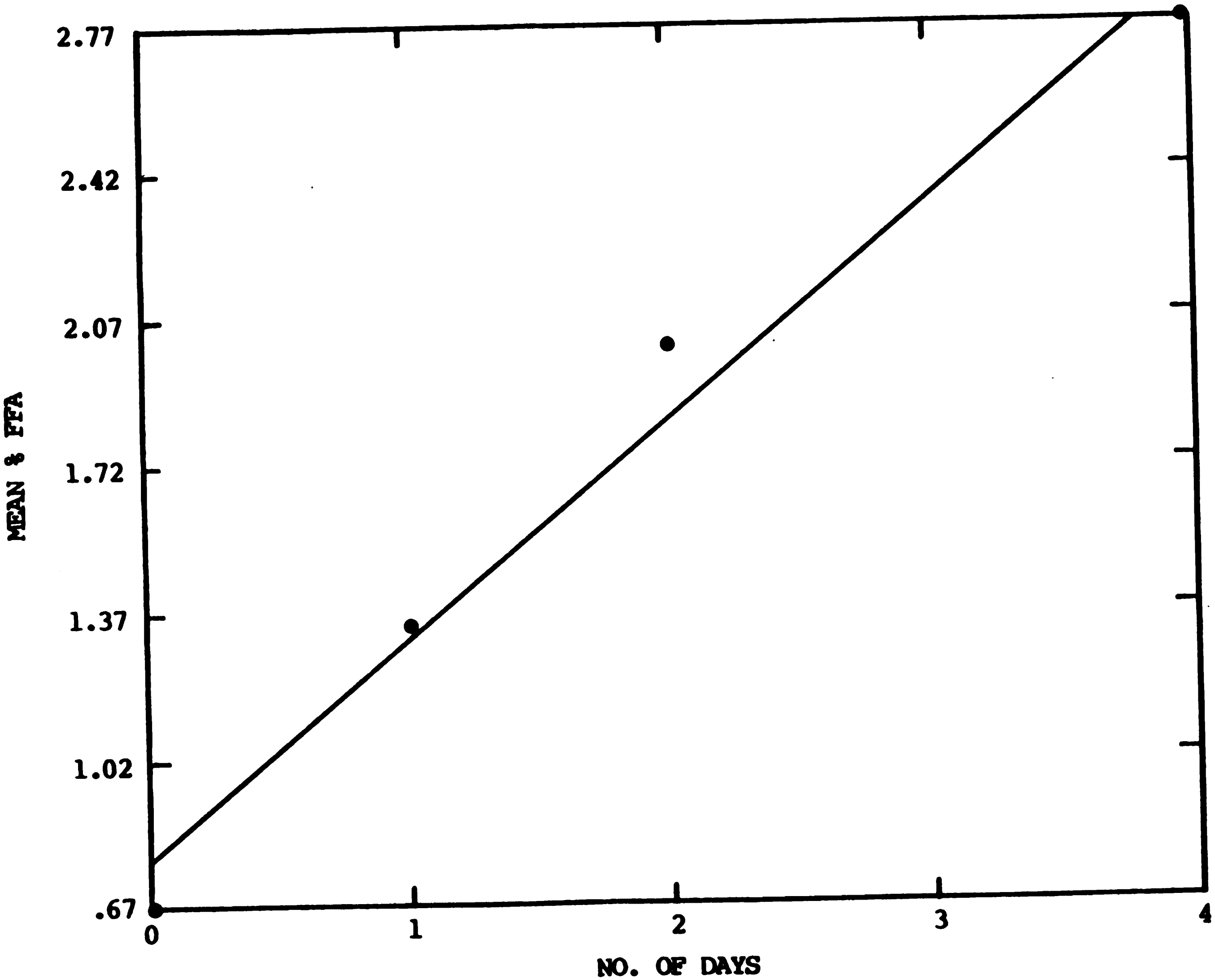


Figure 4.6 Rate of acidification - Dura



Y = a + bX
a = 7.840E - 001
b = 5.206E - 001

R Square = .978

Figure 4.7 Rate of acidification - Pisifera

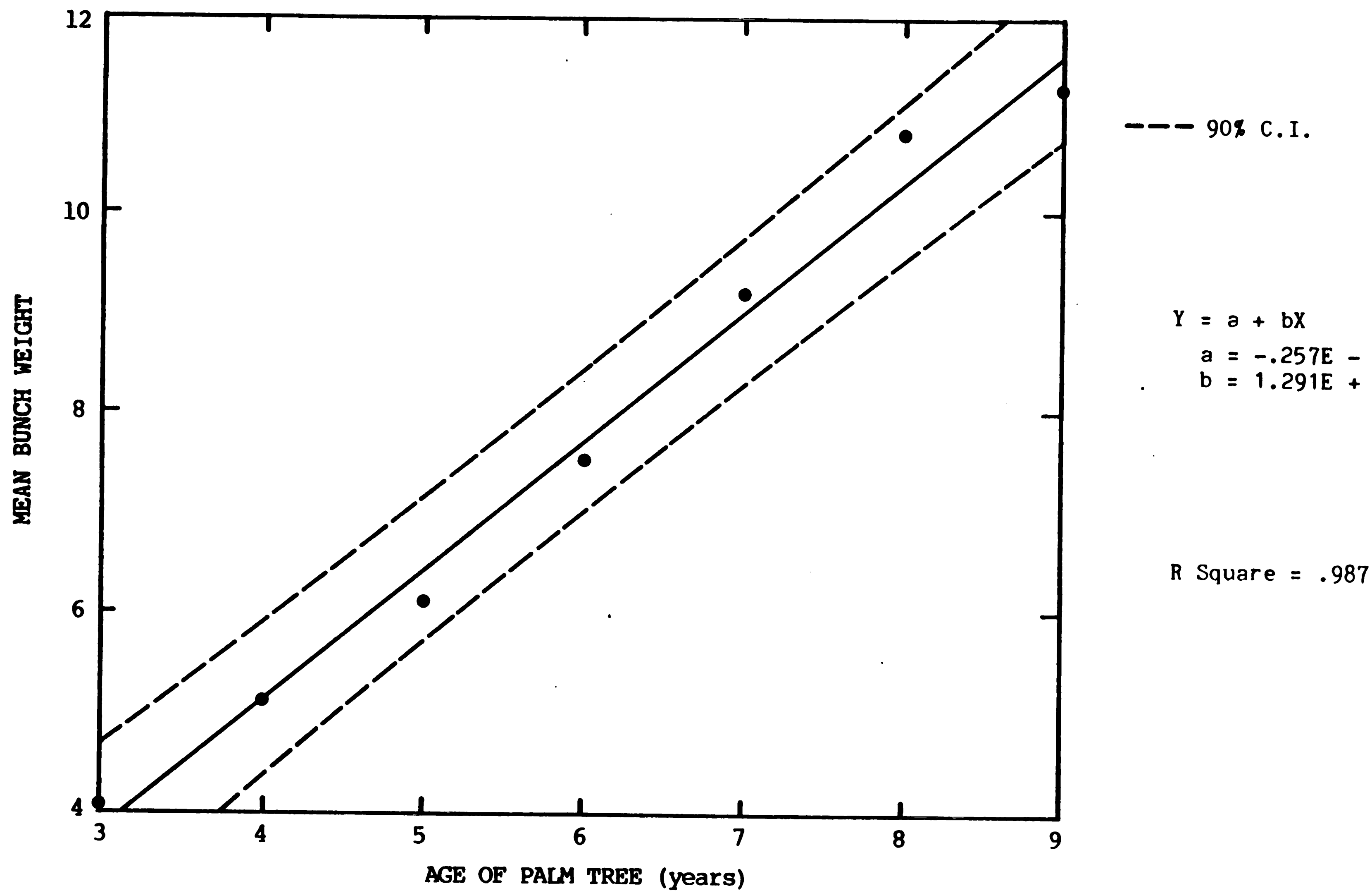


Figure 4.8 Tenera: Mean bunch weight and age.

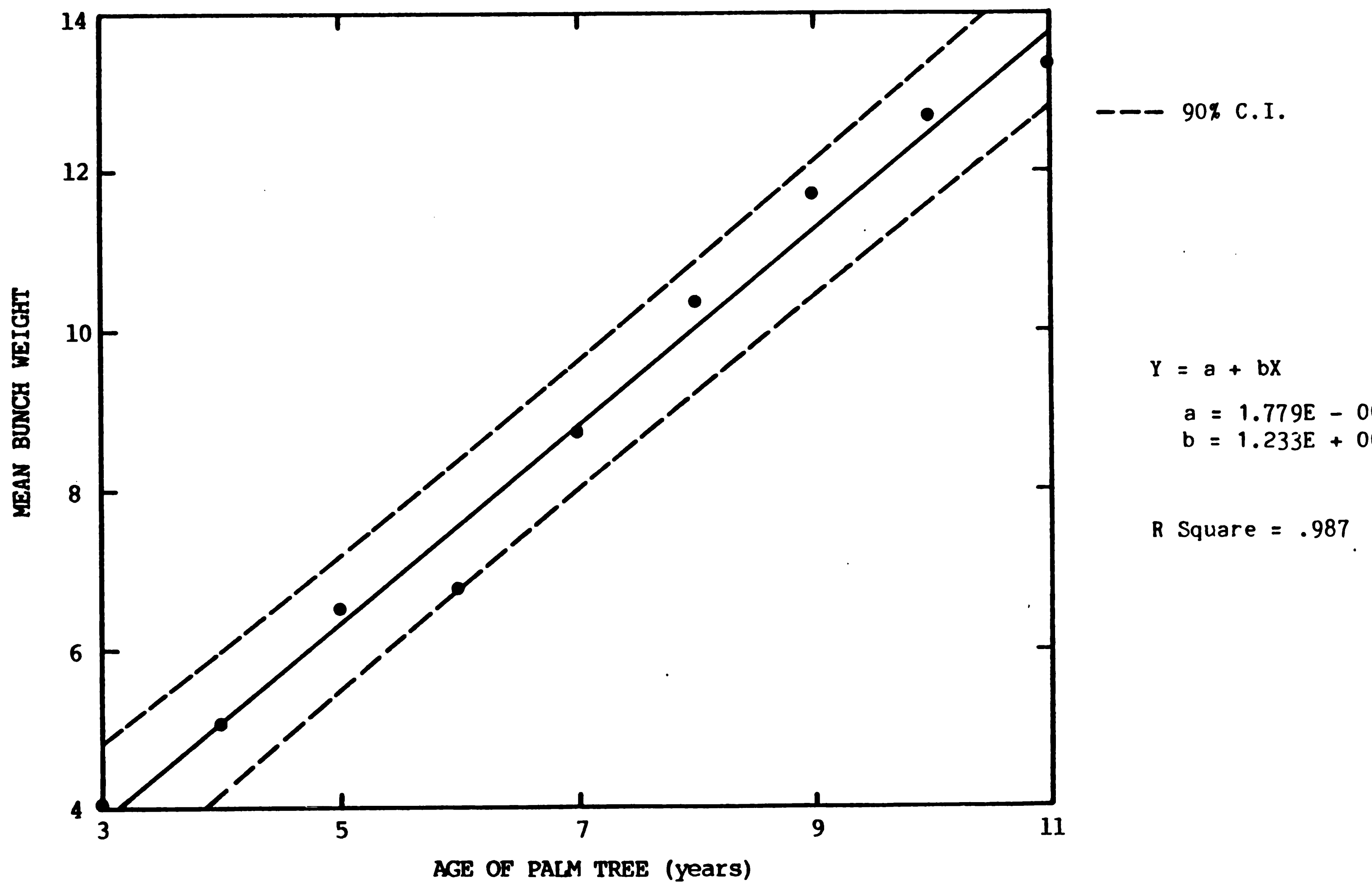


Figure 4.9 Dura: Mean bunch weight and age.

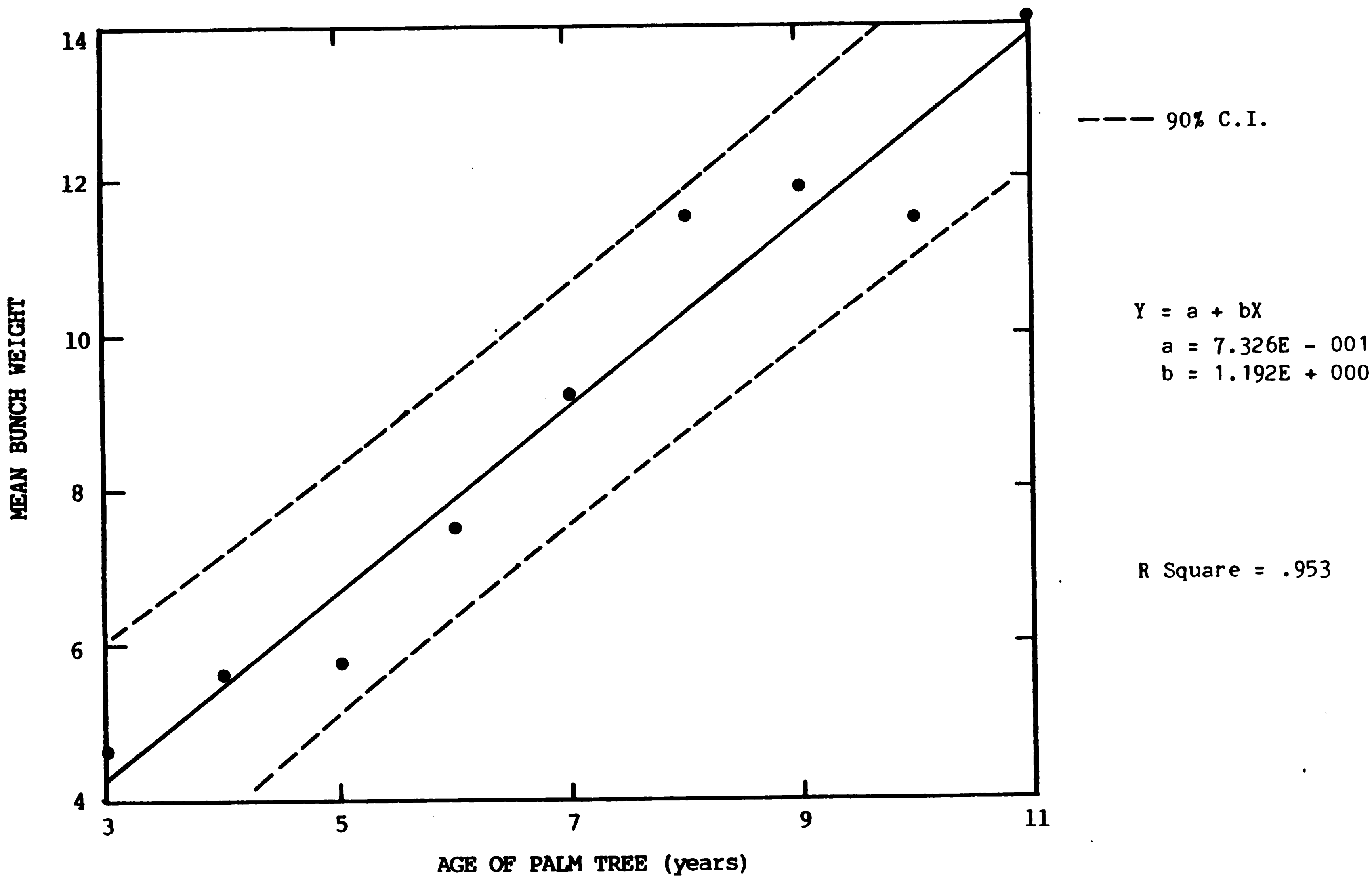


Figure 4.10 Pisifera: Mean bunch weight and age.

Table 4.4 Linear Regression Analysis of % FFA and % Detached Fruit in the Three Locations

	Location A	Location B	Location C
N	35	47	50
a	7.078×10^{-1}	5.732×10^{-1}	5.650×10^{-1}
b	.01660	.01891	.01990
S_b	.00043	.00038	.00033
S_y^2	$(.4985)^2$	$(.5586)^2$	$(.6037)^2$
r^2	.9864	.98839	.98688
$\bar{Y}$	1.3503	1.2087	1.2756
$\bar{Z}$	38.6857	33.7660	35.74
S^2	.0055185	.00554242	.004884529
S_z^2	$(29.6228)^2$	$(29.1914)^2$	$(30.0298)^2$

Loc. A = Elele, Loc. B = Cowan Estate, Loc. C = NIFOR (Nigerian Institute for Oil Palm Research)
a = intercept, b = slope, S_b = std. deviation, S^2 = variance, r^2= coefficient of determination, $\bar{Y}$ = mean of % ffa, $\bar{Z}$ = mean of % detached fruit, S_z^2 = variance of % detached fruit, S_y^2 = variance of % ffa, N = number of observations, NS = Not Significant

Table 4.5 Linear Regression Analysis of % FFA and % Ripe Color in the Three Locations

N	Location A 35	Location B 47	Location C 50
a	4.579×10^{-1}	2.501×10^{-1}	2.216×10^{-1}
b	.01439	.017310	.017620
S_b	.00144	.00144	.0141
S_y^2	$(.4985)^2$	$(.5586)^2$	$(.6037)^2$
r^2	.89649	.89519	.90181
$\bar{Y}$	1.3503	1.2087	1.2756
$\bar{X}$	63.1429	58.9362	62.06
S_x^2	$(30.0521)^2$	$(29.5469)^2$	$(30.5924)^2$
S^2	.06662001	.08298393	.09164438

Loc. A = Elele Loc. B = Cowan Estate, Loc. C = NIFOR (Nigeria Institute for Oil Palm Research)
a = intercept, b = slope, S_b = standard deviation, S^2 = variance, r^2 = coefficient of determination, $\bar{Y}$ = mean of % FFA, $\bar{X}$ = mean of % ripe color, S_x^2 = variance of % ripe color, S_y^2 = variance of % ffa, N = number of observations, location effects significant at .05 level.

For very high accuracy, free fatty acid content and percentage ripe color should be estimated on location. For the purpose of a rough estimate, a generalized model could be used to represent the locations within the "oil palm belt" because of the minor location effect.

An investigation into the loss of loose fruit, during the field trip in Nigeria revealed that many farmers failed to ensure that all loose fruit were collected after harvesting the bunch. This is a potential source of financial loss that should be controlled. At an oil price of ₦800 and kernel price of ₦400 per ton, the loss of one loose fruit for every bunch harvested represents an annual loss per acre of ₦2.15 or ₦5.38 per hectare. (Assuming 10 ton ffb per acre, bunch weight 40 lb, fruit weight 12g, oil/fruit 36.7 and kernel/fruit 7.5%.)

Analysis: For every bunch, 1 loose fruit lost

worth of one fruit: $(12 \times 0.367)_g$ of oil

$800/\text{ton}\ [(12g \times 0.367)\quad 10^6 g/\text{ton}] = 3.52 \times 10^{-3}$ ₦/fruit

12g x .075 of kernel

400 ₦$/\text{ton}\ [(12 \times .075)\quad 10^6\ g/\text{ton}] = 0.36 \times 10^{-3}$ ₦/fruit

Each fruit value is 3.88×10^{-3} ₦/fruit

An acre harvested:

$10\ \text{ton}\quad [(40 \times .45\ kg/lb)\quad (1000\ kg/\text{ton})] = 555.55$ bunch/acre

With a loss of one fruit/bunch, a loss of 555 fruit acre is sustained loss ₦/acre = 3.88 x 10 ₦/fruit x 555 fruit/acre

= 2.15 ₦/acre or ₦5.38/hectare

For Growers:

One fruit is worth: 75 ₦/ton (12g 10^6g/ton) = $.9 \times 10^{-3}$ ₦/fruit

for 550 fruit/acre

$.9 \times 10^{-3}$ ₦/fruit x 550 fruit/acre = .495 ₦/acre

approx. .50 ₦/acre or ₦1.25/ hectare

It takes an extra effort on the parts of the harvesters to pick up the loose fruit at the base of the palm tree and collection points.

An interview with harvesters revealed that picking up the loose fruit was not only tedious but also back-breaking. The harvesters also complained of poor wages and so strongly objected to any harvesting instruction that demanded extra effort and energy on them. This feeling of poor salary structure amongst the field staff (harvesters and carriers) was counter productive. If farmers are to cut down on the field losses, it is necessary that they consider an upward review of the field workers' wages.

The need for a complete collection of loose fruit was emphasized by Turner and Gillbanks (1974). The above analysis confirms this need and demonstrates the importance of ensuring that all loose fruit are collected.

Chapter 5

Model Development and Simulation of a Farmer Supply Processing System

The visual inspection is not sufficient to deal with the problems of quality control as practiced presently. A computer assisted systems analysis approach can provide an effective means for dealing with the problem. This chapter presents a computer aided system analysis approach for the analysis of the harvest composition and prediction of the quality and quantity of the oil in the "oil palm belt" of Nigeria. Traditionally, researchers have relied on conventional, large computers for such analyses, but they are not always readily available in many developing countries. For this reason, a micro computer with BASIC language was used for analysis and simulation of quality control technique in the present research.

5.1 Identification of System Components

This forms a link between the statement of needs and a specific statement of the problems that must be solved in order to satisfy those needs (Manetsch and Park, 1977). At this point, the oil palm quality control system was viewed as a "black box" (Figure 5.1).

Weather, prices, population, inflation, pests and diseases, and availability of labor were defined as exogenous components. The input parameters have an impact upon the desired system output; these parameters tend to be fixed and are as important as decision variables (Manetsch et al., 1974). In the present case, the establishment policy was classified as an input parameter; it consists of such elements as subsidization, discount, standard, and quantity premium. Production function levels such as fertilizers, pesticides, oil palm land, etc. were held constant during the simulation process. The controllable inputs were number of detached fruit, length of time delay before processing, area harvested, etc. The number and combinations of these controllable input levels were changed during the simulation of the system model to alter the performance and results.

The desirable system output for oil palm quality control consists of high quality palm oil with desired ffa level, high market and nutritional value. In addition, high premium and returns accrue to the farmer because of increased production of required standard of fresh fruit bunches. The undesirable systems output are, no premium for the farmer, high loss and poor quality fresh fruit bunches, and loss of interest in oil palm enterprise (see Figure 5.1). These undesirable factors are used to stimulate farmers to readjust their harvesting system and management, thus leading to a feedback mechanism.

The linkages and interactions between identified components in oil palm quality control are illustrated in the simplified model presented in Figure 5.2, and the field factors influencing oil palm quality control are shown in Figure 5.3.

5.1.1 System Constraints and Desirable Model Characteristics:

1. The model should be able to represent a wide range of regional conditions, in this case, the environmental and agronomic conditions prevalent in the "oil palm belt."

2. The model assumes that the probabilistic nature of the weather factors that have deleterious effects on the rate of fruit detachment can be minimized by good supervision and discipline.

3. The model should be able to handle any practical mix of harvest composition and attend to as many farmers as possible per day, with maximum of five hundred bunches each.

4. The model should be of practical application to growers and/or processors in Nigeria.

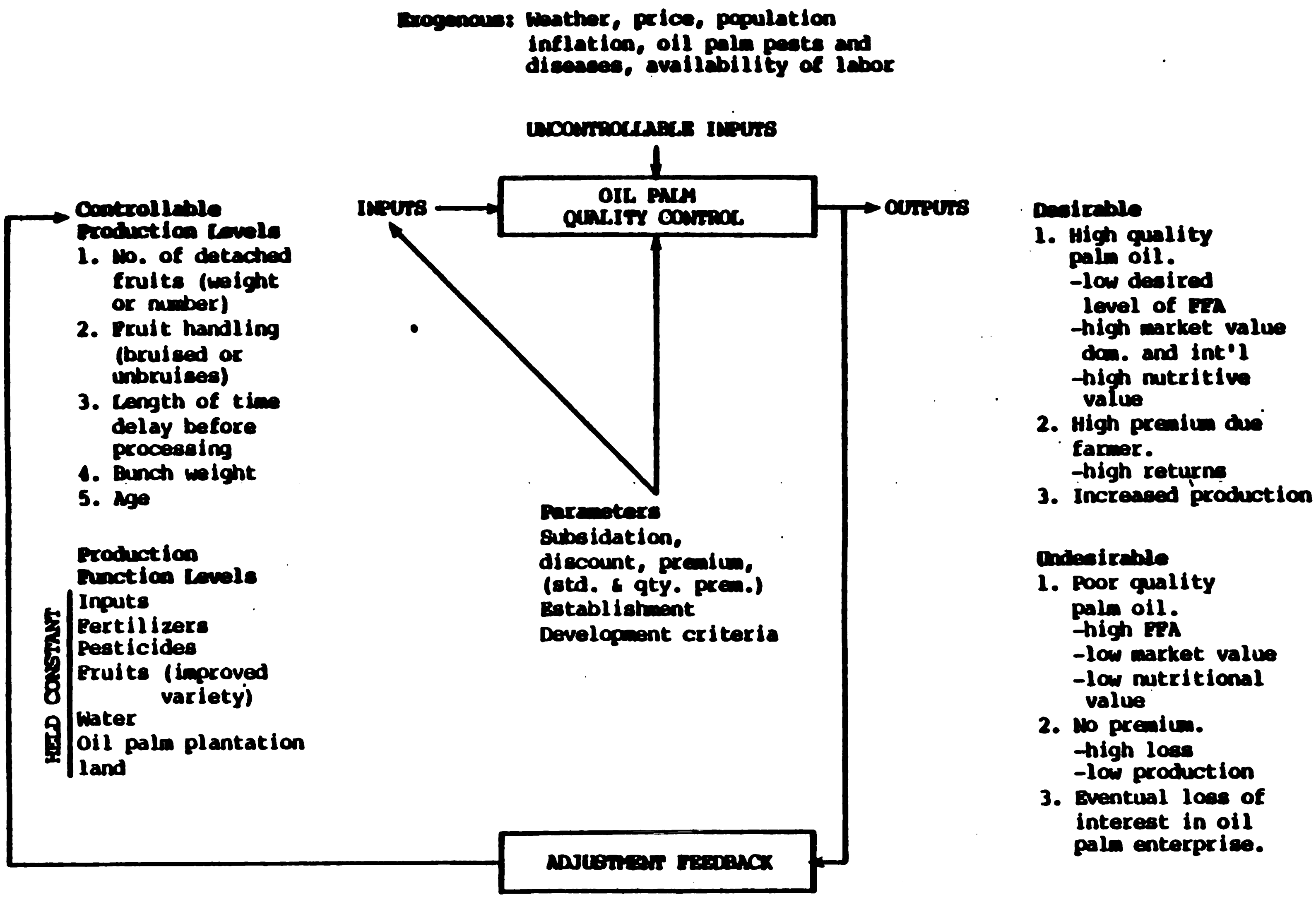


Figure 5.1 Blackbox diagram for a generalized oil palm quality control model.

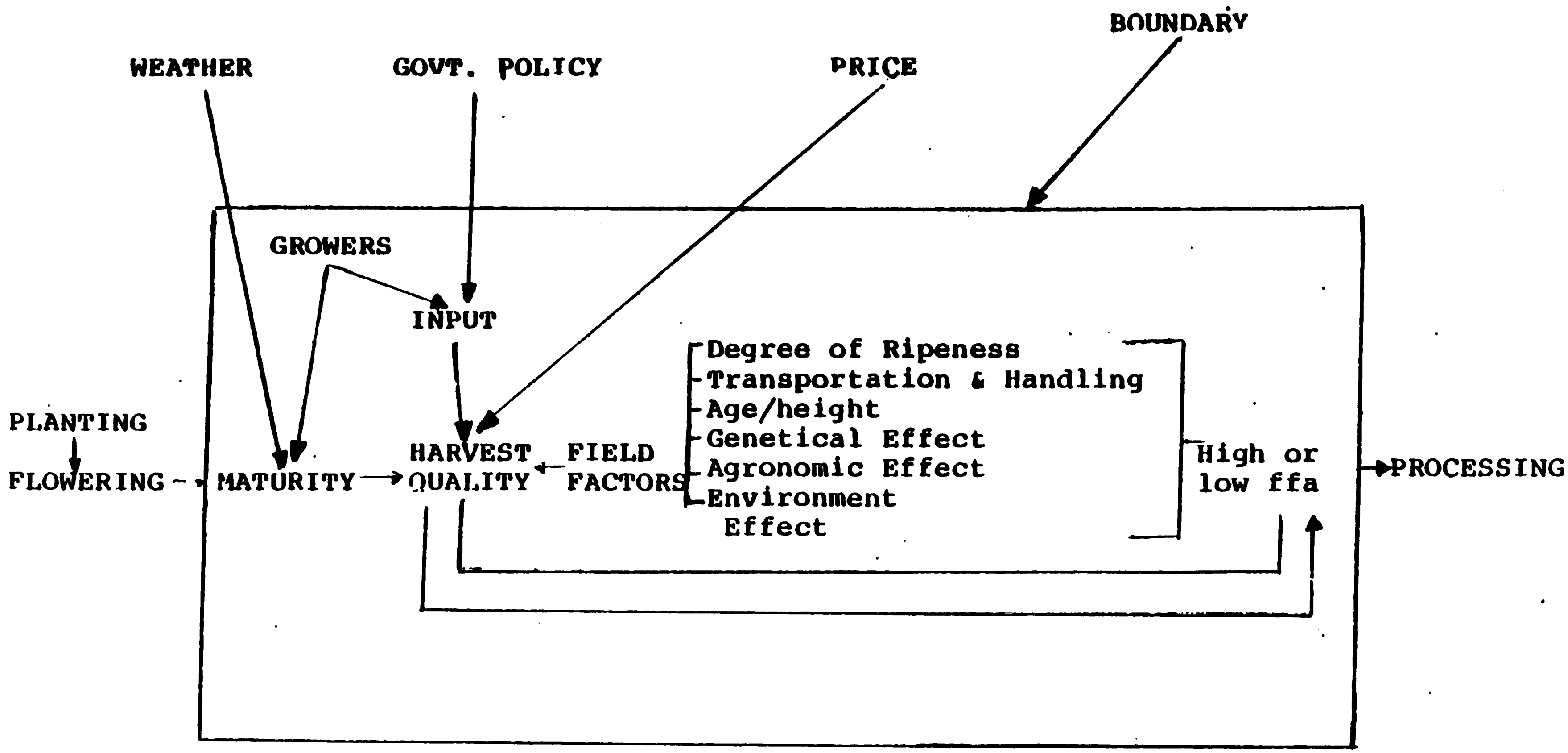


Figure 5.2 Simplified Oil Palm Quality Control System.

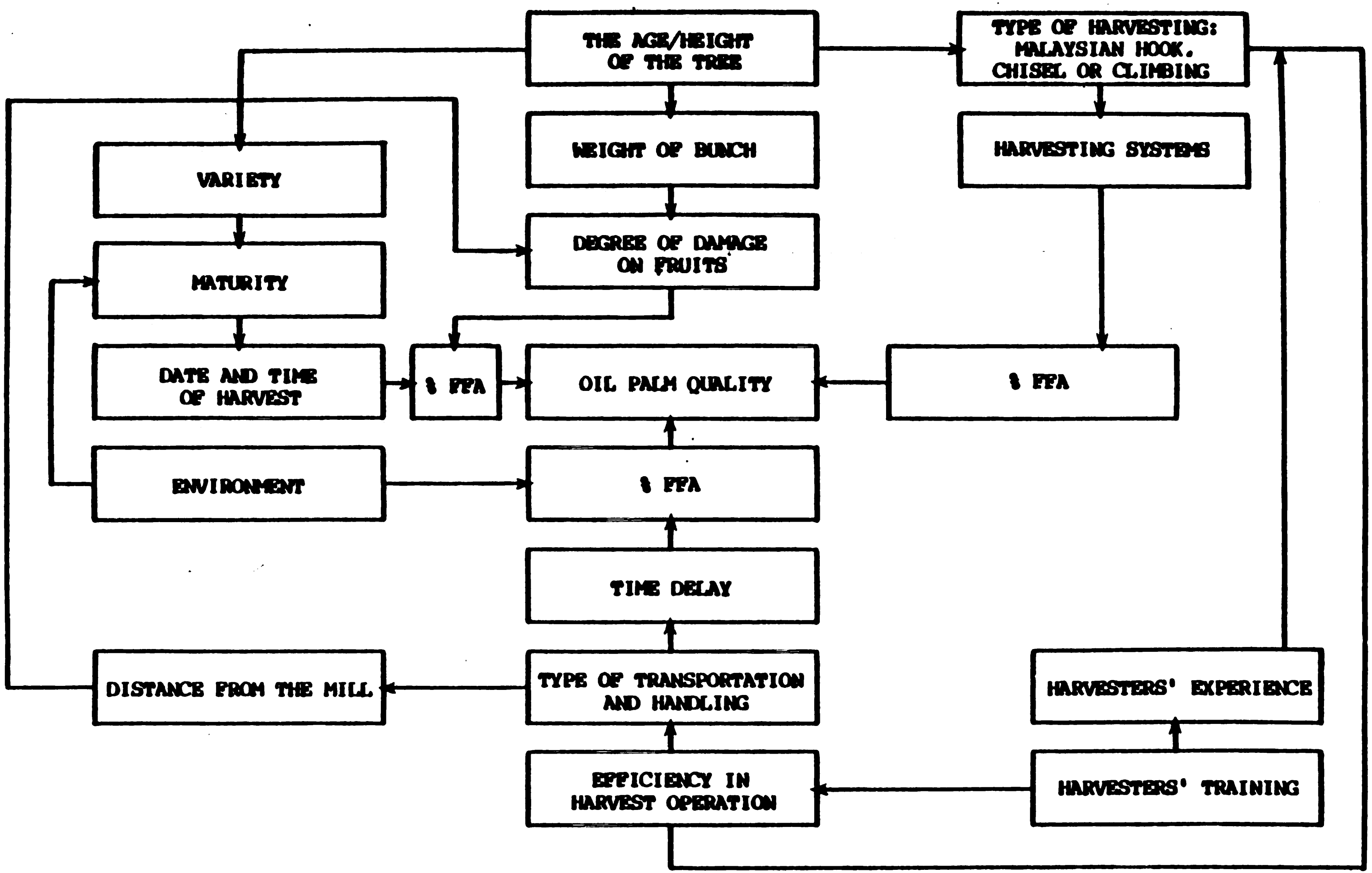


Figure 5.3 Field factors influencing oil palm quality.

5. The model assumes that the method of production throughout the "oil palm belt" is the same, especially the regular maintenance of the plantation.

5.2 Input Data

There were six input data required for the palm oil quality control model. These are:

(i) Percentage detached fruit

(ii) Quantity of fresh fruit bunches

(iii) Length of time delay in days

(iv) Fruit condition (eg. degree of damage, diseased or rotten)

(v) Age of the palm tree, and

(vi) Variety (Tenera, Dura, Pisifera).

5.2.1 Percentage Detached Fruit

This is the percentage weight of the detached fruit with respect to the whole fresh fruit bunch. This is obtained by counting the number of detached fruit before and after cutting the bunch. The bunches are coded according to the percentage detached fruit, ranging from 0 to 6. The different codes represent different levels of ripeness.

The percentage detached fruit is very highly correlated to the free fatty acid of the fresh fruit bunch as shown by the regression analysis in the previous chapter (Figure 4.3). This confirms the work of Dufrane and Berger (1957).

Thus:

$$FFA = a + b\ (R) \qquad (5.1)$$

where R = % detached fruit

b = slope

FFA = estimated free fatty acid

a = intercept

$$LF = f\ (BW, AG) \qquad (5.2)$$

where LF = loose fruit before cutting

BW = average bunch weight

AG = age of palm tree

$$LF = MSTD * BW \qquad (5.3)$$

where
MSTD = minimum harvesting standard

Since average bunch weight is linearly correlated to age (see Figure 4.5).

$$BW = a + b(AG) \qquad (5.4)$$

Substituting (5.4) in (5.3)

$$LF = MSTD * (a + b*AG) \qquad (5.5)$$

Equation (5.5) is used in the model to help the farmer adjust the harvesting system. The number of loose fruit on the ground before harvesting the bunch is the most commonly used measure of ripeness by the harvesters in the field. The percentage of detached fruit of a bunch is the percentage of all the detached fruit after the bunch has been harvested. The definition of a detached fruit in this context is one which has either fallen from its bunch or can be detached by hand. In the analysis in the previous chapter, the number of loose fruit as it is used by the harvesters, and the percentage detached fruit are highly correlated and predict the degree of ripeness very effectively. The percentage detached fruit is frequently used in predicting the free fatty acid in the model because it explains 99% of the change in percentage of free fatty acid (ffa) and has less loopholes than the number of loose fruit techniques. Some of the limitations of the loose fruit on the ground as indicator of ripeness are:

1. The activities of rodents, squirrels, and other pests tend to increase or reduce the number of loose fruit on the ground, thereby misleading the harvesters.

2. Heavy storm a day before harvesting also affects the accuracy of loose fruit on the ground as a measure of ripeness.

3. Loose fruit dropping into the palm fronds or epiphytic growths on the palm trunk are never seen or available and therefore makes the ripeness measurement less accurate.

4. Guessing the weight of bunch when it is up high on the tree is not an easy task for the harvesters and so error of judgement is inevitable.

5.2.2 Quantity

This is the total weight of all the bunches of a particular variety. The quantity premium calculation is based on the bunch code and quantity.

5.2.3 Length of Time Delay in Days

There is still rather inadequate evidence of the relationship between speed of fruit transport to the mill and processing, although there are strong indications that rapid collection and transport are necessary for the production of high quality oils. An estate trial concerning the relationship between delay in processing and free fatty acid level gave the results for three varieties (Table 4.3).

5.2.4 Fruit Condition

This is an evaluation of the condition of the fresh fruit bunches (FFB) on arrival at the mill. For more accurate assessment, the bunches are classified according to the severity of bruises they receive at different stages of handling. Clegg (1973), in his analysis of damage incurred by oil palm bunches during handling and transport, classified impacts in terms of their effect on free fatty acid of the bunches. In this model, there are five categories of bruised condition of bunches.

These are:

(i) unbruised
(ii) moderately bruised
(iii) severely bruised
(iv) very severely bruised
(v) extremely bruised

A bunch is classified as unbruised if there are no bruises at all. Moderately bruised if less than 20% is

bruised. Severely and very severely bruised between 20 and 50% and greater than 50%, respectively. A bunch is very extremely bruised when it is more than 75% bruised. The extent of damage on bunches depends on the stage of ripeness. Over-ripe fruit is more prone to bruises because of the soft membrane.

5.2.5 Age

The age factor has an effect on the rate of bunch ripening. The rate of ripening is most rapid in the youngest material and decreases with an increase in the age of the palm. Within each age group, the smaller the bunches, the faster the total fruit detachment (NG and Southworth, 1973).

The average bunch weight increases with the age of the palm. This was shown in the analysis in the previous chapter (Figure 4.8). For the variety,

DURA -

$$BW = .1779 + 1.233AG \qquad (5.6)$$

$$MSTD = LF/(.1779 + 1.233AG) \qquad (5.7)$$

from Equa. 5

TENERA -

$$BW = -.0257 + 1.291AG \qquad (5.8)$$

$$MSTD = LF/(-.0257 + 1.291AG) \qquad (5.9)$$

PSIFERA -

$$BW = 0.7326 + 1.192AG \qquad (5.10)$$

$$MSTD = LF/(0.7326 + 1.192AG) \quad (5.11)$$

5.3 Oil Palm Quality Control Model

Systems researchers treat models as an abstraction of the real world. For a good representation of the real world, an effective evaluation of the many linkages and factors that constitute the system is a sine qua non. The simplified model is shown in Figure 5.2.

The diagramatic illustration of the concept of oil palm quality control is shown in Figure 5.4. The quality control program defines free fatty acid as the main component of quality; it is affected by the field factors (harvesting). The next step is the development of techniques for measuring this quality through sampling and laboratory tests to cross-check and confirm percentage free fatty acid results. With a predetermined free fatty acid level, upper and lower limits are established. The core of the entire system is the system of economic factors which are very important to growers, processors and the final consumers.

Among all the field factors that affect the free fatty acid of oil palm fruit, the most critical is the percentage of detached fruit. The relationship between the percentage of detached fruit and percentage of FFA is represented in the following equations:

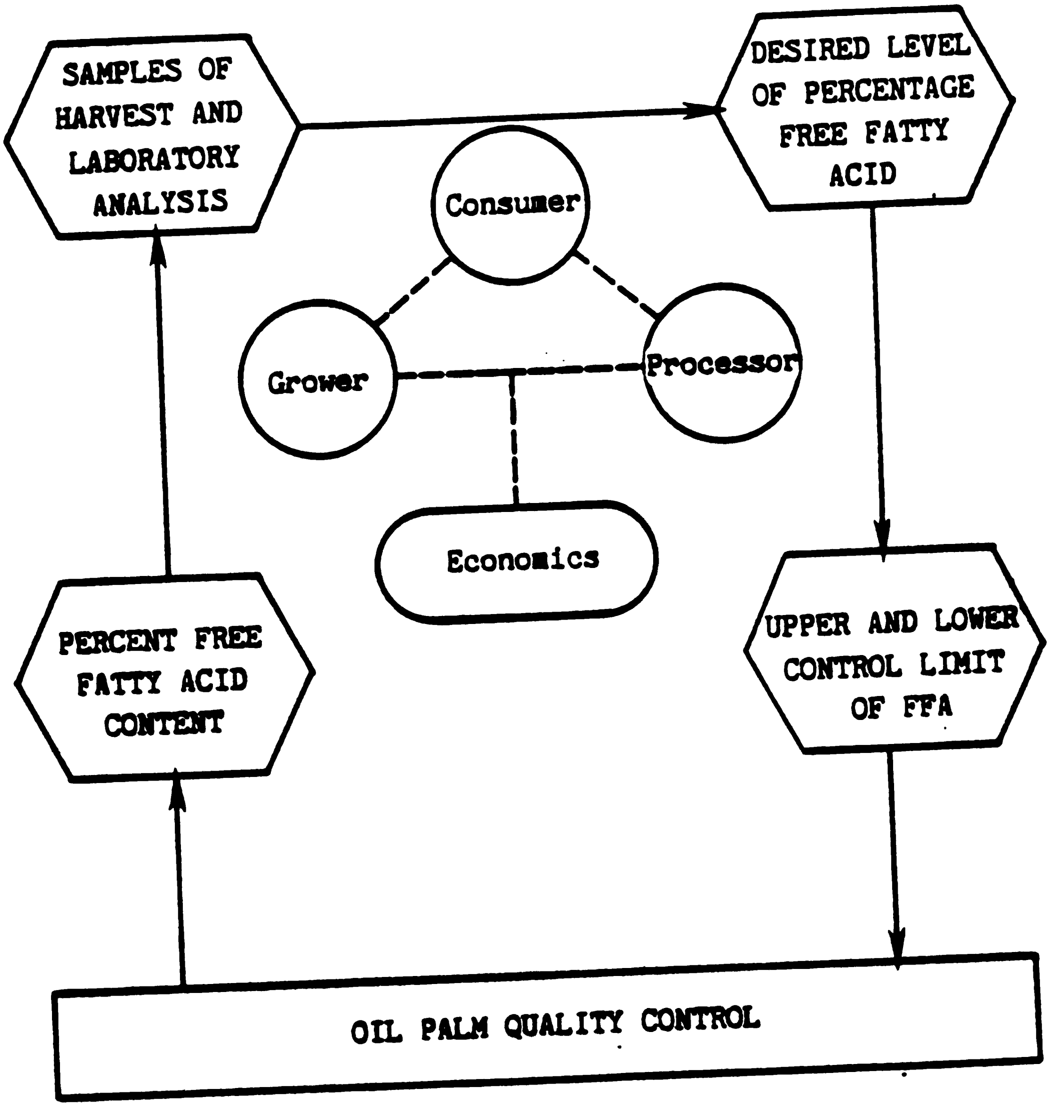


Figure 5.4 The diagram of oil palm quality control concept.

Tenera: $\quad FFA = .614 + .0184R \quad (5.12)$

Dura: $\quad FFA = .614 + .0195R \quad (5.13)$

Pisifera: $\quad FFA = .601 + .0173R \quad (5.14)$

where FF is percentage free fatty acid and R is percentage detached fruit.

Time delay has an effect on the fruit quality, as shown in the data analysis. The effect is expressed in the following equations:

Tenera: $\quad FFA = .724 + .663TD \quad (5.15)$

Dura: $\quad FFA = .726 + .654TD \quad (5.16)$

Pisifera: $\quad FFA = .784 + .521TD \quad (5.17)$

Where TD is time delay in days.

The effect of bruises or damage on fresh fruit bunches was analyzed by Clegg (1973) who classified the impact according to the rise in ffa resulting from the damage on the fresh fruit bunch. In this model, the bruised bunches are classified according to the degree of severity of the bruises. The model rejects very severely bruised, diseased or rotten bunches.

Dufrane and Berger (1957) concluded that oil/fresh mesocarp increases linearly with increasing percentage detached fruit, and from Table 4.2 the linear relationship was developed into the equation:

$$OPM = 45.59 + .13R \quad (5.18)$$

where OPM is the percentage oil per mesocarp weight.

Conversion of Equation 5.18 to kilogram oil per mesocarp = .0456 + .0013R

Equation 5.18 was used to calculate percentage oil per mesocarp at different degrees of ripeness.

With an oil palm plantation where the annual crop is 50,000 tons of ffb, harvesting unripe fruit has been estimated to result in an oil loss of 900 tons (Speldewinde, 1968). This relationship is used to compute the loss due to the harvesting of unripe bunches.

Commercial harvesting will continue to result in a mixture of bunches at various levels of ripeness of under-ripe, of ripe and of over-ripe. The important practical issues are the establishment of a more satisfactory definition of ripeness and how to control the level and range of bunch ripeness to maximize oil yield, oil quality and minimum loss. For this reason, the harvested fresh fruit bunches are classified under three main degrees of ripeness -- under-ripe (UR), ripe (RF), and over-ripe (VR). The corresponding percentages of the detached fruit in a typical harvest composition are denoted by P1, P2, and P3, respectively. An average percentage detached fruit defining such a harvest composition is expressed by the equation:

$$DF = (WUR \times P1) + (WRF \times P2) + (WVR \times P3) \quad (5.19)$$

where W represents weight of bunches in a particular ripeness category.

DF = Average percentage detached fruit

The above equation in conjunction with equation 5.18 is important in computing the percentage free fatty acid and percentage oil per mesocarp.

The award of standard premium is represented in the following expression:

$$Pm' = 1 + Pm\ (2 - FFA) \qquad (5.20)$$

where Pm is standard premium, FFA is free fatty acid percentage and Pm′ is free fatty acid correction factor. For the choice of appropriate premium based on the percentage detached fruit and market price, we should maximize the function:

$$Pmt = K\ (N/\text{kg. oil})\ [1 + Pm\ (2-FFA)]\ [0.456 + 0.0013R]\ \text{kg. oil} \qquad (5.21)$$

where Pmt is the payment in Nigerian currency called Naira and R is percentage detached fruit, K = market price for one kilogram oil. K is modified by the free fatty acid premium.

For the variety, Tenera, substitute equation 5.12 in equation 5.21 to obtain

$$Pmt = K\ [1 + 1.386\ Pm - 0.0184\ PmR]\ [0.456 + 0.0013R]$$

$$\frac{dPmt}{dR} = 0 = K\ [(-0.0184Pm)\ (0.456 + 0.0013R) + (1 + 1.386Pm - 0.0184PmR)\ (0.0013)]$$

$$1.3 = Pm(6.59 + 4.78 \times 10^{-2}\ R)$$

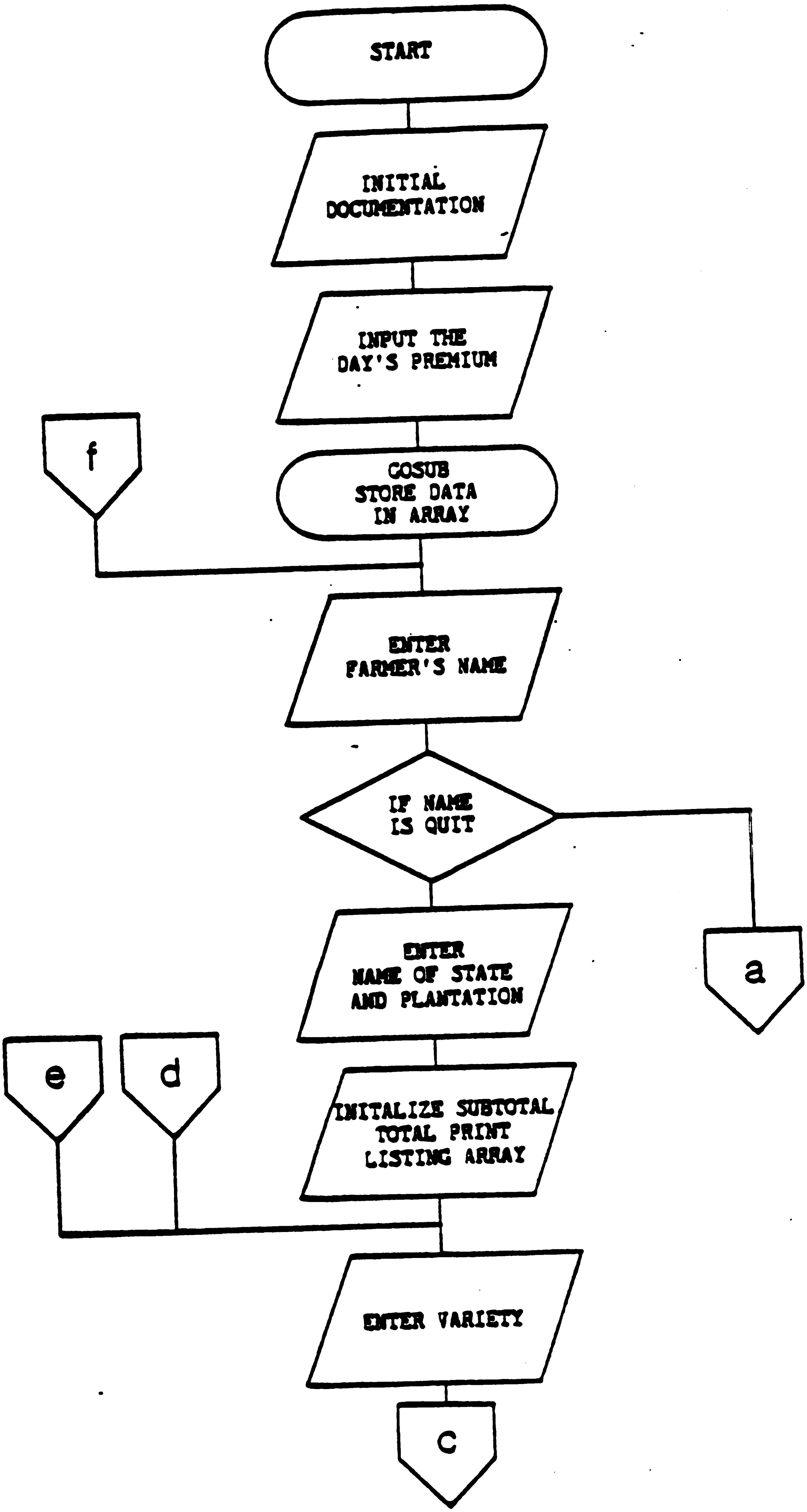
$$Pm = \frac{1.3}{6.59 + 4.78 \times 10^{-2}\ R} = \frac{1}{5.06 + 3.67 \times 10^{-2}R}$$

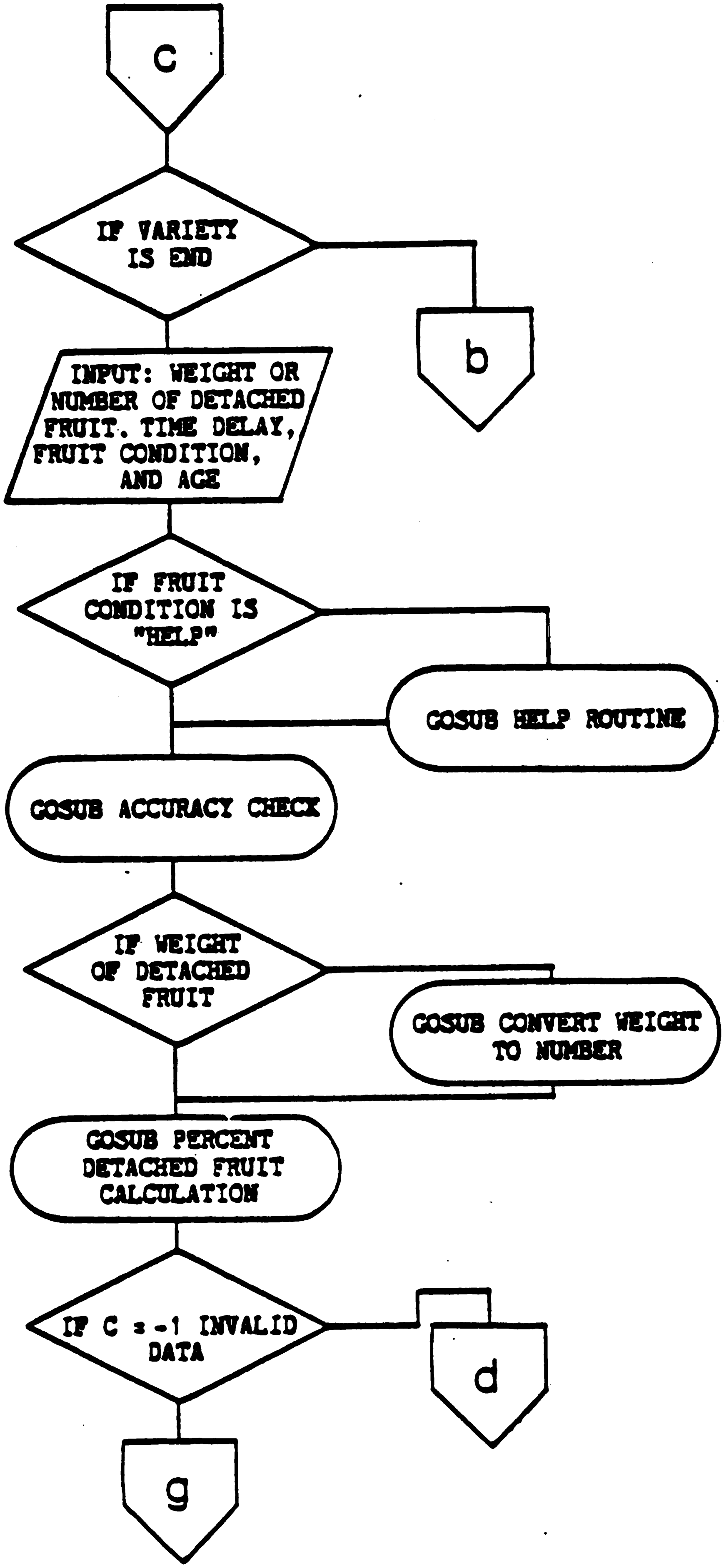
It is assumed that K cannot be zero, else there will be no pricing policy.

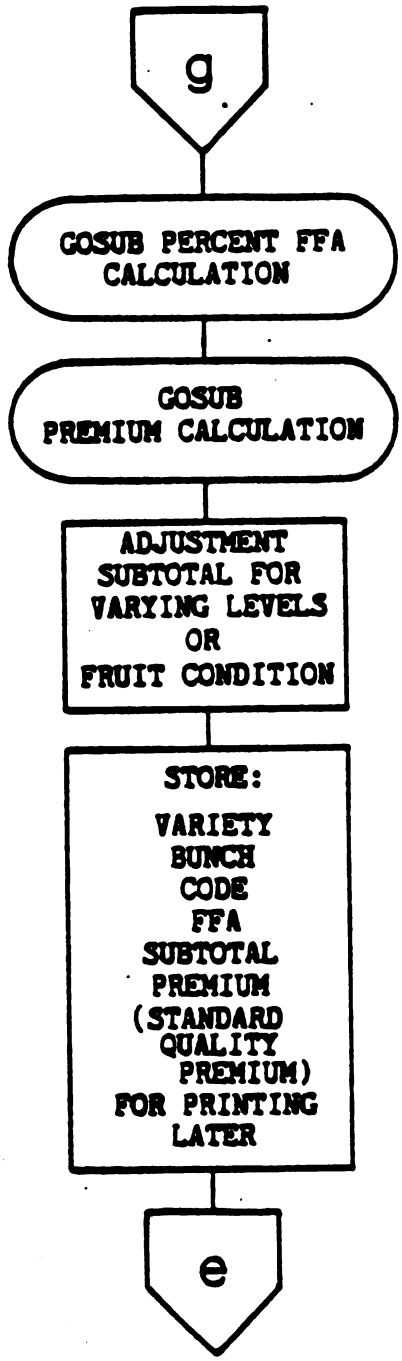
$$Pm = \frac{1}{5.06 + .0367R} \qquad (5.22)$$

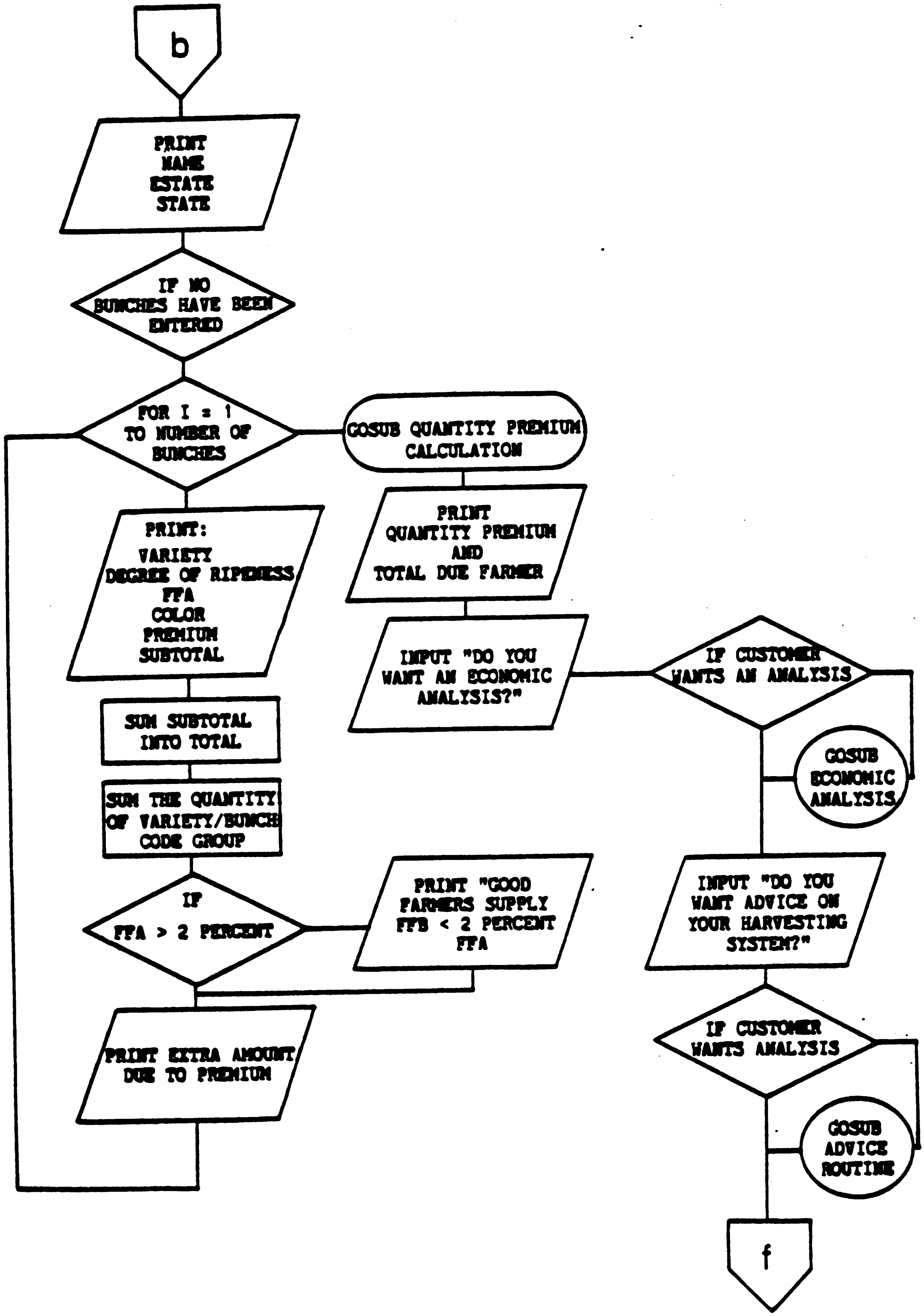
from equation 5.22, the control of percentage detached fruit alone, does not affect the choice of appropriate premium substantially and, therefore, has little or no effect on the revenue accruing to the farmer.

The logical flow chart describing the model is presented in Figure 5.5. The model consists of a main program and ten subroutines. The program prompts the user to enter the day's premium, the name of the farmer, Plantation, State of origin, the variety of the bunch, the number or weight of detached fruit, time delay in days, the fruit condition (bruised or unbruised), and the age of the palm. The percentage detached fruit determines the bunch code and the percentage free fatty acid. The final level of free fatty acid is influenced by the factors like time delay, and the condition of the fruit. Using the bunch code, the program searches a table of information to find the pricing data appropriate to that bunch code. The price of the bunch is modified by the free fatty acid correction factor. Bunches with code numbers 3 and 4 are awarded standard premium. The standard premium is either positive or negative, depending on the percentage free fatty acid fixed by the establishment. The day's premium is used to calculate quantity premium. If this quantity of bunch code numbers 3 and 4 are equal to or greater than the thresholds


START
INITIAL DOCUMENTATION
INPUT THE DAY'S PREMIUM
f
GOSUB STORE DATA IN ARRAY
ENTER FARMER'S NAME
IF NAME IS QUIT
a
ENTER NAME OF STATE AND PLANTATION
e
d
INITALIZE SUBTOTAL TOTAL PRINT LISTING ARRAY
ENTER VARIETY
c


c
IF VARIETY IS END
b
INPUT: WEIGHT OR NUMBER OF DETACHED FRUIT. TIME DELAY, FRUIT CONDITION, AND AGE
IF FRUIT CONDITION IS "HELP"
GOSUB HELP ROUTINE
GOSUB ACCURACY CHECK
IF WEIGHT OF DETACHED FRUIT
GOSUB CONVERT WEIGHT TO NUMBER
GOSUB PERCENT DETACHED FRUIT CALCULATION
IF C = -1 INVALID DATA
d
g


g
GOSUB PERCENT FFA CALCULATION
GOSUB PREMIUM CALCULATION
ADJUSTMENT SUBTOTAL FOR VARYING LEVELS OR FRUIT CONDITION
STORE:
VARIETY
BUNCH
CODE
FFA
SUBTOTAL
PREMIUM
(STANDARD QUALITY PREMIUM)
FOR PRINTING LATER
e


b
PRINT
NAME
ESTATE
STATE
IF NO
BUNCHES HAVE BEEN
ENTERED
FOR I = 1
TO NUMBER OF
BUNCHES
GOSUB QUANTITY PREMIUM
CALCULATION
PRINT
QUANTITY PREMIUM
AND
TOTAL DUE FARMER
PRINT:
VARIETY
DEGREE OF RIPENESS
FFA
COLOR
PREMIUM
SUBTOTAL
INPUT "DO YOU
WANT AN ECONOMIC
ANALYSIS?"
IF CUSTOMER
WANTS AN ANALYSIS
SUM SUBTOTAL
INTO TOTAL
GOSUB
ECONOMIC
ANALYSIS
SUM THE QUANTITY
OF VARIETY/BUNCH
CODE GROUP
IF
FFA > 2 PERCENT
PRINT "GOOD
FARMERS SUPPLY
FFB < 2 PERCENT
FFA
INPUT "DO YOU
WANT ADVICE ON
YOUR HARVESTING
SYSTEM?"
IF CUSTOMER
WANTS ANALYSIS
PRINT EXTRA AMOUNT
DUE TO PREMIUM
GOSUB
ADVICE
ROUTINE
f

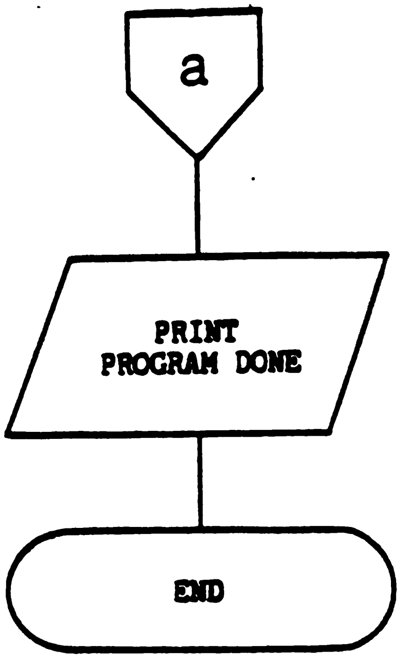


Figure 5.5 Simplified Flow Chart for Oil Palm Quality Control Model.

for those bunch coded numbers, a quantity premium is awarded. It is important to note that the standard premium (if applicable) is applied first to calculate the bunch price, then the quantity premium if applicable is applied to this price. The table of bunch information is stored in the form of data statements in array. The subroutine flow charts are in Appendices 25-34. For detailed in-put format see Appendix 1.

The main functions of the model are:

1. To encourage growers through award of premium to produce and harvest only ripe fruit.

2. Carry out a harvest composition analysis and make an estimate of the percentage free fatty acid and oil/mesocarp.

3. If the harvest composition is high in either unripe or over ripe or both, an appropriate estimate of annual loss in ₦/hectare was made.

4. It is not only a useful decision making tool in the hands of a plantation manager but also helpful in assisting a grower make necessary adjustment needed to attain and maintain maximum production of good fresh fruit bunches.

5. The model is also a useful instrument in the hands of policy makers who require direction and guidelines during the process of policy making.

5.3.1 An Economic Framework for Estimating Annual Revenue from Oil Palm

The discounting techniques were useful because they capture the delay between the initial investment and the return (Upton, 1973). This delay involves cost which should be taken into account in estimating net return. In practice, discounting is generally more useful than compounding because the farmer is concerned with present values, rather than future values in making current decisions. Thus, it is not very helpful to know what the future value of a profit will be in 20 years time.

The process of estimating the present value of future cash flows is known as discounting and is the opposite of compounding.

P = original loan or principal
r = interest rate
v_n = principal plus interest after year n
n = number of years

for compounding: $Vn = P(1 + r)^n$ (5.23)

If both sides are divided by $(1 + r)^n$

$$P = \frac{Vn}{(1+r)^n} \qquad (5.24)$$

The discounting is for time, and not other factors like risk, etc. However, it is possible to add a risk-discount and poor harvest-discount to the rate of interest (r) in order to capture the effect of these factors on returns.

To convert a stream of irregular cash flows, such as may be obtained from a tree crop, into an equivalent annuity, the following formula is used (Upton, 1973):

$$A = \frac{Pan\ r\ (1+r)}{(1+r)\quad - 1} \qquad (5.25)$$

Where A is the equivalent annual cash flow and Pan is the equivalent annual loan.

The net present value is calculated with the formula (Gittinger, 1982)

$$NPV = \sum_{t=1}^{n} \frac{B_n - C_n}{(1+r)^n} \qquad (5.26)$$

where B_n = benefits in each year, C_n = costs in each year, n = number of years, r = interest rate.

The internal rate of return (IRR) which is the yield of the investment or the marginal efficiency of capital can be obtained by calculating NPV of a range of different interest rates and finding at what value, the net present value is equal to zero.

The net present value is determined as follows

$$Pn = 0 \qquad (5.27)$$

$$Pn-1 = \frac{Mn}{1+r} \qquad (5.28)$$

$$Pn-2 = \frac{Mn-1 + Pn-1}{1+r} \qquad (5.29)$$

$$P_1 = \frac{M_2 + P_2}{1 + r} \qquad (5.30)$$

$$P_2 = \frac{M_1 + P_1}{1 + r} \qquad (5.31)$$

Where P = net present value of future returns at the end of year i and M_i = the margin obtained at the end of that year, r = rate of interest and n = crop life in years.

To obtain the Net Present value of cash flow accruing from an oil palm plantation, these must all be discounted to year zero, that is to a point in time before any investment is made (Upton, 1966). The value of the trees can be estimated at any stage of their life either in terms of the total cost of establishment including compound interest, or in terms of the discounted value of expected future returns (Upton, 1973). The former represents the cost and the latter the expected benefit.

Another approach of valuing capital assets such as tree crops is known as the capital profile. The capital profile traces out the pattern of capital requirements of a single activity or a combination of activities over time (Harrison, 1956). Although this approach might lead to some unacceptable conclusion, yet for the purpose of making annual valuation in terms of capital cost, or other costs due to good or bad operational techniques, it is very illustrative. For the activity of producing a hectare of oil palms a capital profile may be established in terms of cumulative costs of establishment. These costs appear as the negative margins in the first four years of the life of the oil palm plantation given in Table 5.10. Thus, the valuation in terms of capital cost of a one year old hectare of oil palms is ₦1067.45. By the end of the second year, the cumulative cost is the cost in the second year plus interest on the cost in the first year. For example, for a ten percent rate of interest then the capital cost by the end of the second year would be 220.99 + 1067.45 (1.10) = 1395.19 (Figures from Table 5.10).

Thus, the calculation of the capital profile proceeds as follows:

$$C_i = -M_i \qquad (5.32)$$

$$C_2 = -M_2 + C_1(1+r) \qquad (5.33)$$

$$C_3 = -M_3 + C_2(1+r) \qquad (5.34)$$

$$C_n = -M_n + C_{n-1}\ (1+r) \qquad (5.35)$$

where C_i = capital valuation at the end of the year i and M_i = the margin obtained during that year, r = rate of interest and n = crop life in years.

5.4 Systems Simulation

Simulation has been defined by Naylor (1960) as the operation of a model that represents a real world system. Manipulation of the system inputs makes it possible to simulate the systems behavior under a given set of assumptions. Simulation models are best at providing an optimal range of information rather than a single optimal point. In the quality control model, the oil palm plantation estates sampled are all within the 'Oil Palm Belt.' The generalized simulation output should be interpreted as an actual representation of the values of variables obtainable in the oil palm belt because the location effect was found to be statistically insignificant. After the simulation model is verified, the sensitivity analysis can be performed using various levels of the controllable input data.

The weather effect on quality was not considered far reaching because the indirect effect of weather on ripening rate could be effectively handled by harvesting discipline. There are basically two seasons in Nigeria and these are dry and rainy seasons. The weather condition does not interrupt the harvesting schedule, especially in the dry season.

5.4.1 System Simulation Output and Discussion

The Systems Simulation output of farmers' supplies of fresh fruit bunches (ffb) or deliveries at the Mill was: (1) the stage of ripeness of the bunches measured in terms of percentage detached fruit, (2) the quality of the bunches, determined by the level of percentage free fatty acid content, (3) the premium award based on the quality of the bunch determined primarily by the level of ffa, which is influenced by the degree of ripeness, handling and other field factors, and (4) the award of quantity premium based on the ability to supply or deliver a predetermined quantity of fresh fruit bunches (ffb) with the specified degree of ripeness and the percent free fatty acid (ffa) content within the desired limit. The quantity premium varies from day to day depending on the establishment's goals and objectives, and (5) The price for each bunch depends on the bunch's degree of ripeness, and is coded from zero to six (See Appendix 2). The probable color of the bunch could be a helpful indicator of ripeness stage when in doubt. For a broader perspective, percentage of ripe color is used.

Some additional outputs are the total amount due to farmer based on the number of bunches sampled and simulated. The harvest composition relates the different proportions of ripeness stages of the bunches in terms of unripe, ripe and very ripe. The net present values on annual and per hectare basis are also obtained for a planned oil palm life span of thirty-five years. At different interest rates, other factors like risk could be incorporated if necessary. The equivalent annual cash flow and the internal rate of return on capital can also be obtained from the output if requested. The capital profile technique is an additional output designed not only to regulate the growers, especially the smallholders, but also serves as an aid in the successful planning of oil palm plantation schemes. The suggested weekly and monthly records (See Appendix 11 and 12) are necessary in order to make adjustments necessary for attainment and maintenance of maximum quality and quantity of oil in an economic way.

Tables 5.1-5.5 are five samples of simulated fresh fruit bunches at the Mill reception. In Sample #1, the five bunches have different percentages of detached fruit and, therefore, are at different levels of ripeness. The age and the time delay are common to all bunches because all the bunches are expected to have come from the same field or block where all the palm trees are of the same age. The weight of the bunches might not necessarily be the same.

In harvesting operations, field or blocks are harvested in rotation and in each block, section or field, the palm trees have the same planting date and are, therefore, the same age. Each bunch is valued on its merits, such as the stage of ripeness, the percentage free fatty acid, the visual assessment of rotten, green or diseased. The subtotal is the current worth of the bunch at the Mill reception. The number of bunches to be sampled will depend on the overall number of bunches supplied and the sampling should be random enough to be representative of the quantity supplied or delivered. A suggested sampling procedure is as follows:

In the estate or plantation environment, for a grower and processor, the following sampling procedure should be

Table 5.1 Tenera: Simulated Fresh Fruit Bunches at the Mill Reception, Sample #1

Sample #1		Bunch# 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	1(W)	2(W)	4(W)	6(W)	8(W)
2.	Wt. of Bunch (kg)	18	18	18	18	18
3.	Time Delay in Days	0	0	0	0	0
4.	Condition of Bunch	(U)	(M)	(S)	(S)	(S)
5.	Age of Palm	16	16	16	16	16
(a)	Degree of Ripeness	Unripe	Under Ripe	Just Ripe	Ripe	Over Ripe
(b)	% FFA	.78%	1.35	1.89	2.23	2.57
(c)	Probable Color	Yellow Green or 40% Ripe Color	Yellow Orange or 50% Ripe Color	Orange or 70% Ripe Color	Red Orange or 80% Ripe Color	Red or 90% Ripe Color
(d)	Std. Premium	Ø	Ø	₦ .0008	-₦.001	-₦.002
(e)	Subtotal	₦ .18	₦ .72	₦1.36	₦1.29	₦.68
(f)	Extra Amt. Due to Premium			₦ .015	-₦.03	-₦.043

(g) Total Amount Due Farmer ₦4.23

(h) Quantity Premium Ø

(i) Harvest Composition 40:40:20

(j) Oil Per Mesocarp 48.84: Overall % FFA = 1.073%

(k) Loss Due to Unripe Harvest: ₦129.60/Acre of ₦324/ha. per ann.

(l) Loss Due to Over Ripe Harvest

(m) Grand Total Amount Due Farmer: ₦4.23

Table 5.2 Tenera: Simulated Fresh Fruit Bunches at the Mill Reception, Sample #2

Sample #2		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	2(W)	4(W)	6(W)	8(W)	10(W)
2.	Wt. of Bunch (kg)	20	20	20	20	20
3.	Time Delay in Days	2	2	2	2	2
4.	Condition of Bunch	(U)	(M)	(S)	(S)	(S)
5.	Age of Palm	19	19	19	19	19
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Ripe	Over Ripe	Very Over Ripe
(b)	% FFA	1.485	2.23	2.39	2.54	2.69
(c)	Probable Color	Yellow Orange or 50% Ripe Color	Orange or 70% Ripe Color	Red Orange or 80% Ripe Color	Red or 90% Ripe Color	Red or 100% Ripe Color
(d)	Std. Premium	Ø	-₦.0003	-₦.003	-₦.002	-₦.0007
(e)	Subtotal	₦ .8	₦1.49	₦1.43	₦ .75	₦ .18
(f)	Extra Amt. Due to Premium		-₦.006	-₦.06	-₦ .04	-₦ .01

(g) Total Amount Due Farmer ₦4.65

(h) Quantity Premium ₦.6

(i) Harvest Composition 20:40:40

(j) Oil Per Mesocarp 49.75: Overall % FFA = 1.20

(k) Loss Due to Unripe Harvest

(l) Loss Due to Over Ripe Harvest: ₦2.15/Acre or ₦5.37/ha. (If Area and Quantity Harvested are 1 hectare and 10 tons, respectively)

(m) Grand Total Amount Due Farmer: ₦5.25

Table 5.3 Tenera: Simulated Fresh Fruit Bunches at the Mill Reception, Sample #3

Sample #3		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	3(W)	4(W)	6(W)	8(W)	10(W)
2.	Wt. of Bunch (kg)	18	18	18	18	18
3.	Time Delay in Days	1	1	1	1	1
4.	Condition of Bunch	(U)	(M)	(S)	(S)	(S)
5.	Age of Palm	15	15	15	15	15
(a)	Degree of Ripeness	Just Ripe	Just Ripe	Ripe	Over Ripe	Over Ripe
(b)	% FFA	1.256	1.741	2.11	2.28	2.45
(c)	Probable Color	Orange or 70% Ripe Color	Orange or 70% Ripe Color	Red Orange or 80% Ripe Color	Red or 90% Ripe Color	Red or 100% Ripe Color
(d)	Std. Premium	₦.005	₦ .002	-₦ .0008	-₦.001	-₦.0004
(e)	Subtotal	₦1.45	₦1.38	₦1.33	₦.69	₦ .17
(f)	Extra Amt. Due to Premium	₦ .10	₦ .03	-₦.01	-₦.02	-₦.008

(g) Total Amount Due Farmer ₦5.02

(h) Quantity Premium ₦.54

(i) Harvest Composition 0:60:40

(j) Oil Per Mesocarp 50.27: Overall % FFA = 1.275

(k) Loss Due to Unripe Harvest

(l) Loss Due to Over Ripe Harvest: ₦2.15 or ₦5.39/ha.

(m) Grand Total Amount Due Farmer: ₦5.56

Table 5.4 Tenera: Simulated Fresh Fruit Bunches at the Mill Reception, Sample #4

Sample #4		Bunch# 1	2	3	4	5	6
1.	Detached Fruit: (Wt. or Number)	2 (W)	3 (W)	4 (W)	6 (W)	8 (W)	10 (W)
2.	Wt. of Bunch (kg)	22	22	22	22	22	22
3.	Time Delay in Days	2	2	2	2	2	2
4.	Condition of Bunch	(U)	(M)	(S)	(S)	(S)	(S)
5.	Age of Palm	24	24	24	24	24	24
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Just Ripe	Ripe	Over Ripe	Over Ripe
(b)	% FFA	1.47	1.94	2.21	2.35	2.48	2.62%
(c)	Probable Color	Yellow Orange or 50% Ripe Color	Orange or 70% Ripe Color	Orange or 70% Ripe Color	Red Orange or 80% Ripe Color	Red or 90% Ripe Color	Red or 90% Ripe Color
(d)	Std. Premium	Ø	₦.0004	-₦.001	-₦.002	-₦.002	-₦.002
(e)	Subtotal	₦ .88	₦1.66	₦1.61	₦1.58	₦ .83	₦ .82
(f)	Extra Amt. Due to Premium		₦ .01	-₦ .03	-₦ .06	-₦ .04	-₦ .05

(g) Total Amount Due Farmer ₦7.38

(h) Quantity Premium ₦.99

(i) Harvest Composition 17:50:33

(j) Oil Per Mesocarp 49.69: Overall % FFA = 1.19

(k) Loss Due to Unripe Harvest

(l) Loss Due to Over Ripe Harvest

(m) Grand Total Amount Due Farmer: ₦8.37

Table 5.5 Tenera: Simulated Fresh Fruit Bunches at the Mill Reception, Sample #5

Sample #5		Bunch# 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	2 (W)	4 (W)	8 (W)	8 (W)	10 (W)
2.	Wt. of Bunch (kg)	20	20	20	20	20
3.	Time Delay in Days	0	0	0	0	0
4.	Condition of Bunch	(U)	(U)	(U)	(U)	(U)
5.	Age of Palm	19	19	19	19	19
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Over Ripe	Over Ripe	Very Over Ripe
(b)	% FFA	.92	1.22	1.84	1.84	2.14
(c)	Probable Color	Yellow Orange or 50% Ripe Color	Orange or 70% Ripe Color	Red or 90% Ripe Color	Red or 90% Ripe Color	Red or 100% Ripe Color
(d)	Std. Premium	0	₦ .006	0	0	₦ .0001
(e)	Subtotal	₦.8	₦1.62	₦ .8	₦ .8	₦ .19
(f)	Extra Amt. Due to Farmer		₦ .12			-₦ .003

(g) Total Amount Due Farmer ₦4.21

(h) Quantity Premium .3

(i) Harvest Composition 25:25:50

(j) Oil Per Mesocarp 49.82: Overall % FFA = 1.21

(k) Loss Due to Unripe Harvest

(l) Loss Due to Over Ripe Harvest: ₦2.15/Acre

(m) Grand Total Amount Due Farmer: ₦4.51

considered. Sampling should be carried out so that results of the analysis are representative of the whole harvest. In which case the sterilizer cage may be taken as a sample size.

(i) The number of sample cages for daily analysis should not be less than the number of fields, blocks or divisions harvested.

(ii) The bunches sampled should be at random and and as much as possible harvests should be grouped according to plantings of the same year or age.

(iii) Bunches to be sampled should still have stalks with a white (fresh) cut surface, otherwise,the time delay in days should be indicated. If the bunches have very dry, moldy or rotten cut surfaces, they should be discarded and classified as "not codeable." The same applies to bunches in advanced stages of rot pest-damage or disease.

(iv) The sampling exercise should be carried out according to a program prepared at the beginning of the year. This is to simplify the control of the representative sampling. The number of samples for the whole year should be equitably distributed among the years of planting divisions.

As a processor, receiving fresh fruit bunches from farmers, the following sampling procedure should be considered:

(i) For the analysis, the fresh fruit bunch may be taken as the smallest sample size. The number of bunches to be sampled will depend on the total bulk supplied. For example, with the supply of forty fresh fruit bunches, a sample size of fifteen to twenty will be considered adequate.

(ii) The bunches sampled are taken at random and accordingly coded based on percentage detached fruit and resultant level of free fatty acid.

(iii) Visual inspection of the bunches is important to ensure that the bunches are not rotten, moldy, or diseased. Bunches that are excessively damaged by bruising or delayed should be noted. Diseased and rotten bunches should normally be classified as "not codeable" and discarded.

(iv) Only fresh fruit bunches are considered for analysis and coded. Abnormal bunches, not fully developed, dry and very wrinkly should not be considered.

(v) Accurate and consistent assessment of degree of damage or bruising, proper record of year of planting, weight or number of detached fruit and time delay are important in order to obtain approximate harvest composition of the grower's supply.

In all cases, a laboratory test for free fatty acid content is necessary.

In Sample #1 (Table 5.1), the grand total amount due the farmer is ₦4.23 which is 4 percent higher than what he would receive in the absence of any control measures. This would have been ₦4.05. The model has warned the farmer because of the high percentage of unripe fruit which gives rise to the low oil content and the low extraction ratio. Although the overall percentage of free fatty acids is low, the premium obtained for such low free fatty acid cannot offset the loss resulting from harvesting unripe bunches. In this case, a loss of ₦129.60/acre or ₦324/ha.per annum will be suffered if in a year nine tons of fresh fruit bunches with the same harvest composition is supplied. In Tables 5.2, 5.3 and 5.5 the amounts due the farmer are ₦5.25, ₦5.56 and ₦4.51, respectively; instead of ₦4.50, ₦5.40 and ₦1.50. The record of the loss due to unripe harvest is necessary and serves as a timely warning for the farmer to do something about the harvesting system. In this case, there is need to either increase the minimum harvesting standard or the harvesting circle, or both. A constant check on the harvesting discipline is also important.

In Sample #4, Table 5.4, the grand total amount due the farmer is ₦8.37. This amount is 25% higher than what the farmer would otherwise receive because he is compensated by an award of standard and quantity premium for producing fresh fruit bunches of high quality and quantity. From Table 5.6, it is clear that the number of unripe and over ripe bunches in a harvest, or in other words, it is the harvest composition that determines the free fatty acid content and the percentage oil content. The more the unripe and over-ripe bunches are minimized, when compared to the proportion of the ripe bunches, the better the compromise between free fatty acid and the quantity of oil. Sample #4

Table 5.6 Summary of Simulated Fresh Fruit Bunches at Mill Reception: Tenera

	Harvest Composition	% Detached Fruit	%FFA Content	Oil per Mesocarp	Amount Due Farmer	Remark
1	40:40:20	25	1.07	48.84	₦4.23	Warning loss due to unripe harvest
2	20:40:40	32	1.20	49.75	₦5.25	Warning loss due to over ripe harvest
3	0:60:40	36	1.27	50.27	₦5.56	Warning loss due to over ripe harvest
4	17:50:33	31.55	1.19	49.69	₦8.37	
5	25:25:50	32.5	1.21	49.82	₦4.51	Warning loss due to unripe harvest

(Table 5.4) has a crop composition that tends towards the right combination of the different degrees of ripeness. The resultant high revenue is due to the standard and quantity premium intended to encourage the growers to adjust their harvesting system in order to come up with similar harvest composition in which unripe and over-ripe bunches are at the minimum in relative proportion to the ripe bunches.

The oil content of under-ripe bunches is low and this increases as the bunches move to the stage of optimum ripeness through increased percentage of detached fruit. The free fatty acid (ffa) percentage also increases with the increased detached fruit. The control of percentage detached fruit alone, does not affect the choice of appropriate premium substantially and, therefore, has little or no effect on the revenue accruing to the farmer. In commercial practice, the objective should, therefore, be to get as many bunches as possible within the range of desired percentage detached fruit to total fruit. The use of the world market price for oil and the FFA premium award in formulating quality control policy will not be effective because of the little difference in revenue between the maximum detached fruit and zero detached fruit. The farmer or management can vary the harvesting by changing the harvesting interval and the minimum harvesting standard. The influence of these factors have been shown by Southworth, 1973. The harvesting interval determines the spread of degree of ripeness in the crop, while the minimum standard determines the minimum level of ripeness. Since the change in free fatty acid with respect to detached fruit is linear, the harvesting circle and harvesting minimum standard can be varied to any combination which will give the number of detached fruit per bunch appropriate for the required ffa. However, in the case of oil yield, the relationship between the harvesting system is not very straightforward and simple because of the discrepancies as to when the oil synthesis in the bunch terminates. From the simulation, any bunches having less than 25% detached fruit to total fruit will contain less oil than those with greater than 25% detached fruit to total fruit. The closer a bunch is to zero detached fruit, the lower will be its oil content (Figure 5.6).

A simulated observation of degree of ripeness based on percentage detached fruit of the harvest composition is shown in Tables 5.7, 5.8, 5.9, for the varieties Tenera, Pisifera and Dura, respectively. For Tenera, to harvest sufficiently ripe bunches, the number of loose fruit on the circle before cutting of the bunch should be at least half loose fruit per 1 kilogram of bunch weight. A bunch is also considered unripe when less than 50% of the outer fruit are ripe colored.

As a compromise, (see Figures 5.7, 5.8 and 5.9) for simplicity of the harvesting instruction, a minimum ripeness

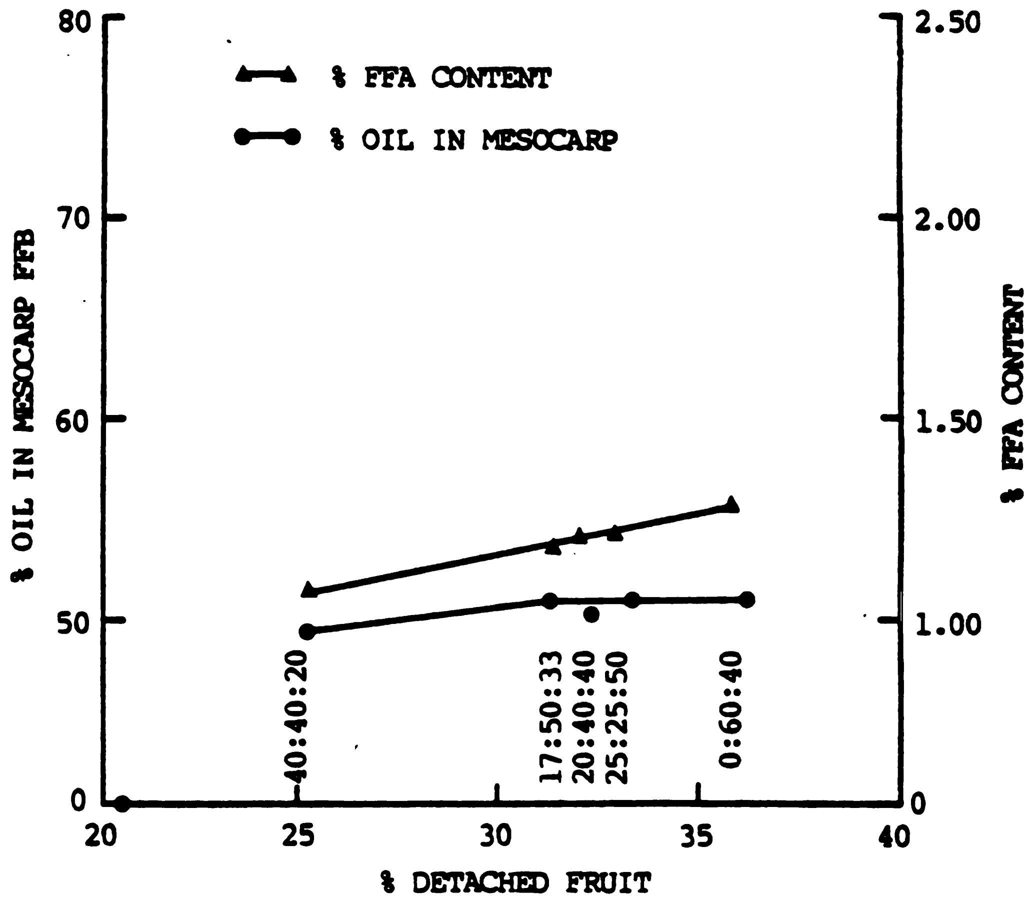


Figure 5.6 Relationship of oil per mesocarp of the fresh fruit bunches (FFB) and FFA content with degree of ripeness for the five harvest compositions.

Table 5.7 Observation of Degree of Ripeness - Tenera

Age[1]	Average Bunch wt.[2]	Before Cutting[3]	Min. Harvest Standard[4]	After Cutting[5]	Color[6]	Bunch Classification[7]	Degree of Ripeness[8]
5	6.42	1	.17	3	40	1	Unripe
10	12.88	5	.45	15	50	2	Under Ripe
12½	16.33	7	.49	20	50	2	Under Ripe
14½	18.86	10	.53	25	70	3	Just Ripe
19	24.56	14	.57	35	70	3	Just Ripe
21	27.12	16	.59	40	70	3	Just Ripe

(1) Age of Palm Tree

(2) Average Bunch Weight

(3) Number of loose fruit on the ground before the bunch is considered harvestable

(4) Number of loose fruit per kilogram of bunch weight

(5) Number of loose fruit expressed as percentage of outer fruit

(6) Percentage of outer fruit which are ripe colored

(7) Class code to which the respective bunches belong

(8) Degree of ripeness

Table 5.8 Observation of Degree of Ripeness - Pisifera

Age[1]	Average Bunch Wt.[2]	Before Cutting[3]	Min. Harvest Standard[4]	After Cutting[5]	Color[6]	Bunch Classification[7]	Degree of Ripeness[8]
5	6.69	2	.30	10	40	1	Unripe
10	12.65	5	.40	20	50	2	Under Ripe
15	18.61	8	.43	30	50	2	Under Ripe
20	24.57	11	.45	40	70	3	Just Ripe
25	30.53	14	.46	50	90	4	Ripe
30	36.4	17	.47	60	90	4	Ripe

(1) Age of Palm Tree

(2) Average Bunch Weight

(3) Number of loose fruit on the ground before the bunch is considered harvestable

(4) Number of loose fruit per kilogram of bunch weight

(5) Number of loose fruit expressed as percentage of outer fruit

(6) Percentage of outer fruit which are ripe colored

(7) Class code to which the respective bunches belong

(8) Degree of ripeness

Table 5.9 Observation of Degree of Ripeness - Dura

Age[1]	Average Bunch Wt.[2]	Before Cutting[3]	Min. Harvest Standard[4]	After Cutting[5]	Bunch Classification[6]	Degree of Ripeness[7]
5	6.4	1	.16	5	1	Unripe
10	12	2	.17	12	2	Under Ripe
15	18.67	9	.48	45	4	Ripe
20	24.8	12	.48	60	4	Ripe
23	28	14	.50	70	5	Over Ripe
24	30	16	.53	80	5	Over Ripe

(1) Age of Palm Tree

(2) Average Bunch Weight

(3) Number of loose fruit on the ground before the bunch is considered harvestable

(4) Number of loose fruit per kilogram of bunch weight

(5) Number of loose fruit expressed as percentage of outer fruit

(6) Class code to which the respective bunches belong

(7) Degree of ripeness

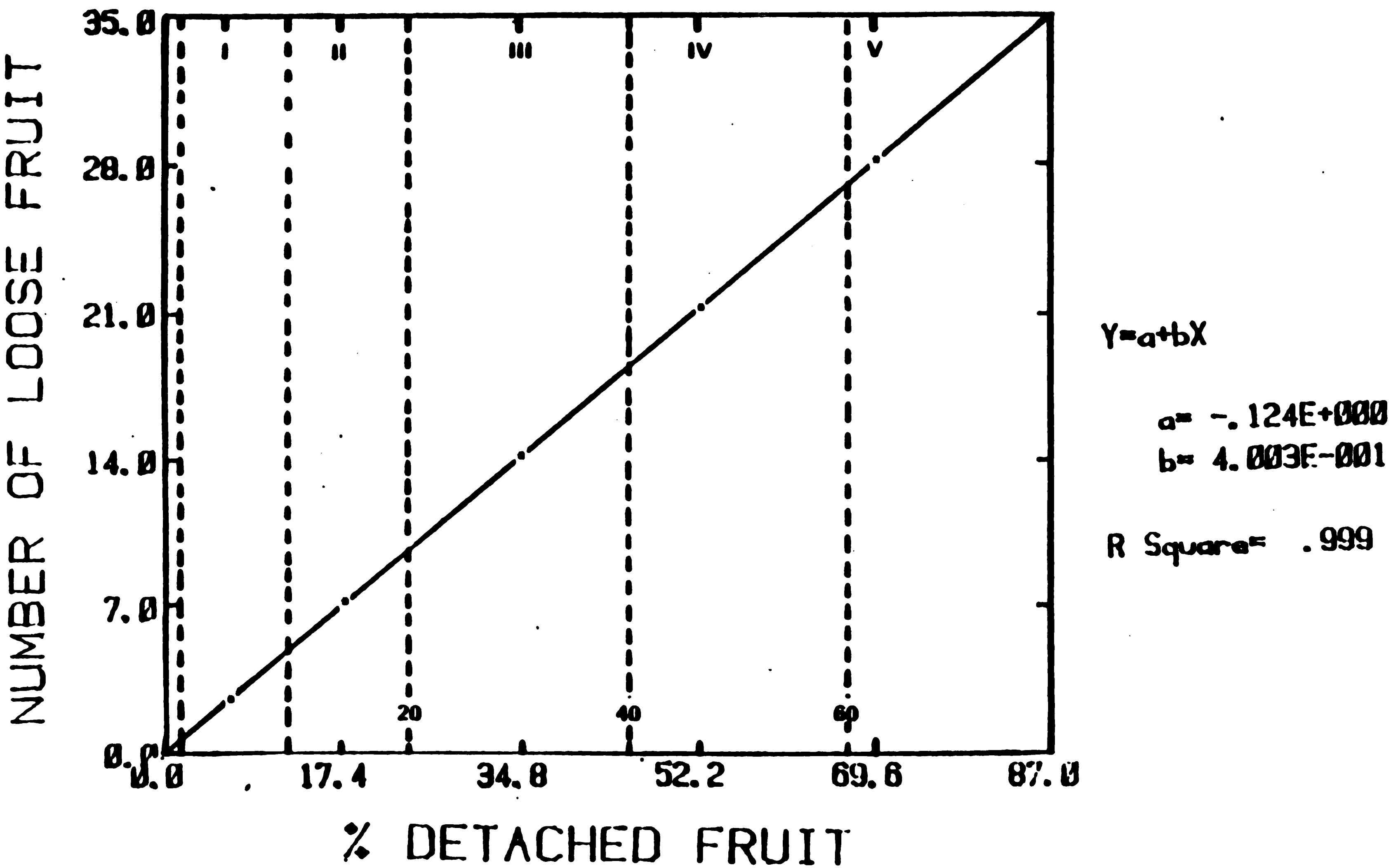


FIGURE 5.7 TENERA: RELATIONSHIP BETWEEN LOOSE FRUIT ON THE CIRCLE BEFORE CUTTING THE BUNCH AND PERCENTAGE DETACHED FRUIT TO TOTAL FRUIT AFTER CUTTING THE BUNCH.

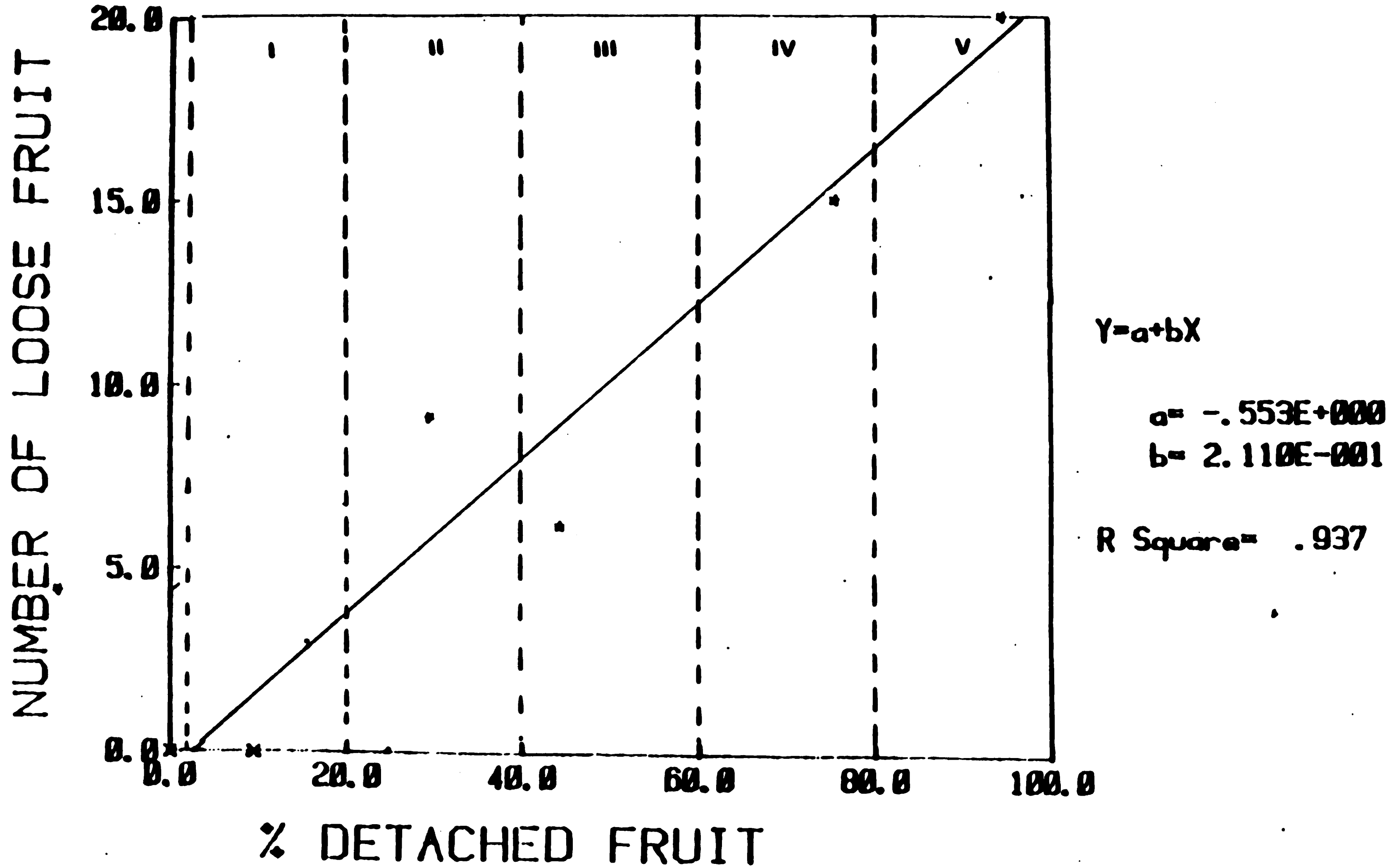
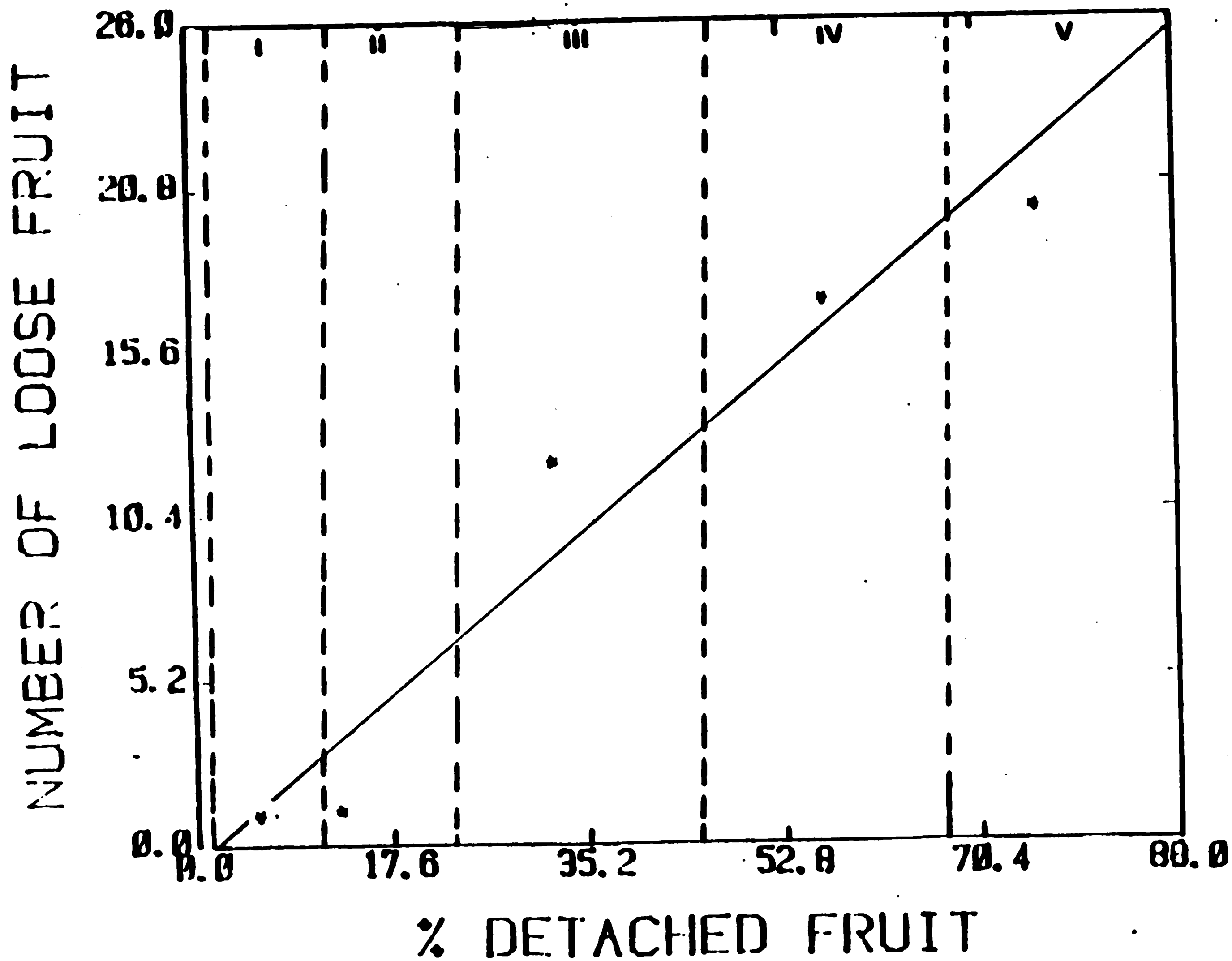


FIGURE 5.8 DURA: RELATIONSHIP BETWEEN LOOSE FRUIT ON THE CIRCLE BEFORE CUTTING THE BUNCH AND PERCENTAGE DETACHED FRUIT TO TOTAL FRUIT AFTER CUTTING THE BUNCH



Y=a+bX

a= -.415E+000
b= 2.965E-001

R Square= .973

FIGURE 5.9 PISIFERA: RELATIONSHIP BETWEEN LOOSE FRUIT ON THE CIRCLE BEFORE CUTTING THE BUNCH AND PERCENTAGE DETACHED FRUIT TO TOTAL FRUIT AFTER CUTTING THE BUNCH criterion of twelve loose fruit may be suggested for Tenera which may be combined with the assessment of ripeness by the consideration of color. The color of the outer fruit should be at least 70% ripe color for Tenera and Pisifera. Thus besides counting or weighing loose fruit, the harvester must also consider the color of the bunch, especially when in doubt. However, to judge the color of the bunch from the ground before cutting is rather difficult, especially when the tree is high. A harvesting interval of seven days, which is common throughout the palm belt, is considered practical.

When the criterion chosen is twelve loose fruit for any size of Tenera bunch, the result will be as shown below:

Bunch Weight(kg)	No. of Loose Fruit per kg of Bunch Weight	Bunch Code
10	1.2	6
12	1.00	6
14	.85	6
18	.66	4
22	.54	3
26	.46	2
30	.40	2
34	.35	1
38	.31	1
42	.28	0

With this criterion, when the harvesting interval is 7 days, it is found that very over ripe bunches with the bunch code #6 are usually consisting of small bunches which are less than 18 kilogram weight. It is, therefore, better to have different criteria for different fields or blocks within an estate.

The simulated capital profiles for interest rates of 9.5%, 10%, 10.54%, 11% and 12% are illustrated in Figure 5.10. It is noteworthy that although positive margins are obtained from the fifth year onward (Table 5.10); when interest is charged at 10% the crop does not pay for itself until the end of twenty-seventh year (Table 5.12). In other words, up to this time, there is a positive capital investment. At 11%, the revenue is never sufficient to cover total capital investment, meaning that there is no breakeven point. At 12%, the capital investment is increasing throughout the crop life.

At the interest rate of 10.54% which is the "internal rate of return" or "yield" the capital investment will just be recovered at about the end of the productive life of the investment.

The simulated discounted future returns are illustrated in Figure 5.11. The profiles of NPV for interest rates of 9.5%, 10%, 10.54%, 11% and 12%. These curves are more closely similar than equivalent capital profiles, so the effect of interest rate on valuation, especially in the

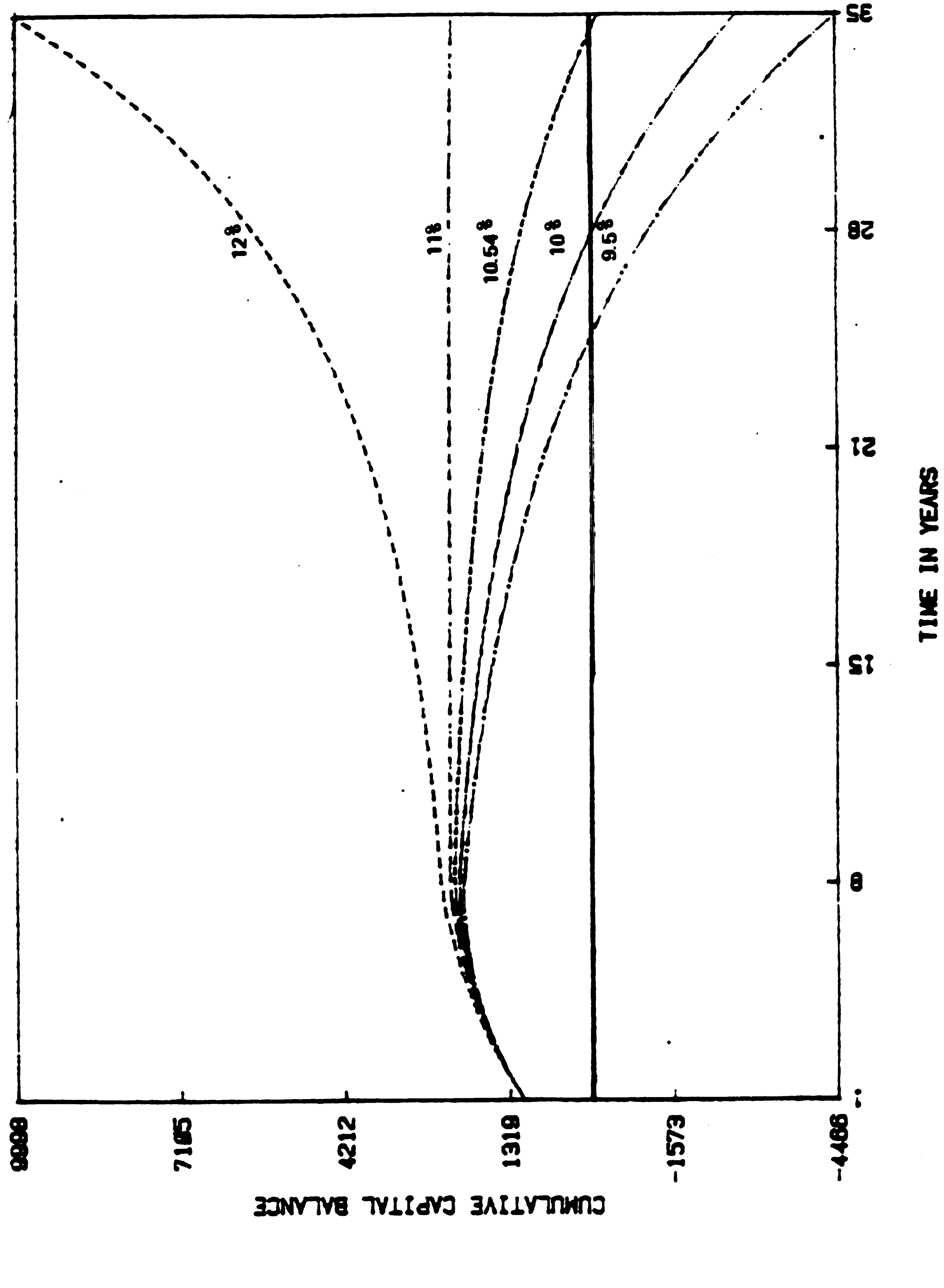


FIGURE 5.10 CAPITAL PROFILE FOR ONE HECTARE OF OIL PALMS

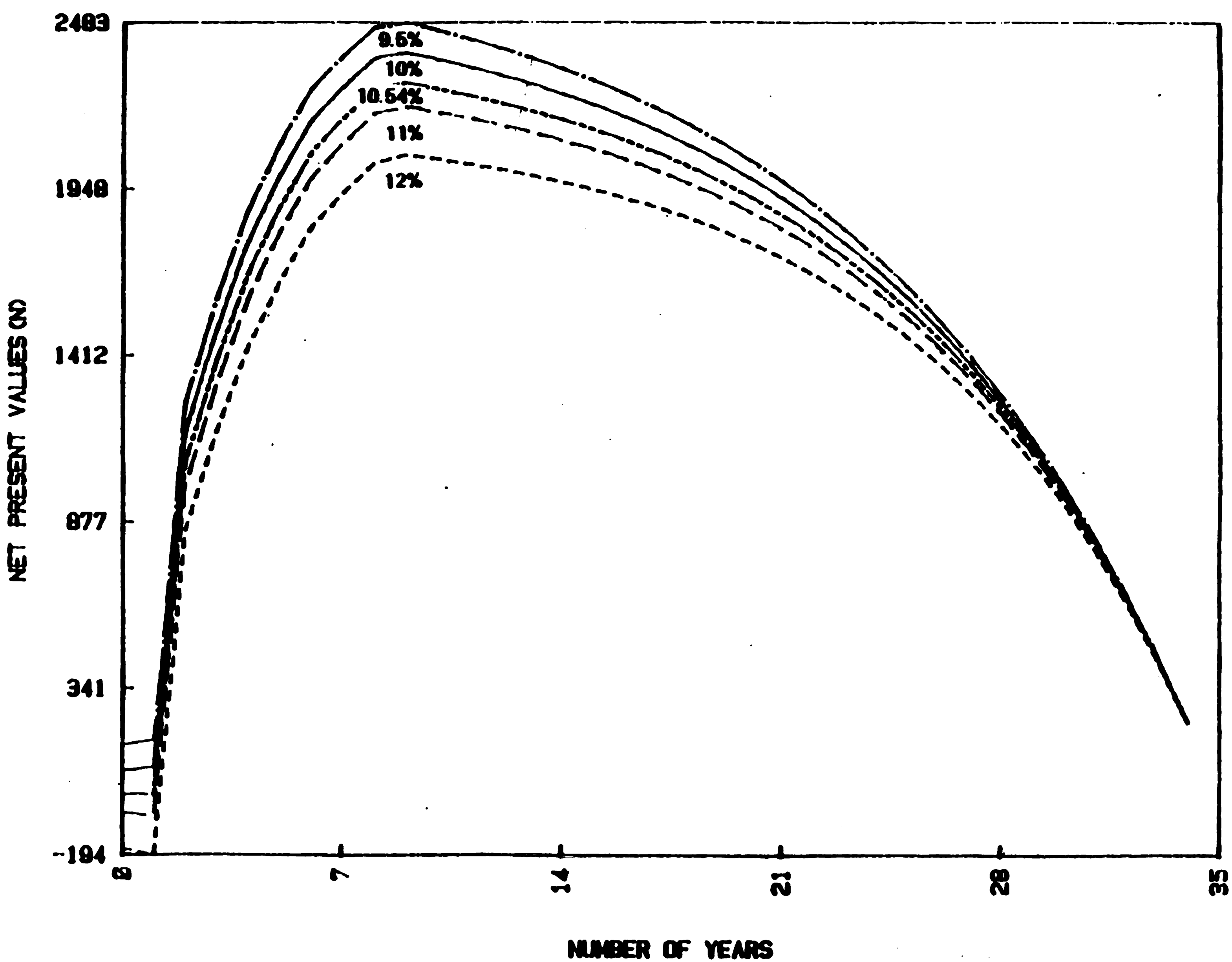


FIGURE 6.11 DISCOUNTED NET PRESENT VALUE OF FUTURE RETURNS FROM ONE HECTARE OF OIL PALMS OVER ITS LIFE

Table 5.10 Revenue and Costs Per Hectare of Oil Palms

I Year Number	II Yield (kg fruit)	₦ III Revenue	IV Costs	V Margin	VI Cumulative Cost
1	NIL	NIL	1067.45	-1067.45	-1067.45
2	NIL	NIL	220.99	- 220.99	-1288.44
3	NIL	NIL	128.09	- 128.09	-1416.53
4	560	42	78.47	- 36.47	-1453.00
5	1680	126	100.98	+ 25.02	-1427.98
6	2800	210	100.98	+ 109.02	-1318.96
7	3360	252	117.48	+ 134.52	-1184.44
8	4480	336	117.48	+ 218.52	- 965.92
9	5040	378	117.48	+ 260.52	- 705.40
10	5040	378	117.48	+ 260.52	- 444.88
11	5040	378	117.48	+ 260.52	- 184.36
12-35	5040	378	117.48	+ 260.52	Positive balances

Note: The original estimates prepared by an F.A.O. advisory team for the Ministry of Agriculture and Natural Resources of Western Nigeria (F.A.O. Team 1974) for use in planning farm settlements. These estimates have been updated using current costs and prices. The third column is obtained by multiplying the yield from the second column by 75/1000 because the current price is ₦75 per ton. The margin in the fifth column is simply the revenue (column III) minus the costs (column IV). The cumulative cost in column VI is the total of all the annual margins up to and including that year.

latter years, is relatively small. Using the data given in Table 5.10 and assuming that the margin accrues at the end of the year, the value of a hectare of oil palms at the end of its thirty-fourth year would be the discounted margin for the thirty-fifth year. At an interest rate of 10%, this would be ₦236.84 (see Table 5.11).

As when compounding costs, the interest rate when discounting returns represents the opportunity cost of postponed receipts of money and will incorporate an allowance to cover risk, poor harvesting (too early or late harvesting). Farmers who are abiding with the quality control specifications are encouraged by using a rate equivalent to opportunity cost of capital. In which case, the benefit lost by farmers is the opportunity cost of oil quality and quantity improvement.

Valuation by this method are only negative in the early years of an investment which is uneconomic to start with. For the oil palm crop at an interest rate of 12%, which is higher than the internal rate of return, the valuation is negative at the end of the first year (Table 5.11).

The difference in valuation obtained by the two methods may be illustrated by considering the value of one hectare of oil palms which have been established for 20 years (See Table 5.13).

From this table it is clear that if the opportunity cost of capital is less than the internal rate of return,

Table 5.11 Discounted Net Present Value of Future Returns and Capital Profile from One Hectare of Oil Palm over Its Life Span at 12%, 11%, 10.54%, 10% and 9.5%

Year	Net Present 12%	Net Present 11%	Capital Profile 11%	Net Present 10.54%	Net Present 10%	Net Present 9.5%	Capital Profile 9.5%
0	- 173.469	- 59.832		.660	79.296	160.297	
1	- 194.286	- 66.414	1067.45	.729	87.225	175.525	1067.45
2	849.849	993.729	1405.859	1068.256	1163.398	1259.650	1389.847
3	1172.821	1324.029	1688.594	1401.840	1500.728	1600.307	1649.973
4	1441.649	1597.763	1910.809	1677.684	1778.890	1880.426	1843.190
5	1651.117	1809.987	2095.978	1890.982	1993.250	2095.537	1993.273
6	1824.231	1984.065	2217.516	2065.272	2167.555	2269.593	2073.614
7	1934.119	2093.292	2326.922	2173.932	2275.290	2376.184	2136.088
8	2031.694	2189.035	2364.364	2268.544	2368.299	2467.402	2120.496
9	2056.977	2211.308	2363.924	2289.129	2386.609	2483.285	2061.423
10	2043.294	2194.032	2363.436	2269.883	2364.750	2458.677	1996.739
11	2027.969	2174.856	2362.894	2248.609	2340.705	2431.732	1925.909
12	2010.806	2153.570	2362.292	2225.092	2314.256	2402.226	1848.350
13	1991.583	2129.943	2361.624	2199.097	2285.161	2369.918	1763.424
14	1970.053	2103.717	2360.883	2170.362	2253.157	2334.540	1670.429
15	1945.939	2074.606	2360.060	2138.598	2217.953	2295.801	1568.600
16	1918.932	2042.292	2359.147	2103.486	2179.228	2253.382	1457.097
17	1888.684	2000.425	2358.133	2064.674	2136.631	2206.934	1335.001
18	1854.806	1966.611	2357.007	2021.771	2089.775	2156.073	1201.306
19	1816.862	1922.419	2355.758	1974.345	2038.232	2100.380	1054.910
20	1774.366	1873.365	2354.372	1921.921	1981.535	2039.396	894.607
21	1726.770	1818.915	2352.833	1863.972	1919.169	1972.618	719.074
22	1673.462	1758.476	2351.124	1799.915	1850.566	1899.497	526.866
23	1613.758	1691.388	2349.228	1729.106	1775.102	1819.429	316.399
24	1546.889	1616.921	2347.123	1650.834	1692.093	1731.755	85.937
25	1471.996	1534.262	2344.787	1564.311	1600.782	1635.752	- 166.418
26	1388.115	1442.511	2342.193	1468.670	1500.340	1530.628	- 442.748
27	1294.169	1340.667	2339.315	1362.948	1389.854	1415.518	- 745.329
28	1188.949	1227.621	2336.119	1246.083	1268.320	1289.472	-1076.655
29	1071.103	1102.139	2332.573	1116.900	1134.632	1151.452	-1439.458
30	939.116	962.855	2328.636	974.101	987.575	1000.320	-1836.726
31	791.290	808.249	2324.266	816.251	825.813	834.831	-2271.735
32	625.725	636.636	2319.415	641.764	647.874	653.620	-2748.070
33	440.292	446.146	2314.031	448.886	452.142	455.194	-3269.657
34	232.607	234.702	2308.054	235.679	236.836	237.917	-3840.794
35			2301.420				-4466.190

Table 5.12 Capital Profile for One Hectare of Oil Palm Over Its Life Span at 12%, 10.54% and 10%

Year	Interest Rates 12%	10.54%	10%
1	1067.45	1067.45	1067.45
2	1416.534	1400.949	1395.18
3	1714.608	1676.699	1662.79
4	1956.831	1889.893	1865.54
5	2166.630	2064.068	2027.07
6	2317.606	2172.600	2120.76
7	2461.199	2267.073	2198.32
8	2538.023	2287.502	2199.63
9	2582.065	2268.085	2159.07
10	2631.393	2246.621	2114.46
11	2686.641	2222.895	2065.39
12	2748.518	2196.668	2011.41
13	2817.820	2167.677	1952.03
14	2895.438	2135.630	1886.71
15	2982.371	2100.206	1814.86
16	3079.735	2061.047	1735.83
17	3188.784	2017.762	1648.89
18	3310.918	1969.914	1553.26
19	3447.708	1917.023	1448.07
20	3600.913	1921.927	1332.35
21	3772.503	1793.929	1205.07
22	3964.683	1722.489	1065.06
23	4179.925	1643.520	911.04
24	4420.996	1556.227	741.63
25	4690.995	1459.733	555.27
26	4993.395	1353.069	350.28
27	5332.082	1235.163	124.79
28	5711.412	1104.829	- 123.24
29	6136.262	960.758	- 396.09
30	6612.093	801.502	- 696.22
31	7145.025	625.460	-1026.36
32	7741.908	430.864	-1389.52
33	8410.417	215.757	-1788.99
34	9159.147	- 22.021	-2228.41
35	9997.725	- 284.862	-2711.77

Table 5.13 Valuations of One Hectare of 20-Year-Old Oil Palms (₦)

	Rate of Interest/Opportunity Cost of Capital		
		Yield*	
	10%	10.54%	12%
Cumulative Expenditure	1332.35	1921.92	3600.91
Discounted Future Returns (Net Present Value)	1981.53	1921.92	1774.36
		Yield Value	

* The valuation obtained by compounding or discounting at the rate of the internal rate of return is referred to as the "yield value."

for example at the rate of 10%, the net present value is greater than the yield value and the cost is lower. Conversely, if the opportunity cost of capital is greater than the internal rate of return, for example at the rate of 12%, the net present value is less than the yield value and the capital cost is higher. This is a useful guideline in the choice of interest rates and payment of compensation as an incentive for the improvement and expansion of oil palm production.

Table 5.14 illustrates the different annual revenues from different harvesting procedures. For example, in the first year of harvest, if normal harvesting is done, the annual revenue per hectare would be ₦42 but if unripe fresh fruit bunches are always harvested, the annual revenue would be ₦21.84, which is about 50% loss. A loss of this magnitude should be of great concern to any serious farmer or grower.

Table 5.14b shows higher gross revenue of 12%, under quality control measures. The increase is due to the award of standard premium. Although it assumed that there is no increase in cost in order to adopt the quality evaluation process, the fact remains that growers are offered the opportunity to increase their revenue through the award of standard and quantity premium. This is more vividly illustrated in Figure 5.12b.

Figure 5.12 is a graphical explanation of the farmers

Table 5.14 Simulated Annual Revenue for One Hectare of Oil Palm - Grower

Year	Revenue	Revenue Harvesting Unripe Fruit	Revenue Harvesting Over Ripe Fruit		
			LF 10	LF 20	LF 30
1	NIL	--			
2	NIL	--	--	--	--
3	NIL	--	--	--	--
4	42	21.84	41.28	28	21
5	126	65.52	123.90	121.80	119.70
6	210	109.20	206.50	203	199.50
7	252	131.04	247.80	243.60	239.40
8	336	174.72	330.40	324.80	319.20
9	378	196.56	371.70	365.40	359.10
10	378	196.56	371.70	365.40	359.10
11	378	196.56	371.70	365.40	359.10
12-35	378	196.56	371.70	365.40	359.10

LF = Loose Fruit

Table 5.14B Showing a Grower's Annual Gross Revenue for One Hectare of Oil Palm and the Associated Losses when Under-ripe and Over-ripe FFB are Harvested

	Gross Revenue without Quality Control			Gross Revenue with Quality Control
Year	Unripe	Normal	Over-ripe	Normal
1	--	--	--	--
2	--	--	--	--
3	--	--	--	--
4	21.84	42	21	47.32
5	65.52	126	119.70	141.96
6	109.20	210	199.50	236.00
7	131.04	252	239.40	283.92
8	174.72	336	319.20	378.56
9	196.56	378	359.10	425.88

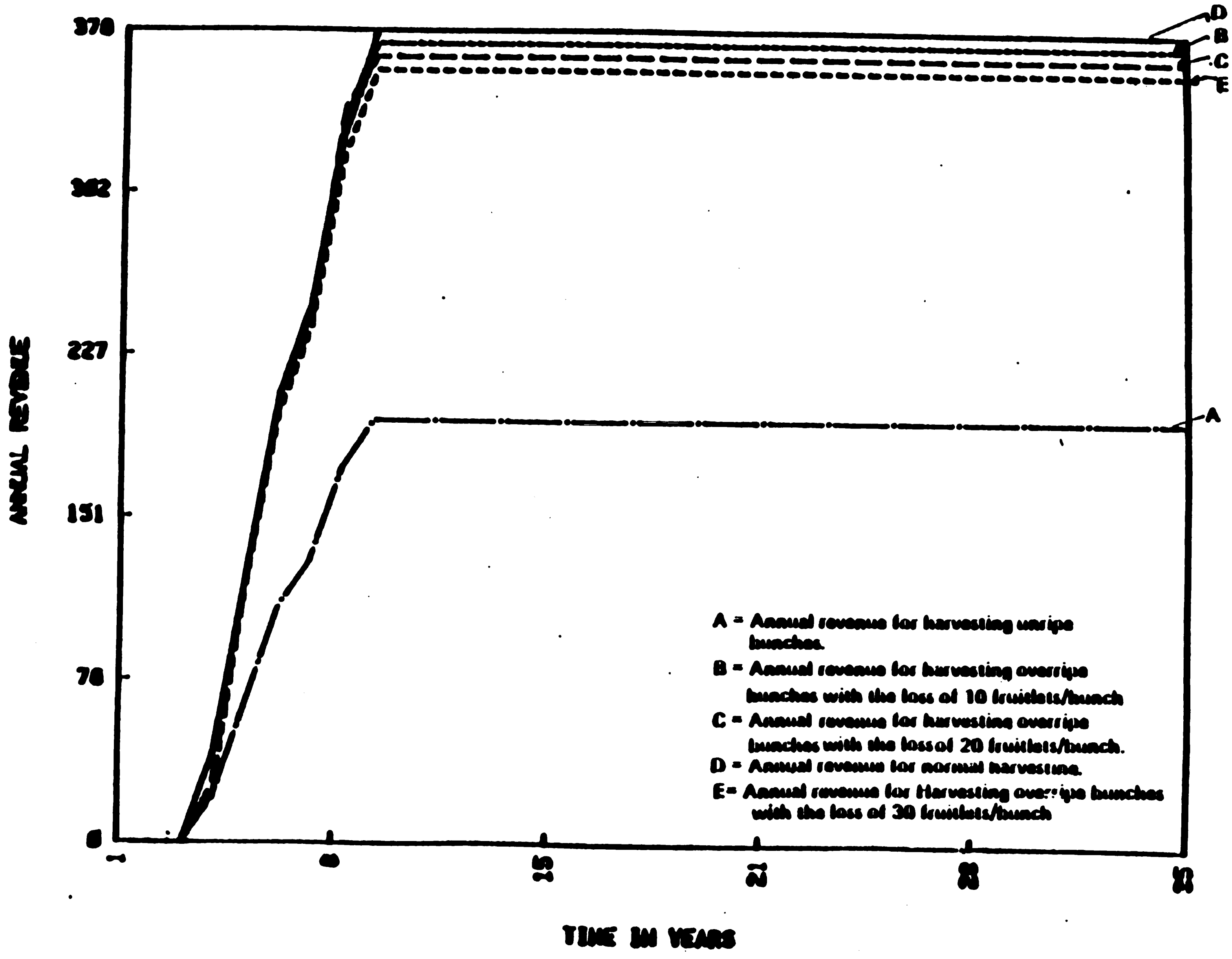


FIGURE 5.12 SIMULATED ANNUAL REVENUE FOR ONE HECTARE OF OIL PALM - GROWER

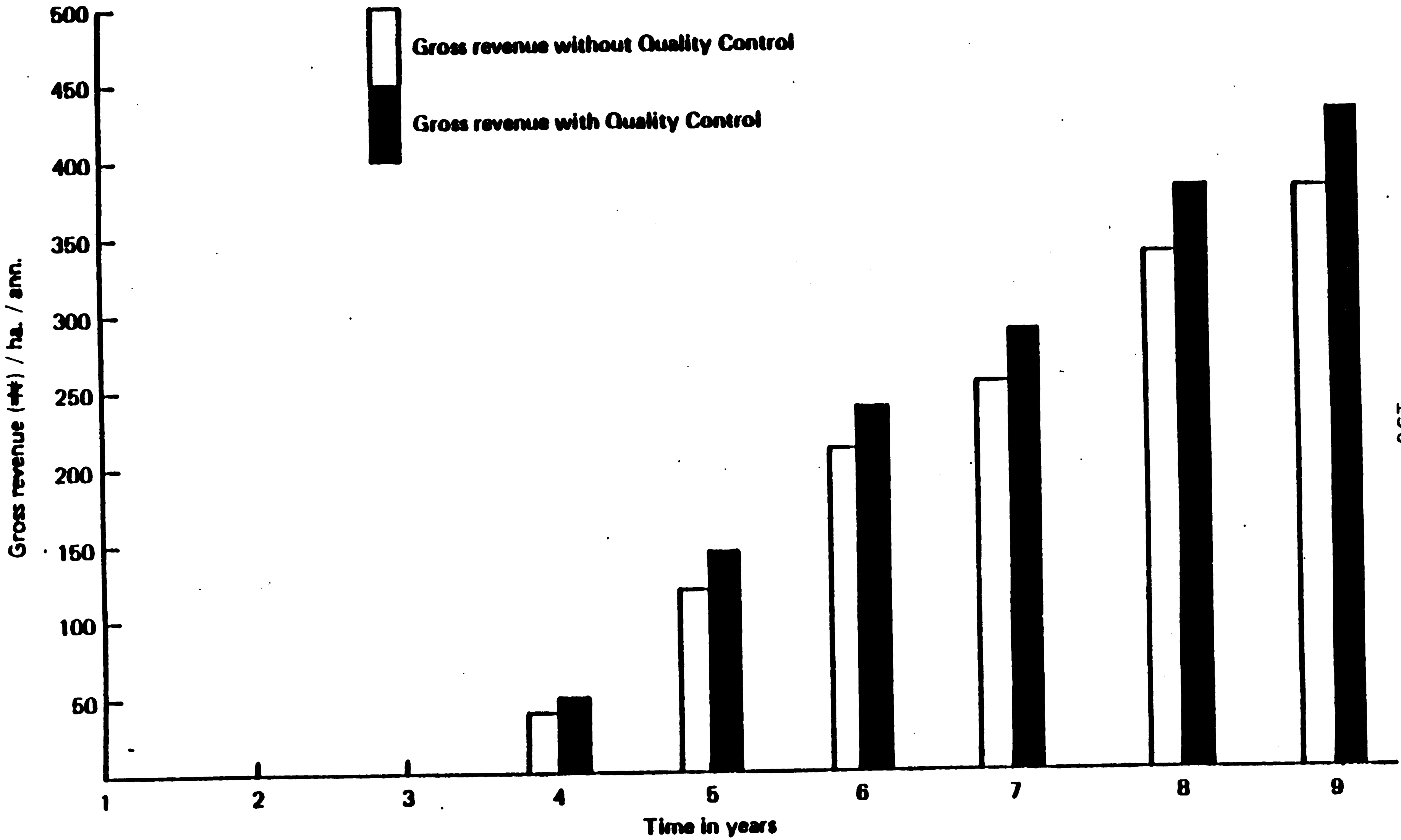


Figure 5.12b Showing a grower's annual gross revenue per hectare of oil palm with and without Quality Control.

annual income based on the harvesting performance. Similarly, Table 5.15 and Figure 5.13 are for processors or both. For the processor or both, the low annual revenue as a result of harvesting over ripe fresh fruit bunches (ffb) are more obvious because the loss is not only due to increased loose fruit but also due to the poor quality of the oil resulting from the increased free fatty acid (ffa) content.

Tables 5.16, 5.17, 5.18 illustrate the effect of time delay and the fruit condition on quality and value for the varieties, Tenera, Dura and Pisifera, respectively. These tables are simulated effects of time delay in days on unbruised, moderately and severely bruised fruit in terms of quality and value. Although the two factors, quantity and quality are inextricably related, the harvesting criterion is directly most important in oil quantity and indirectly in quality. This is because of the damage factor in quality deterioration that undamaged ripe fruit contains low free fatty acid. For example in Table 5.16, the variety-Tenera contains as low as 1.29% free fatty acid when unbruised and processed the same day and the fresh fruit bunch is valued at one naira, sixty-six kobo (N1.66). When moderately bruised and delayed for three days, the free fatty acid rises to 2.40% and the bunch value drops to one naira, forty kobo (₦1.40). If it were possible to avoid damage entirely, then maximum oil quantity could be obtained without quality

Table 5.15 Simulated Annual Revenue for One Hectare of Oil Palm - Processor or Both

Year	Revenue	Revenue Harvesting Unripe Fruit	Revenue Harvesting Over Ripe Fruit		
			10	20	30
1	NIL	--			
2	NIL	--	--	--	--
3	NIL	--	--	--	--
4	42	21.84	39.00	36.00	33.00
5	126	65.52	117	108	99
6	210	109.20	194.95	179.90	164.85
7	252	131.04	233.94	215.88	197.82
8	336	174.72	311.92	287.84	263.76
9	378	196.56	350.91	323.82	296.73
10	378	196.56	350.91	323.82	296.73
11	378	196.56	350.91	323.82	296.73
12-35	378	196.56	350.91	323.82	296.73

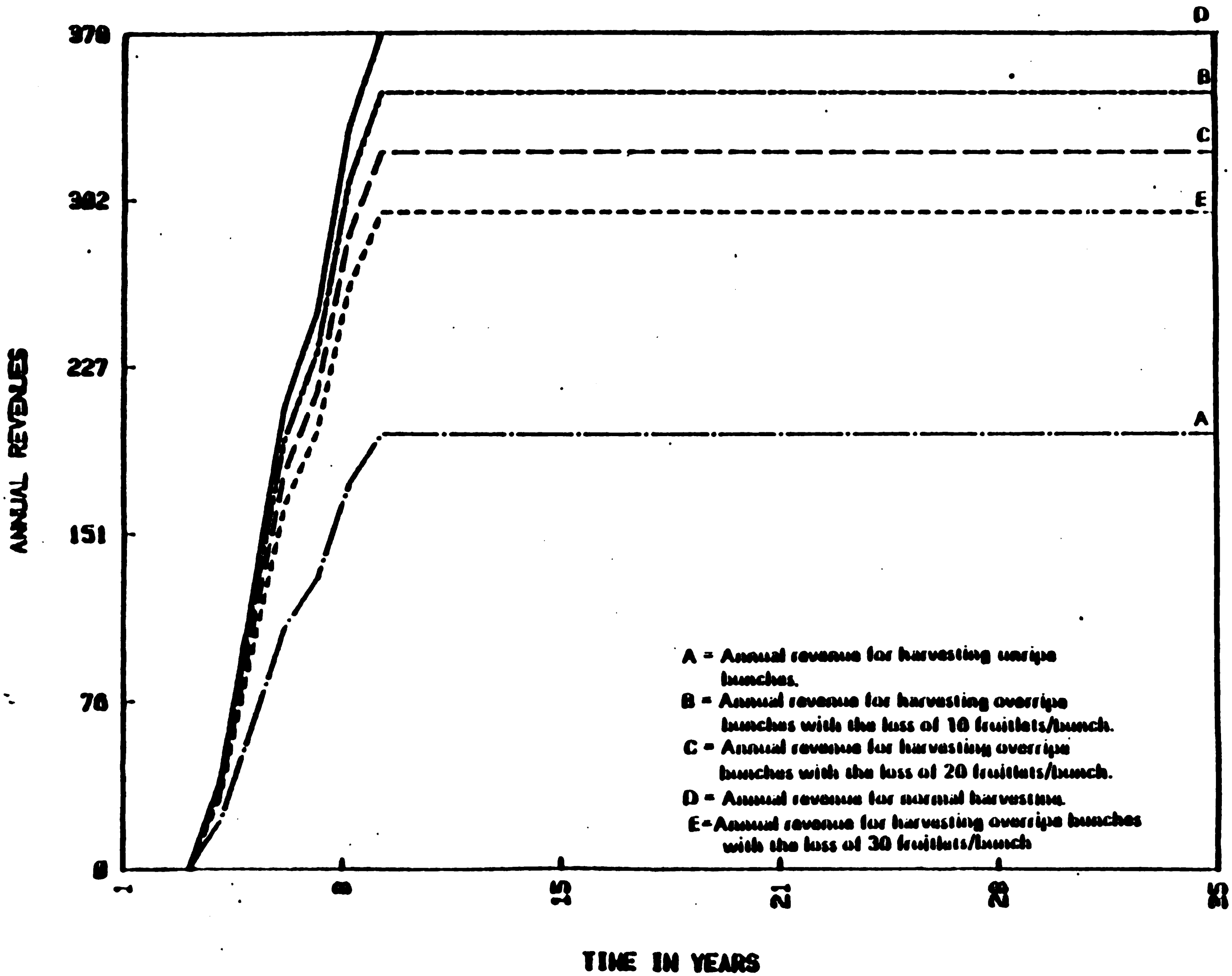


FIGURE 6.13 SIMULATED ANNUAL REVENUE FOR ONE HECTARE OF OIL PALM — PROCESSOR OR BOTH.

Table 5.16 Simulated Effect of Time Delay and Fruit Condition on Fruit Quality and Value

Variety: Tenera

Fruit Condition (Degree of Bruising)	Length of Delay (Days)	% FFA Content	Amount Due Farmer (₦/FFB)
U	0	1.29	1.66
M	1	1.74	1.56
M	2	2.07	1.47
M	3	2.40	1.40
S	1	1.94	1.51
S	2	2.27	1.43
S	3	2.60	1.35

U = Unbruised

M = Moderately bruised

S = Severely bruised

Table 5.17 Simulated Effect of Time Delay and Fruit Condition on Fruit Quality and Value

Variety: Dura

Fruit Condition (Degree of Bruised)	Length of Delay (Days)	% FFA Content	Amount Due Farmer (₦/FFB)
U	0	1.26	1.68
M	1	1.72	1.57
M	2	2.05	1.48
M	3	2.37	1.41
S	1	1.92	1.52
S	2	2.25	1.44
S	3	2.57	1.36

U = Unbruised

M = Moderately bruised

S = Severely bruised

Table 5.18 Simulated Effect of Time Delay and Fruit Condition on Fruit Quality and Value

Variety: Pisifera

Fruit Condition (Degree of Bruised)	Length of Delay (Days)	% FFA Content	Amount Due Farmer (₦/FFB)
U	0	1.22	1.69
M	1	1.66	1.58
M	2	1.92	1.52
M	3	2.18	1.45
S	1	1.86	1.53
S	2	2.12	1.47
S	3	2.38	1.40

U = Unbruised

M = Moderarely bruised

S = Severely bruised

degradation through free fatty acid increase, but at present the greater mount of oil derived from fruit is accompanied by higher free fatty acid values. The higher the loose fruit number, the higher is the free fatty acid (ffa) content. The exocarp becomes softer as the fruit ripens, so the fruit is damaged more readily.

Figures 5.14, 5.15, 5.16 further convey the idea that quality control begins in the field because as far as free fatty acid content is concerned, the influence of harvesting, handling standards and timing of fruit flow to the mill are of paramount importance if oil of low free fatty acid is to be produced. The effect of time delay on the fruit becomes critical when the bunch or fruitlets have suffered some degree of brusing or damage. For example, in Figure 5.14 the severely bruised fruit delayed for three days has 20% quality degradation than the moderately bruised fruit delayed for the same number of days.

The objective of oil palm cultivation is to produce the highest yield of good quality palm oil per unit area in the most economical way. The last consideration requires harvesting with an interval of several days. Consequently the crop will consist of bunches at different stages of ripeness. Therefore, the aim of harvesting is to get a crop with a composition as near as possible to ideal, that is the largest number of exactly ripe bunches. Regular analysis of crop composition is a means of crop quality control. The

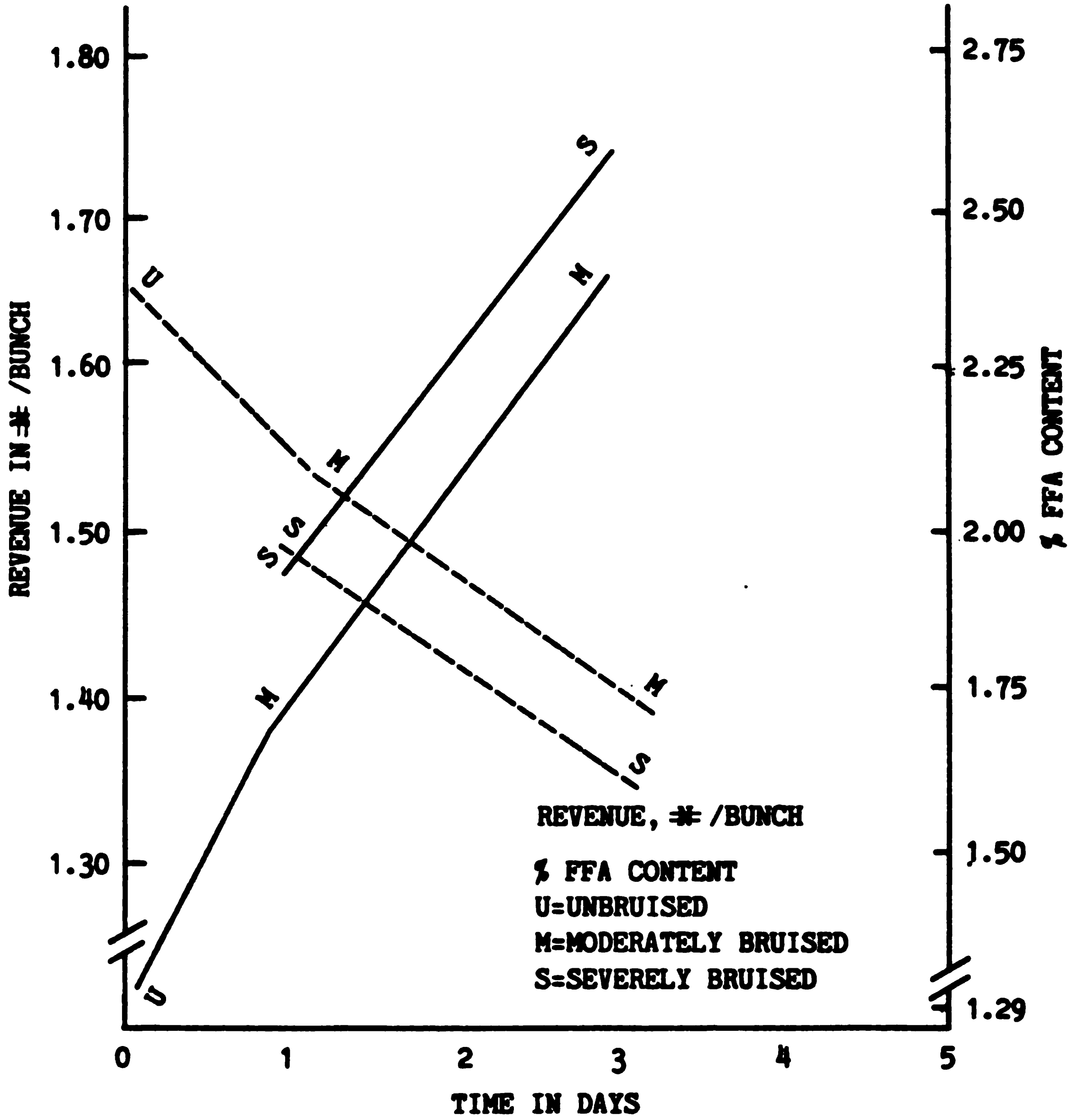


FIGURE 5.14 TENERA: SIMULATED EFFECT OF TIME DELAY AND FRUIT CONDITION ON QUALITY AND VALUE.

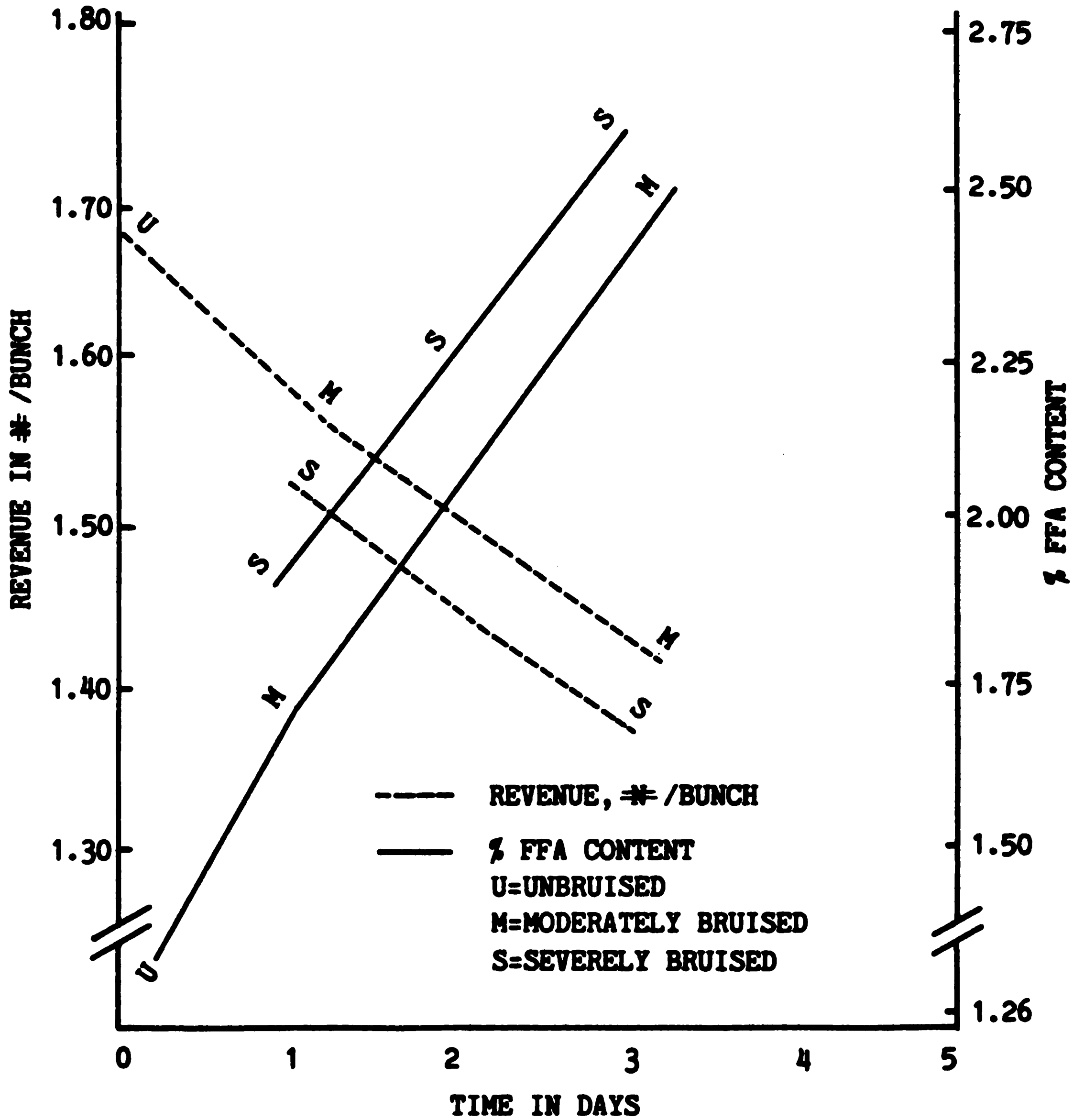


FIGURE 5.15 DURA: SIMULATED EFFECT OF TIME DELAY AND FRUIT CONDITION ON QUALITY AND VALUE.

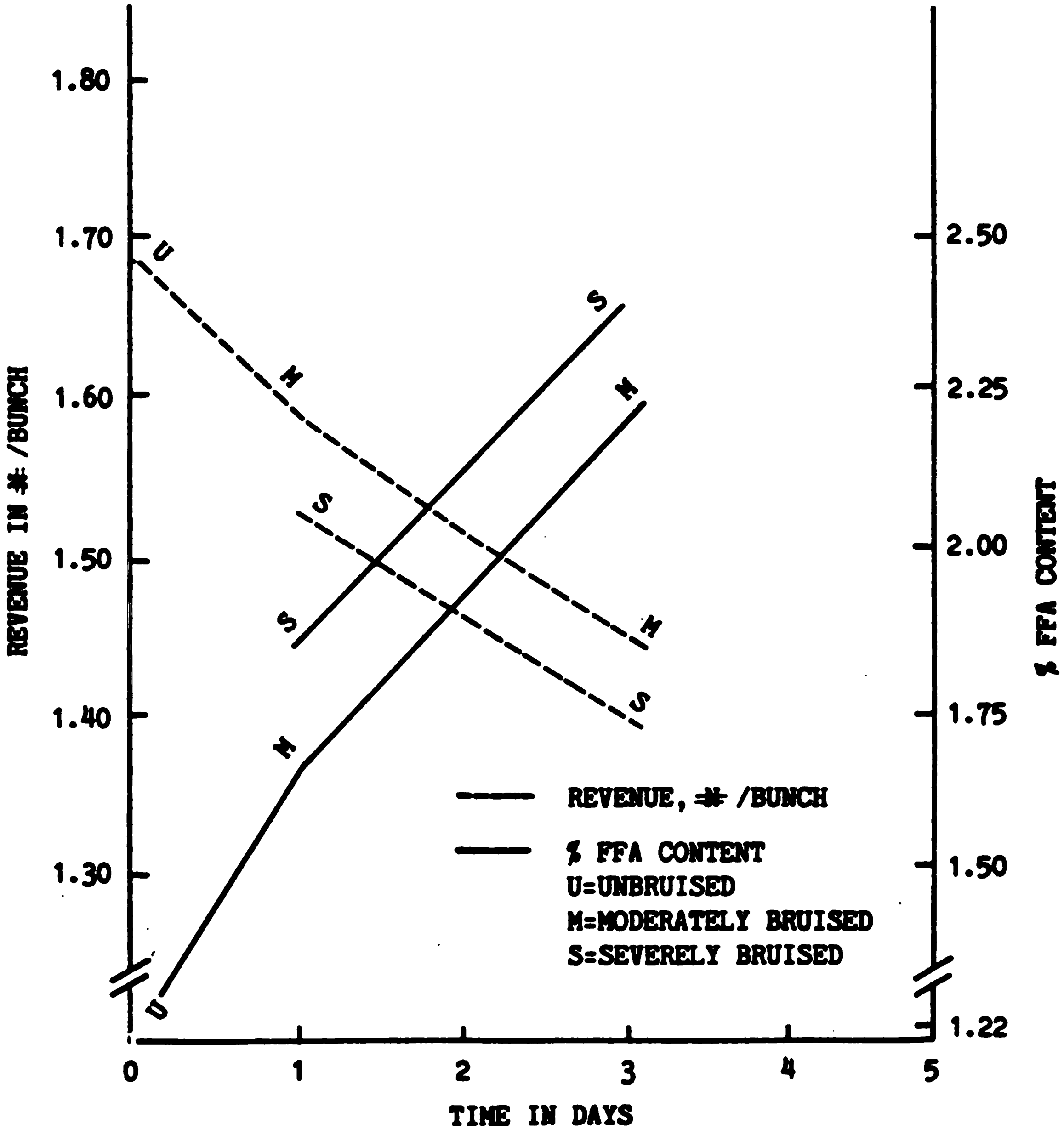


FIGURE 5.16 PISIFERA: SIMULATED EFFECT OF TIME DELAY AND FRUIT CONDITION ON QUALITY AND VALUE.

model achieves this by sorting samples of harvest according to degree of ripeness. The most convenient place to do this is at the reception station of the Mill. Under estate or plantation environment, the control can be effected at the collection points in the field in order to check the discipline of the harvesters, and ensure that the minimum ripeness critera are being obeyed.

The assessment of the incoming crop quality on daily basis and the analysis of a farmer's supply by this model is very useful both to the Mill manager and the grower. The data collected in the analysis using the forms designed for that purpose (see Appendix 11 and 12), could be periodically compared with that from previous analyses. Under estate or plantation environment by following these data every day, one may know whether because of change in climate or other factors, crops are becoming more unripe or ripe, whether minimum ripeness criteria and harvesting cycle should be adjusted or not and whether loose fruits are collected completely or not. One may also account for changes in oil and free fatty acid content, whether oil content is declining because of an increase of losses in the processing mill or because of an increase in quantity of unripe bunches or because of incomplete fruiting and whether free fatty acid level is increasing because the number of over ripe bunches is increasing or not. Similarly, compiled monthly report to a farmer or supplier could also be of assistance in making adjustments where necessary.

Since there are many variable conditions, such as variety of planting, age of planting, climate, discipline and intelligence of the harvesters, etc., it is difficult to get experimental evidence upon which to base a definite ripeness criterion. Therefore, a decision on the minimum ripeness criterion and harvesting cycle for a certain planting should be made by trial and error. For this, harvest analysis data may be used. The right combination of minimum harvest ripeness criterion and harvesting interval is the one that will yield a crop composition as shown by harvest analysis data, which is in accordance with quality and quantity requirements. Examples of such harvest analysis are shown in the appendices. Once the right criterion and cycle are found, these may be adjustd later when required as indicated by harvest analysis data. An unripe harvest which has too many unripe bunches, is not only the result of a too low criterion or too short harvesting rounds, but also the result of low discipline of harvesters. In which case, the farmers should also learn to set up high incentives for the harvesters, if they hope to enjoy the benefit of the quality control measures.

The sensitivity tests were made to identify the degree of this model response to various input variables. The examples of these test results are presented in Table 5.19.

From Table 5.19, the first sensitivity analysis, with a

Table 5.19 The Sensitivity Analysis Results

Item		Sensitivity Analysis 1	2	3
Harvest Composition		25:50:25	20:60:20	15:70:15
	% detached fruit	28.75	29	29.25
	% FFA	1.14	1.14	1.15
	% oil in mesocarp	49.32	49.36	49.39
Net Present Value	Int. Rate/ Opp. Costs of Capital	10 yrs.	20 yrs.	33 yrs.
	10.54%	2269.88	1921.92	448.88
	11%	2194.03	1873.36	446.14
	12%	2043.29	1774.36	440.29
*Quality and Value	Time Delay in Days	U	M	S
	.5	1.09	1.49	1.69
		†(₦1.54)	(₦1.46)	(₦1.41)
	1	1.25	1.65	1.85
		(₦1.51)	(₦1.42)	(₦1.38)
	2	1.58	1.98	2.18
		(₦1.44)	(₦1.35)	(₦1.30)

*The first sensitivity analysis was for unbruised bunch, while the 2nd and 3rd runs were for bunches with different degrees of damage, in this case moderately and severely bruised, respectively.

† Value of bunch.

₦ Nigerian currency (1 ₦ = $1.33)

harvest composition of 25:50:25, the percentage detached fruit is 28.75, the percentage free fatty acid is 1.14 and the percentage oil in mesocarp is 49.32. In the second analysis, with harvest composition 20:60:20, the percentage fruit is 29.00, the percentage free fatty acid is 1.14 and the percentage oil in mesocarp is 49.36, and in the third analysis with harvest composition 15:70:15, the percentage detached fruit is 29.25, percentaged free fatty acid is 1.15 and percentage oil in mesocarp is 49.39. The table shows that 20% increase in the proportion of ripe fruit and the same percentage decrease in the proportion of unripe and over ripe fruit, there is little or no effect on the quality, in terms of free fatty acid content (1.14%). But with 40% increase in the proportion of ripe fruit and the same percentage decrease in the proportion of unripe and very ripe fresh fruit bunches, there is an increase in free fatty acid content from 1.14% to 1.15%. The model, therefore, is not very sensitive to small changes in a harvest composition, especially when the ripe proportion is double or more than double the unripe and very ripe proportion.

The net present value at the interest rate of 10.54% is ₦2269.88 at the tenth year but with 11% interest rate, for the same year, there is a decrease of 3% (₦2194.03) and with 12% interest rate for the same year, there is a decrease of 7% (₦2043.29) but at the later year, for example 33rd year there is only 1% decrease irrespective of the rate of interest. The model is, therefore, more sensitive to the effect of interest rate, inflation, etc. at the, early life span of the palm tree and very insensitive to the effect of interest rate on net present value in the later years of the crop. This means that the effect of interest rate on the valuation especially in the later years is relatively small (see Figure 5.11).

The model is sensitive to the effect of time delay on quality and value of the fresh fruit bunches. The sensitivity of the effect of the bunch condition on its quality and value is very high and has an overriding effect on the time delay per se. For example, the table shows that an unbruised fresh fruit bunch delayed for two days has about the same value (₦1.44) as moderately bruised fresh fruit bunch delayed for only half a day. In addition the quality of severely bruised fresh fruit bunch (ffb), delayed for just half day is very much lower than the quality of an unbruised fresh fruit bunch delayed for two days. This means that much as it is important to transport the fresh fruit bunches to the Mill as soon as possible, it is more important to avoid bruising and damage as far as possible at all stages from the time of harvesting to the time of the fruit sterilization.

CHAPTER 6

Summary

The objective of oil palm cultivation is to produce the highest yield of good quality palm oil per unit area at the farmer's level. This last consideration requires harvesting with an interval of several days. Consequently the crop will consist of bunches at different stages of ripeness. Therefore, the ultimate goal of harvesting is to get a crop with a composition that has the largest number of exactly ripe bunches. Regular analysis of crop composition is a means of crop quality control. A system analysis approach was used in the analysis of the harvest composition and prediction of the quality and quantity of the oil from fresh fruit bunches (ffb) supplied in the "oil palm belt" of Nigeria.

The assessment of the incoming crop quality on daily basis and the analysis of a farmers supply by this model is very useful both to the mill manager and the grower. The data collected in the analysis could be compared with data from previous analysis periodically. Under estate or

plantation environment, by following these data every day, one may know whether because of change in climate or other factors, crops are becoming more unripe or ripe, whether minimum ripeness criteria and harvesting cycle would be adjusted or not and whether the loss due to increased loose fruit are prevalent or not. One may also account for changes in oil and free fatty acid content, whether oil content is declining because of an increase of losses in the processing mill or because of an increase in quantity of unripe bunches or because of incomplete fruiting and whether free fatty acid level is increasing because the number of over ripe bunches is increasing or not. Similarly, a compiled monthly report to a farmer or supplier could also be of assistance in making adjustments where necessary.

The discounting technique and capital profile method are used as the economic framework for estimating returns from the oil palm trees and tracing the pattern of capital requirement throughout the economic life of the tree.

Crop quality control by harvest analysis, using this model, which sorts the fresh fruit bunches into different bunch codes or classes according to different degree of ripeness, as described in the main text, is very useful both for the mill manager, field manager and the grower. By this means the manager may account for processing results, especially a decrease of oil yield and increase of free fatty acid caused by field factors. The field manager or grower may decide at the right time to adjust the minimum harvest ripeness criterion and harvesting cycle to changing outside factors, like influence of climate, age and others.

For the 'oil palm belt' area, a minimum harvesting standard of twelve loose fruit is suggested if 30% detached fruit is the target. At the mill end, the management should aim at having as many bunches as possible within the range of 28% to 31% detached fruit to total fruit. The color of the outer fruit should be at least 70% ripe color. However, color alone cannot be used as a ripeness criterion, especially by inexperienced harvesters because of the variation in color within bunches in the same class of ripeness. These variations suggest that visual symptoms of ripeness can indicate either apparent or optimum ripeness of a bunch and harvesting the bunches on the basis of visual assessment only can lead to either high or low free fatty acid (ffa). In addition when the harvester has to harvest a bunch from a height, particularly when it is partially hidden from view by the subtending fronds, a certain amount of error in judgement is unavoidable. Although the change in color is highly correlated to change in percentage free fatty acid, for more accurate assessment of ripeness, other factors in addition to color changes should be used. The use of color as an indicator will be more accurate if the harvesters are given some special training.

It is apparent from all these basic considerations that the most important requirement for obtaining oil of low ffa content from ripe fruit is to avoid bruising and damage as far as possible at all stages from the time of harvesting to the time of processing. The management or grower should ensure that unripe and very ripe bunches are kept to a minimum and that all loose fruit are collected.

CHAPTER 7

Conclusions

1. The number of loose fruit as it is used by the harvesters in the field and the percentage detached fruit are highly correlated and predict the degree of ripeness very effectively. Therefore, the quality control measures can be enforced from the Mill reception end by relating the percentage detached fruit at the Mill to the number of loose fruit at the base of the tree.
2. The control of percentage detached fruit alone does not affect the choice of appropriate premium substantially and, therefore, has little or no effect on the revenue accruing to the farmer. The world market price of ₦800 per ton of oil and the quality premium award of 1 percent per every percent below 5 percent are not enough to encourage Nigeria growers to produce high quality oil. To recapture market share, Nigeria must offer artificial incentives not based on

world market premiums.

3. Although the change in color is highly correlated to change in percentage free fatty acid, color alone cannot be used as a ripeness criterion, especially by inexperienced harvesters because of the variation in color within bunches in the same class of ripeness.
4. The quality control model can supply information necessary to take management decisions related to adjustment of harvesting system. The model can predict a yield in terms of quantity (oil in mesocarp), and quality (percent free fatty acid content).
5. Based on the simulation results the most important requirement for obtaining oil of low free fatty acid content from ripe fruit is to avoid bruising and damage as far as possible at all stages from time of harvesting to the time of processing.

CHAPTER 8

Suggestions for Further Study

In this study, it is assumed that the effects of weather can be minimized by good supervision and discipline. The effect of exogenous variables like weather effects, soil fertility and other environmental factors on different types and ages of palm should be studied.

The model developed in this way should further be expanded to include labor availability and its relation to fruit quality.

In this study, it is assumed that within broad limits, changes in harvesting systems do not significantly affect the harvesting cost. This is not necessarily true. So an in-depth study is required to assess and put cost to any combination of harvesting interval and harvesting standard by considering the amount of loose fruit and the walking time between palms containing ripe bunches. This cost can then be used in conjunction with the oil yield and oil quality data to obtain the optimal harvesting system.

The effort required to develop a workable model, from a measurement concept, in the absence of instrumentation (spectrophotometers) to follow changes during maturation of the oil palm bunches, can indeed be quite substantial. However, the development of effective instrumentation and measurement techniques for quality evaluation and quality control is one of many important challenges for scientists and engineers in the oil palm industry. The future need for such instruments will become even more important in view of increasing labor costs and the trend toward mechanical harvesting and handling of oil palm bunches.

APPENDICES

Appendix 1 Input Format for the Oil Palm Quality Control Model

Input	Description
Premium:	This is the quantity premium which could vary on a daily basis.
Farmers Name:	The name of the farmer or field supervisor's name in the case of a government estate.
The State Name:	The State of origin where the plantation is located.
The Name of Plantation:	The name of the plantation, but in the case of a government owned estate, the field number should be entered.
The Variety:	Three varieties are considered and these are (1) Pisifera, (2) Tenera and (3) Dura.
Number of Detached Fruit:	N or W. This is entered either in number or weight.
Bunch Weight:	The weight of the bunch is entered in kilograms.
Time Delay:	Time delay is entered in days. This is the time delay between the time the fresh fruit bunches (ffb) are harvested and their delivery at the mill for processing.
Condition of the Fruit:	U = unbruised M = moderately bruised S = severely bruised V = very severely bruised X = extremely bruised Help = gives more detailed explanation to aid classification of degree of bruising
Age:	The age of the palm tree in years.

Appendix 2 Price of Fresh Fruit Bunches Based on Bunch Code

Bunch Code	Price (₦/Ton)
0	Green Bunches Rejected
1	10.00
2	40.00
3	75.00
4	75.00
5	40.00
6	10.00

The above is the suggested computer simulation prices based on degree of ripeness. Current price is ₦75/ton for any fresh fruit bunch accepted irrespective of the degree of ripeness.

Appendix 3 Percentage FFA from Fruit Bunches at Different Stages of Ripeness from Different Estates - Tenera

Estate (L)	Average Bunch Weight (K)	Bunch Degree of Ripeness	No. of Loose Fruits (W)	No. of Tests	% FFA (Y)	Bunch Color (CO)	% of Ripe Color (X)	% Detached Fruits (Z)
Elele (A)	11	very unripe	0	4	.75	green	0	0
	14	unripe	3	4	.81	yellow green	37	6
	14.5	under ripe	6	6	1.01	yellow orange (tint)	53	15
	15	just ripe	12	6	1.20	orange (shade)	69	37
	17	ripe	20	5	1.48	red orange (tone)	77	50
	17	over ripe	29	5	1.90	red	89	69
	18	very over ripe	36	5	2.17	red	100	85
Cowan (B)	12	very unripe	0	6	.60	green	0	0
	15	unripe	4	6	.67	yellow green	40	7
	15	under ripe	8	10	.80	yellow orange	50	17
	17	just ripe	14	10	1.21	orange	68	30
	15	ripe	23	5	1.70	red orange	82	55
	16.5	over ripe	30	5	1.91	red	88	70
	17.5	very over ripe	35	5	2.21	red	100	90
NIFOR (C)	13	very unripe	0	6	.60	green	0	0
	16	unripe	3	6	.67	yellow green	43	8
	17	under ripe	5	10	.73	yellow orange	47	12
	16	just ripe	13	10	1.35	orange	73	35
	16	ripe	18	6	1.63	red orange	81	50
	19	over ripe	28	6	2.05	red	93	76
	20	very over ripe	35	6	2.22	red	100	85
MEAN	12	very unripe	0	16	.65	green	0	0
	15	unripe	3	16	.72	yellow green	40	7
	15.5	under ripe	6	26	.85	yellow orange	50	15
	16	just ripe	13	26	1.25	orange	70	34
	16	ripe	20	16	1.60	red orange	80	52
	17.5	over ripe	29	16	1.95	red	90	72
	18.5	very over ripe	35	16	2.20	red	100	87

Appendix 4 Pisifera: Percentage Free Fatty Acid from Fruit Bunches at Different Degrees of Ripeness Data Collected from Nigerian Institute for Oil Palm Research (NIFOR)

Bunch Code (CO)	Bunch Weight (K)	% Detached Fruits (Z)	% FFA (Y)	Bunch Color (BC)	% Ripe Color (X)
0	14	0	.60	Green	0
1	14.5	6	.70	Yellow Green	35
2	16	12.5	.82	Yellow Orange	50
3	17	32	1.2	Orange	70
4	17	56	1.5	Red Orange	90
5	16.5	75	1.9	Red	95
6	17.5	88	2.15	Red	100

Appendix 5 Dura: Percentage Free Fatty Acid from Fruit Bunches at Different Degrees of Ripeness Data Collected from Nigerian Institute for Oil Palm Research (NIFOR)

Bunch Code (CO)	Bunch Weight (K)	% Detached Fruits (Z)	% FFA (Y)	Bunch Color (BC)
0	10	0	.37	Black
1	14	9.5	.73	Black
2	14	16	1.06	Black
3	14.5	30	1.30	Black (shiny)
4	12	45	1.65	Black (shiny)
5	15	75	2.05	Black (shiny)
6	16	94	2.30	Black (shiny)

Appendix 6 Mean Bunch Weight (kg) and Corresponding Age for Different Varieties - Dura, Tenera, and Pisifera on an Inland Loan Soil

Age	Dura Weight	Tenera Weight	Pisifera Weight
2-3	--	4.05	4.65
3-4	5.18	5.10	5.63
4-5	6.53	6.01	5.77
5-6	6.76	7.52	7.50
6-7	8.71	9.19	9.20
7-8	10.36	10.81	11.49
8-9	11.71	11.26	11.89
9-10	12.69	NA	11.49
10-11	13.36	NA	14.08
Mean Weight	9.41	7.71	9.07
Variance	9.46	7.92	11.18
Standard Deviation	3.07	2.81	3.34
Coefficient Variation	33%	36%	37%

Source: Cowan Estate, Ajagbodudu, Bendel State.

Appendix 7 Mean Bunch Weight (kg) and Age of Palm for Tenera, Pisifera and Dura

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Linear Regression Analysis

Tenera $Y = A + B*X$

Intercept, A = -5.785656E-02
Slope, B = 1.293929

Source	Sum of Sq.	Deg. Freedom	Mean Sq.
Regression	46.87901	1	46.87901
Residual	.6575241	5	.1315048
Total	47.53653	6	

F= 356.4813

Coeff. of Determination = .98
Coeff. of Correlation = .99

Standard Error of Estimate = .3626359

Linear Regression Analysis

Pisifera $Y = A + B*X$

Intercept, A = .7326107
Slope, B = 1.192167

Source	Sum of Sq.	Deg. Freedom	Mean Sq.
Regression	85.27579	1	85.27579
Residual	4.230744	7	.604392
Total	89.50653	8	

F= 141.0935

Coeff. of Determination = .95
Coeff. of Correlation = .97

Standard Error of Estimate = .7774265

Linear Regression Analysis

Dura $Y - A + B*X$

Intercept, A = 7.678604E-02
Slope, B = 1.244762

Source	Sum of Sq.	Deg. Freedom	Mean Sq.
Regression	65.07619	1	65.07619
Residual	1.177048	6	.1961746

F= 331.7258

Coeff. of Determination = .98
Coeff. of Correlation = .99

Standard Error of Estimate = .4429161

Appendix 8 Tenera: Simulated Harvest Compcsitions with Associated Percentage Detached Fruit, Percentage Free Fatty Acid and Percentage Oil Content and Revenue (₦/kg)

Harvest Composition	% Detached Fruit	% FFA Content	% Oil Content	Revenue (₦/kg)
0:100:0	30	1.16	49.49	0.0848
5:95:0	29	1.14	49.36	0.0853
10:90:0	28	1.12	49.23	0.0853
15:85:0	27	1.10	49.10	0.0858
20:80:0	26	1.09	48.97	0.0858
25:75:0	25	1.07	48.84	0.0862
30:70:0	24	1.05	48.71	0.0863
35:65:0	23	1.03	48.58	0.0866
40:60:0	22	1.01	48.45	0.0868
50:50:0	20	.98	48.19	0.0872
0:95:5	30	1.17	49.58	0.0850
0:90:10	31.5	1.19	49.68	0.0847
0:85:15	32.2	1.20	49.78	0.0846
0:80:20	33	1.22	49.88	0.0844
0:75:25	33.7	1.23	49.97	0.0842
0:70:30	34	1.24	50.08	0.0841
0:65:35	35.2	1.26	50.17	0.0839
0:60:40	36	1.27	50.27	0.0838
0:55:45	36.7	1.28	50.36	0.0836
0:50:50	37.5	1.30	50.46	0.0834
25:50:25	28.7	1.14	49.32	0.0853
20:60:20	29	1.14	49.36	0.0853
15:70:15	29.2	1.15	49.39	0.0838
10:80:10	29.5	1.15	49.42	0.0838
5:90:5	29.7	1.16	49.45	0.0851
5:85:10	30.5	1.17	49.55	0.0850
15:75:10	28.5	1.13	49.29	0.0854
5:80:15	31.2	1.18	49.65	0.0848
20:40:40	32	1.20	49.75	0.0846
40:40:20	25	1.07	48.84	0.0862
20:70:10	27.5	1.11	49.16	0.0857
10:85:5	28.7	1.14	49.32	0.0853
50:25:25	23.7	1.05	48.67	0.0863
25:25:50	32.5	1.21	49.81	0.0845
60:10:30	22.5	1.02	48.51	0.0868
30:10:60	33	1.20	49.88	0.0846
10:75:15	30.2	1.16	49.49	0.0848

Appendix 9 Pisifera: Simulated Harvest Compositions with Associated Percentage Detached Fruit, Percentage Free Fatty Acid and Percentage Oil Content

Harvest Composition	% Detached Fruit	% FFA Content	% Oil Content
0:100:0	30	1.12	49.49
5:95:0	29	1.10	49.36
10:90:0	28	1.08	49.23
15:85:0	27	1.06	49.10
20:80:0	26	1.05	48.97
25:75:0	25	1.03	48.84
30:70:0	24	1.01	48.71
35:65:0	23	.99	48.58
40:60:0	22	.98	48.45
50:50:0	20	.94	48.19
0:95:5	30.7	1.13	49.58
0:90:10	31.5	1.14	49.68
0:85:15	32.2	1.15	49.78
0:80:20	33	1.17	49.88
0:75:25	33.7	1.18	49.97
0:70:30	34.5	1.19	50.07
0:65:35	35.2	1.21	50.17
0:60:40	36	1.22	50.27
0:55:45	36.7	1.23	50.36
0:50:50	37.5	1.24	50.46
25:50:25	28.7	1.09	49.32
20:60:20	29	1.10	49.36
15:70:15	29.2	1.10	49.39
10:80:10	29.5	1.11	49.42
5:90:5	29.7	1.11	49.45
5:85:10	30.5	1.12	49.55
15:75:10	28.5	1.09	49.29
5:80:15	31.2	1.14	49.65
10:60:30	32.5	1.16	49.81
20:40:40	32	1.15	49.75
40:40:20	25	1.03	48.84
30:60:10	25.5	1.04	48.90
20:70:10	27.5	1.07	49.16
10:85:5	28.7	1.09	49.32
50:25:25	23.7	1.01	48.67
25:25:50	32.5	1.16	49.81
60:10:30	22.5	.99	48.51
30:10:60	33	1.17	49.88
10:75:15	30.2	1.12	49.52

Appendix 10 Dura: Simulated Harvest Compositions with Associated Percentage Detached Fruit, Percentage Free Fatty Acid and Percentage Oil Content

Harvest Composition	% Detached Fruit	% FFA Content	% Oil Content
0:100:0	30	1.18	49.49
5:95:0	29	1.16	49.36
10:90:0	28	1.14	49.23
15:85:0	27	1.12	49.10
20:80:0	26	1.10	48.97
25:75:0	25	1.08	48.84
30:70:0	24	1.06	48.71
35:65:0	23	1.04	48.58
40:60:0	22	1.02	48.45
50:50:0	20	.98	48.19
0:95:5	30.7	1.19	49.58
0:90:10	31.5	1.21	49.68
0:85:15	32.2	1.22	49.78
0:80:20	33	1.24	49.88
0:75:25	33.7	1.25	49.97
0:70:30	34.5	1.27	50.07
0:65:35	35.2	1.28	50.17
0:60:40	36	1.29	50.27
0:55:45	36.7	1.31	50.36
0:50:50	37.5	1.32	50.46
25:50:25	28.7	1.15	49.32
20:60:20	29	1.16	49.36
15:70:15	29.2	1.16	49.39
10:80:10	29.5	1.17	49.42
5:90:5	29.7	1.17	49.45
15:75:10	28.5	1.15	49.29
5:80:15	31.2	1.20	49.65
10:60:30	32.5	1.23	49.81
20:40:40	32	1.22	49.75
40:40:20	25	1.08	48.84
30:60:10	25.5	1.09	48.90
20:70:10	27.5	1.13	49.16
10:85:5	28.7	1.15	49.32
50:25:25	23.7	1.06	48.67
25:25:50	32.5	1.23	49.81
60:10:30	22.5	1.03	48.51
10:75:15	30.2	1.18	49.52

Appendix 11 A Sample of a Monthly Report Sheet on a Fresh Fruit Bunch Analysis

Estate: **Month:** **Year:**

Day	%UR	%RF	%VR	Bruised	Diseased Bunches %	Rotten Bunches %	Satisfactory FFB%
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							
27							
29							
30							

UR = Unripe Fruit, FR = Ripe Fruit, VR = Very Ripe Fruit, FFB = Fresh Fruit Bunches

Appendix 12 A Sample Sheet for Recording the Quality of Fruit Delivered to a Mill

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Estate: Farmer's Name Source:

Lorry/ Tractor No.	Date Harvested	Field Number	Date & Ex-Estate	Date & Time at Factory

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Fruit Bunch Information:

(a) Variety

(b) No. of detached fruits before cutting the bunch

No. of detached fruits after cutting the bunch

Total No. of detached fruits/weight in kg =

(c) Bunch weight in kilograms =

(d) Bunch Conditions: Bruised Unbruised

Diseased No. of bunches

Rotten No. of bunches

(e) Height of tree (measured from the crown) ft:

Age (yrs.)

(f) Estimate of time delay (in days)

Remarks:

Appendix 13 Pisifera: Simulated Fresh Fruit Bunches at Mill Reception

Sample #1		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	1(W)	2(W)	4(W)	6(W)	8(W)
2.	Wt. of Bunch (kg)	18	18	18	18	18
3.	Time Delay in Days	0	0	0	0	0
4.	Condition of Bunch	(U)	(U)	(U)	(U)	(U)
5.	Age of Palm	16	16	16	16	16
(a)	Degree of Ripeness	Unripe	Under Ripe	Just Ripe	Ripe	Over Ripe
(b)	% FFA	.75	.91	1.22	1.53	1.84
(c)	Probable Color	Yellow Green or 50% Ripe Color	Yellow Orange or 50% Ripe Color	Orange or 70% Ripe Color	Red Orange or 70% Ripe Color	Red or 95% Ripe Color
(d)	Std. Premium	0	0	₦ .006	₦ .003	0
(e)	Subtotal	₦ .18	₦ .72	1.45	₦1.41	₦ .72
(f)	Extra Amt. Due Premium			₦ .10	₦ .06	

(g) Total Amount Due Farmer ₦4.48

(h) Quantity Premium 0

(i) Harvest Composition 40:40:20

(j) Oil Per Mesocarp 48.84: Overall % FFA = 1.03%

(k) Loss Due to Unripe Harvest: ₦144/Acre or ₦360/ha.

(l) Loss Due to Over Ripe Harvest:

(m) Grand Total Amount Due Farmer: ₦4.48

Appendix 13 (cont'd.)

Sample #2		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	2 (W)	4 (W)	6 (W)	8 (W)	10 (W)
2.	Wt. of Bunch (kg)	20	20	20	20	20
3.	Time Delay in Days	2	2	2	2	2
4.	Condition of Bunch	(U)	(M)	(S)	(V)	(X)
5.	Age of Palm	19	19	19	19	19
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Ripe	Over Ripe	Very Over Ripe
(b)	% FFA	1.35	1.89	2.23	2.57	2.
(c)	Probable Color	Yellow Orange or 50% Ripe Color	Orange or 70% Ripe Color	Red Orange or 70% Ripe Color	Red or 95% Ripe Color	Red or 100% Ripe Color
(d)	Std. Premium	0	₦ .0008	-₦.001	-₦.002	-₦.0009
(e)	Subtotal	₦ .8	₦1.51	₦1.46	₦ .75	₦ .18
(f)	Extra Amt. Due Premium		₦ .01	-₦.03	-₦.04	-₦.01

(g) Total Amount Due Farmer ₦4.70

(h) Quantity Premium ₦.60

(i) Harvest Composition 20:40:40

(j) Oil Per Mesocarp 49.75: Overall & FFA = 1.15%

(k) Loss Due to Unripe Harvest:

(l) Loss Due to Over Ripe Harvest: ₦2.15/Acre or ₦5.39/ha.

(m) Grand Total Amount Due Farmer: ₦5.30

Appendix 13 (cont'd.)

Sample #3		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	3(W)	4(W)	6(W)	8(W)	10(W)
2.	Wt. of Bunch (kg)	18	18	18	18	18
3.	Time Delay in Days	1	1	1	1	1
4.	Condition of Bunch	(U)	(M)	(S)	(V)	(X)
5.	Age of Palm	15	15	15	15	15
(a)	Degree of Ripeness	Just Ripe	Just Ripe	Ripe	Over Ripe	Very Over Ripe
(b)	% FFA	1.18	1.66	2.01	2.37	2.72
(c)	Probable Color	Orange or 70% Ripe Color	Orange or 70% Ripe Color	Red Orange or 70% Ripe Color	Red or 95% Ripe Color	Red or 100% Ripe Color
(d)	Std. Premium	₦.006	₦.002	-₦.0001	-₦.001	-₦ .0007
(e)	Subtotal	₦1.46	1.39	1.34	₦.69	₦.16
(f)	Extra Amt. Due Premium	₦ .11	₦.04	-₦.002	-₦.02	-₦.01

(g) Total Amount Due Farmer ₦5.04

(h) Quantity Premium ₦.54

(i) Harvest Composition 0:60:40

(j) Oil Per Mesocarp 50.27: Overall % FFA = 1.22

(k) Loss Due to Unripe Harvest:

(l) Loss Due to Over Ripe Harvest: ₦2.69/ha if 5 tons were harvested

(m) Grand Total Amount Due Farmer: ₦5.58

Appendix 13 (cont.'d.)

Sample #4		Bunch # 1	2	3	4	5	6
1.	Detached Fruit: (Wt. or Number)	2(W)	3(W)	4(W)	6(W)	8(W)	10(W)
2.	Wt. of Bunch (kg)	22	22	22	22	22	22
3.	Time Delay in Days	2	2	2	2	2	2
4.	Condition of Bunch	(U)	(M)	(S)	(S)	(S)	V)
5.	Age of Palm	24	24	24	24	24	24
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Just Ripe	Ripe	Ripe	Over Ripe
(b)	% FFA	1.34	1.80	2.06	2.19	2.32	2.64
(c)	Probable Color	Yellow Orange or 50% Ripe Color	Orange or 70% Ripe Color	Orange or 70% Ripe Color	Red Orange or 70% Ripe Color	Red Orange or 70% Ripe Color	Red or 95% Ripe Color
(d)	Std. Premium	0	₦ .002	-₦.000	-₦.002	-₦.00	-₦.002
(e)	Subtotal	₦.88	₦1.68	₦1.63	₦1.61	₦1.59	₦ .83
(f)	Extra Amt. Due Premium		₦ .03	-₦.01	-₦.03	-₦.06	-₦.04

(g) Total Amount Due Farmer ₦8.22

(h) Quantity Premium ₦1.32

(i) Harvest Composition 16:67:17

(j) Oil Per Mesocarp 49.41: Overall % FFA = 1.10

(k) Loss Due to Unripe Harvest: ₦144/Acre

(l) Loss Due to Over Ripe Harvest: ₦2.15/Acre

(m) Grand Total Amount Due Farmer: ₦9.54

Appendix 13 (cont'd.)

Sample #5		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	2(W)	4(W)	8(W)	8(W)	10(W)
2.	Wt. of Bunch (kg)	20	20	20	20	20
3.	Time Delay in Days	0	0	0	0	0
4.	Condition of Bunch	(U)	(U)	(U)	(M)	(U)
5.	Age of Palm	19	19	19	19	19
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Over Ripe	Over Ripe	Very Over Ripe
(b)	% FFA	.88	1.15	1.71	1.71	1.99
(c)	Probable Color	Yellow Orange or 50% Ripe Color	Orange or 70% Ripe Color	Red or 90% Ripe Color	Red or 90% Ripe Color	Red or 100% Ripe Color
(d)	Std. Premium	Ø	₦ .006	0	0	Ø
(e)	Subtotal	₦ .8	₦1.63	₦ .8	₦ .8	₦ .2
(f)	Extra Amt. Due Premium		₦ .13			

(g) Total Amount Due Farmer ₦4.23

(h) Quantity Premium ₦.3

(i) Harvest Composition 20:20:60

(j) Oil Per Mesocarp 50.14: Overall % FFA 1.20

(k) Loss Due to Unripe Harvest:

(l) Loss Due to Over Ripe Harvest: ₦2.15/Acre or ₦5.39/ha.

(m) Grand Total Amount Due Farmer: ₦4.53

Appendix 14 Dura: Simulated Fresh Fruit Bunches at Mill Reception

Sample #1		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	1(W)	2(W)	4(W)	6(W)	8(W)
2.	Wt. of Bunch (kg)	18	18	18	18	18
3.	Time Delay in Days	0	0	0	0	0
4.	Condition of Bunch	(U)	(M)	(S)	(V)	(V)
5.	Age of Palm	16	16	16	16	16
(a)	Degree of Ripeness	Unripe	Under Ripe	Just Ripe	Ripe	Over Ripe
(b)	% FFA	.76	1.33	1.86	2.40	2.73
(c)	Probable Color	Black	Black	Shiny Black	Shiny Black	Shiny Black
(d)	Std. Premium	Ø	Ø	₦ .001	-₦.003	-₦.003
(e)	Subtotal	.18	.72	₦1.36	₦1.29	₦ .66
(f)	Extra Amt. Due Premium			₦ .01	-₦.05	-₦.05

(g) Total Amount Due Farmer ₦4.21

(h) Quantity Premium Ø

(i) Harvest Composition 40:40:20

(j) Oil Per Mesocarp 48.84: Overall % FFA ₦1.08

(k) Loss Due to Unripe Harvest: ₦144/Acre

(l) Loss Due to Over Ripe Harvest:

(m) Grand Total Amount Due Farmer: ₦4.21

Appendix 14 (Cont'd.)

Sample #2		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	2 (W)	4 (W)	6 (W)	8 (W)	10 (W)
2.	Wt. of Bunch (kg)	20	20	20	20	20
3.	Time Delay in Days	2	2	2	2	2
4.	Condition of Bunch	(U)	(M)	(S)	(V)	(X)
5.	Age of Palm	19	19	19	19	19
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Ripe	Over Ripe	Over Ripe
(b)	% FFA	1.46	2.01	2.36	2.71	3.06
(c)	Probable Color	Black	Shiny Black	Shiny Black	Shiny Black	Shiny Black
(d)	Std. Premium	Ø	-₦.0001	-₦.002	-₦.002	-₦.004
(e)	Subtotal	.8	1.49	1.44	₦.74	.71
(f)	Extra Amt. Due Premium		-₦.002	-₦.05	-₦.05	-₦.08

(g) Total Amount Due Farmer ₦5.18

(h) Quantity Premium ₦.6

(i) Harvest Composition 20:40:40

(j) Oil Per Mesocarp 49.75: Overall % FFA 1.22

(k) Loss Due to Unripe Harvest:

(l) Loss Due to Over Ripe Harvest: ₦2.15

(m) Grand Total Amount Due Farmer: ₦5.78

Appendix 14 (cont'd.)

Sample #3		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	3(W)	4(W)	6(W)	8(W)	10(W)
2.	Wt. of Bunch (kg)	18	18	18	18	18
3.	Time Delay in Days	1	1	1	1	1
4.	Condition of Bunch	(U)	(M)	(S)	(V)	(X)
5.	Age of Palm	15	15	15	15	15
(a)	Degree of Ripeness	Just Ripe	Just Ripe	Ripe	Over Ripe	Very Over Ripe
(b)	% FFA	1.24	1.72	2.09	2.45	2.82
(c)	Probable Color	Shiny Black	Shiny Black	Shiny Black	Shiny Black	Shiny Black
(d)	Std. Premium	₦ .005	₦ .002	-₦ .0007	-₦.001	-₦.0008
(e)	Subtotal	₦1.45	₦1.38	₦1.33	₦ .68	₦ .16
(f)	Extra Amt. Due Premium	₦ .10	₦ .03	-₦.01	-₦.03	-₦.01

(g) Total Amount Due Farmer ₦5.00

(h) Quantity Premium ₦.54

(i) Harvest Composition 0:60:40

(j) Oil Per Mesocarp 50.27: Overall % FFA 1.29

(k) Loss Due to Unripe Harvest:

(l) Loss Due to Over Ripe Harvest: ₦2.15/Acre or ₦5.39/ha.

(m) Grand Total Amount Due Farmer: ₦5.54

Appendix 14 (cont'd.)

Sample #4		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	2 (W)	3 (W)	4 (W)	6 (W)	8 (W)
2.	Wt. of Bunch (kg)	22	22	22	22	22
3.	Time Delay in Days	2	2	2	2	2
4.	Condition of Bunch	(U)	(M)	(S)	(S)	(S)
5.	Age of Palm	24	24	24	24	24
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Just Ripe	Ripe	Ripe
(b)	% FFA	1.45	1.92	2.19	2.32	2.46
(c)	Probable Color	Black	Shiny Black	Shiny Black	Shiny Black	Shiny Black
(d)	Std. Premium	Ø	₦ .0006	-₦.001	-₦.002	-₦.003
(e)	Subtotal	₦.88	₦1.66	₦1.61	₦1.59	₦1.57
(f)	Extra Amt. Due Premium		₦ .01	-₦.03	-₦.05	-₦.07

(g) Total Amount Due Farmer ₦7.31

(h) Quantity Premium ₦1.32

(i) Harvest Composition 20:80:0

(j) Oil Per Mesocarp 48.37: Overall % FFA = 1.105

(k) Loss Due to Unripe Harvest:

(l) Loss Due to Over Ripe Harvest:

(m) Grand Total Amount Due Farmer: ₦8.63

Appendix 14 (cont'd.)

Sample #5		Bunch # 1	2	3	4	5
1.	Detached Fruit: (Wt. or Number)	2(W)	4(W)	8(W)	8(W)	10(W)
2.	Wt. of Bunch (kg)	20	20	20	20	20
3.	Time Delay in Days	0	0	0	0	0
4.	Condition of Bunch	(U)	(U)	(U)	(M)	(U)
5.	Age of Palm	19	19	19	19	19
(a)	Degree of Ripeness	Under Ripe	Just Ripe	Over Ripe	Over Ripe	Over Ripe
(b)	% FFA	.90	1.20	1.80	2.20	2.10
(c)	Probable Color	Black	Shiny Black	Shiny Black	Shiny Black	Shiny Black
(d)	Std. Premium	Ø	₦ .006	Ø	-₦.0008	-₦.0004
(e)	Subtotal	₦ .8	₦1.62	.8	₦ .78	₦ .79
(f)	Extra Amt. Due Premium		₦ .12		-₦.01	-₦.008

(g) Total Amount Due Farmer ₦4.79

(h) Quantity Premium ₦.3

(i) Harvest Composition 20:20:60

(j) Oil Per Mesocarp 50.14: Overall % FFA = 1.28

(k) Loss Due to Unripe Harvest:

(l) Loss Due to Over Ripe Harvest: ₦2.15/Acre or ₦5.39/ha.

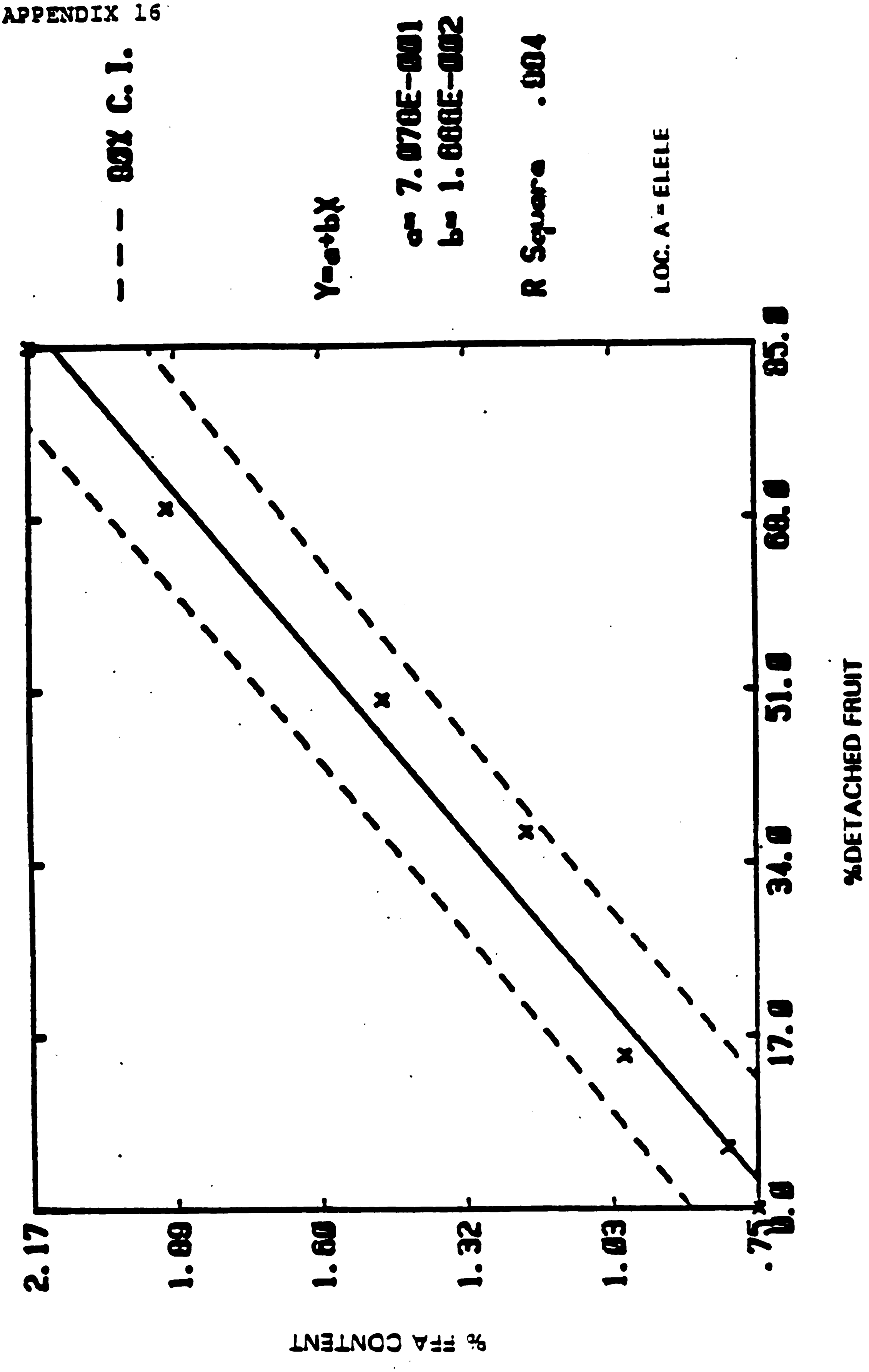
(m) Grand Total Amount Due Farmer: ₦5.09

Appendix 15 Analyses of Tenera Fruit Samples Obtained in a Prospection of Eastern Nigerian Groves

Area	Village	Number of Tenera	Average Fruit Weight (g)	Range of fruit weight (g)	Mesocarp (%)	Shell (%)	Range of Shell (%)	Kernel (%)
Awka	Egwuoba	102	9.5	14.7-5.5	78.8	10.6	4-20	10.7
	Akpugo	77	8.9	12.1-3.6	80.3	7.2	3-18	12.4
	Ufuma	31	8.6	14.8-5.2	81.1	7.8	3-17	11.1
	Akpu	47	12.3	15.3-7.8	87.4	4.2	2-8	8.4
	Ekwulobia	221	9.9	17.7-4.4	80.0	7.2	2-17	12.2
Nnewi	Ozubulu	73	10.2	18.0-5.3	81.9	7.6	2-21	10.3
	Nnewi	16	8.2	10.6-6.5	83.3	7.4	2-21	8.5
	Azia	28	10.0	15.9-6.5	77.6	9.6	3-25	12.6
	Ezinifite	19	7.7	11.3-4.0	73.4	11.7	3-25	12.6
Owerri	Orodo	70	12.3	18.2-6.6	88.6	3.7	1-11	7.6
	Mbieri	34	10.4	14.6-7.0	82.8	7.1	3-24	9.9
	Umuokauna	49	11.3	16.9-7.7	78.8	8.6	3-21	12.6
	Hile	13	7.7	9.0-5.2	74.4	14.4	8-22	11.4
Okigwe	Umukele	69	10.9	17.2-5.8	83.1	7.5	3-15	9.4
	Okigwe (East)	43	9.1	13.5-5.9	81.5	7.0	2-18	11.6
Aba(south)	Ogwe	17	13.0	17.5-8.4	74.1	9.6	6-12	16.2
	Ihie	27	11.7	20.0-8.4	74.0	12.1	7-25	13.9
	Azumini	33	9.8	12.0-7.4	68.7	10.8	4-25	20.6
Abak	Opoikot Anang	22	7.1	--	77.1	--	--	--
	Oblo Akpa	241	8.3	--	75.2	9.4	--	15.4
	Obonuny Ikot	59	9.8	--	75.3	6.7	--	18.0
	Ekeparakwa	319	8.9	--	84.7	6.1	--	9.2
Umuahia	Olo Umuahia	97	12.6	--	84.0	8.2	--	7.8
Ikot Ekpene	Ikot Ekpene	100	9.9	--	81.5	8.1	--	10.4
Arochuku	Arochuku	38	8.4	--	63.0	--	--	--
	Ikot Ekpika	106	6.2	--	83.3	6.8	--	9.9
	Ibiaku	119	7.1	--	86.2	11.5	--	2.3
Coast	Opobo	104	7.0	--	71.3	18.1	--	10.6
	Ndiya	135	8.8	--	73.4	12.5	--	14.1
	Eket	86	9.8	--	73.5	--	--	--
	Oron	133	5.3	--	70.5	10.0	--	19.5

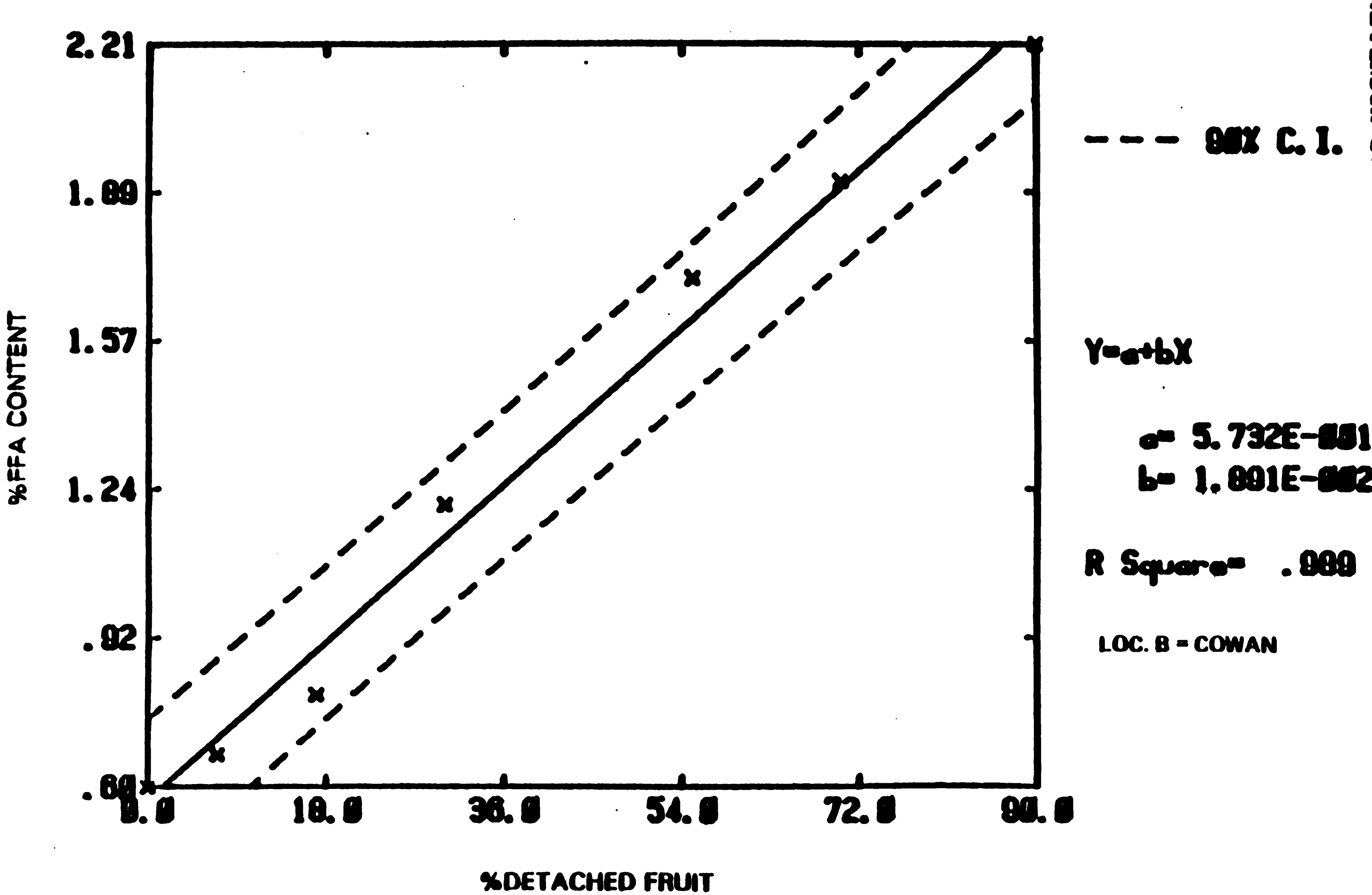
Source: Hartley, C.W.S. (1967)

APPENDIX 16



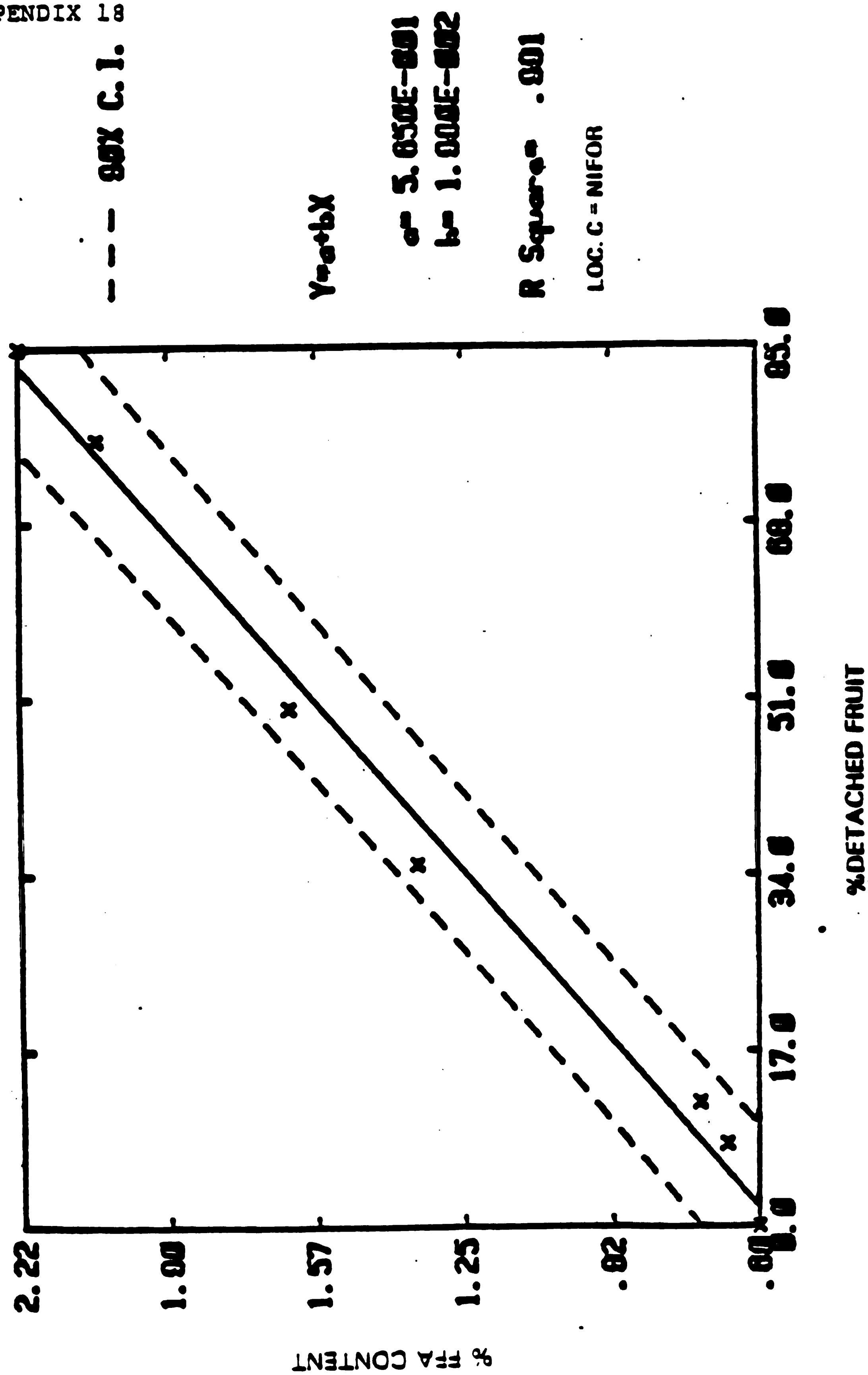
TENERA: %DETACHED FRUITS VS. %FFA LOCATION A

APPENDIX 17



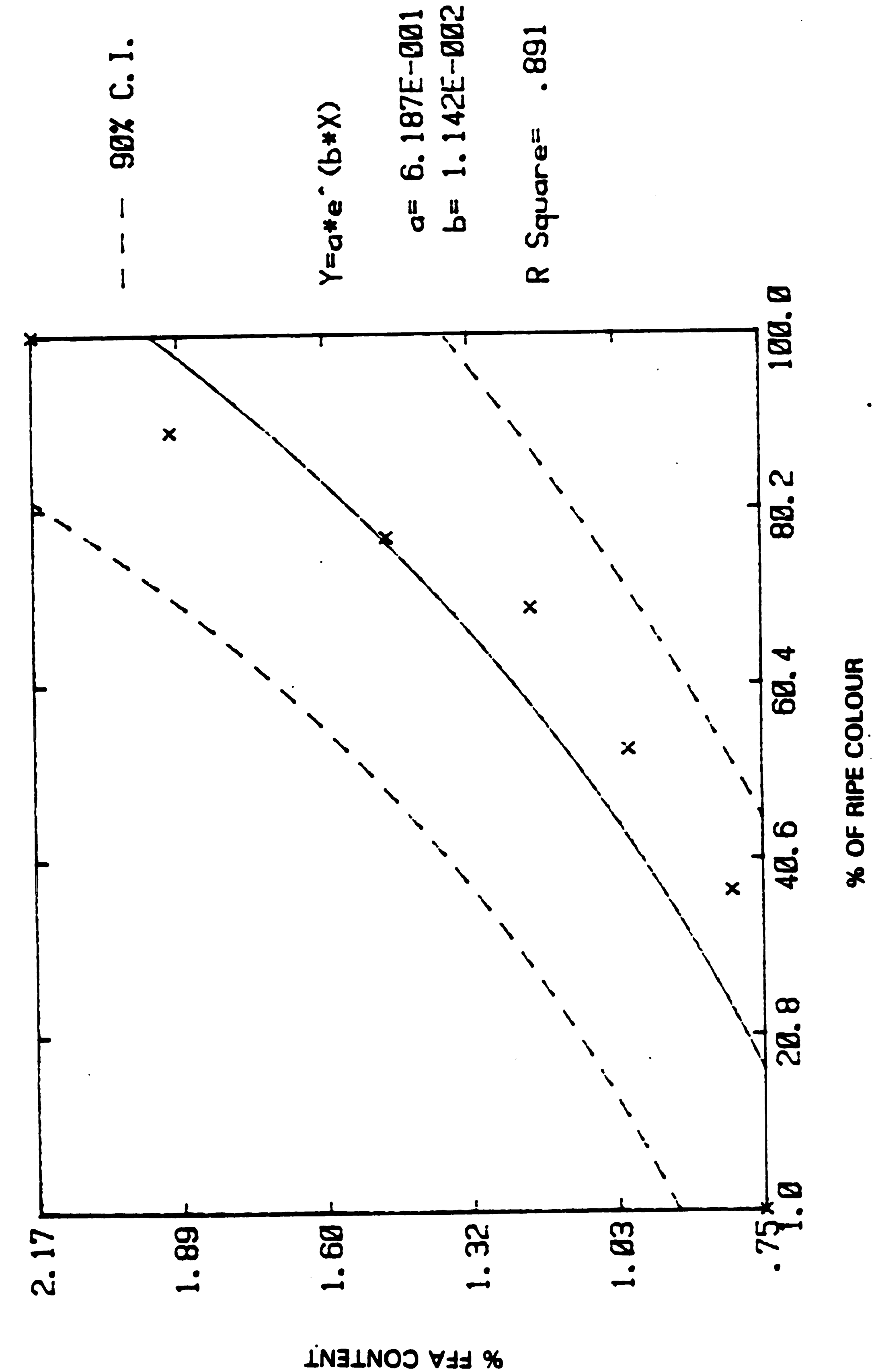
TENERA: %FFA VS. %DETACHED FRUIT LOCATION B

APPENDIX 18



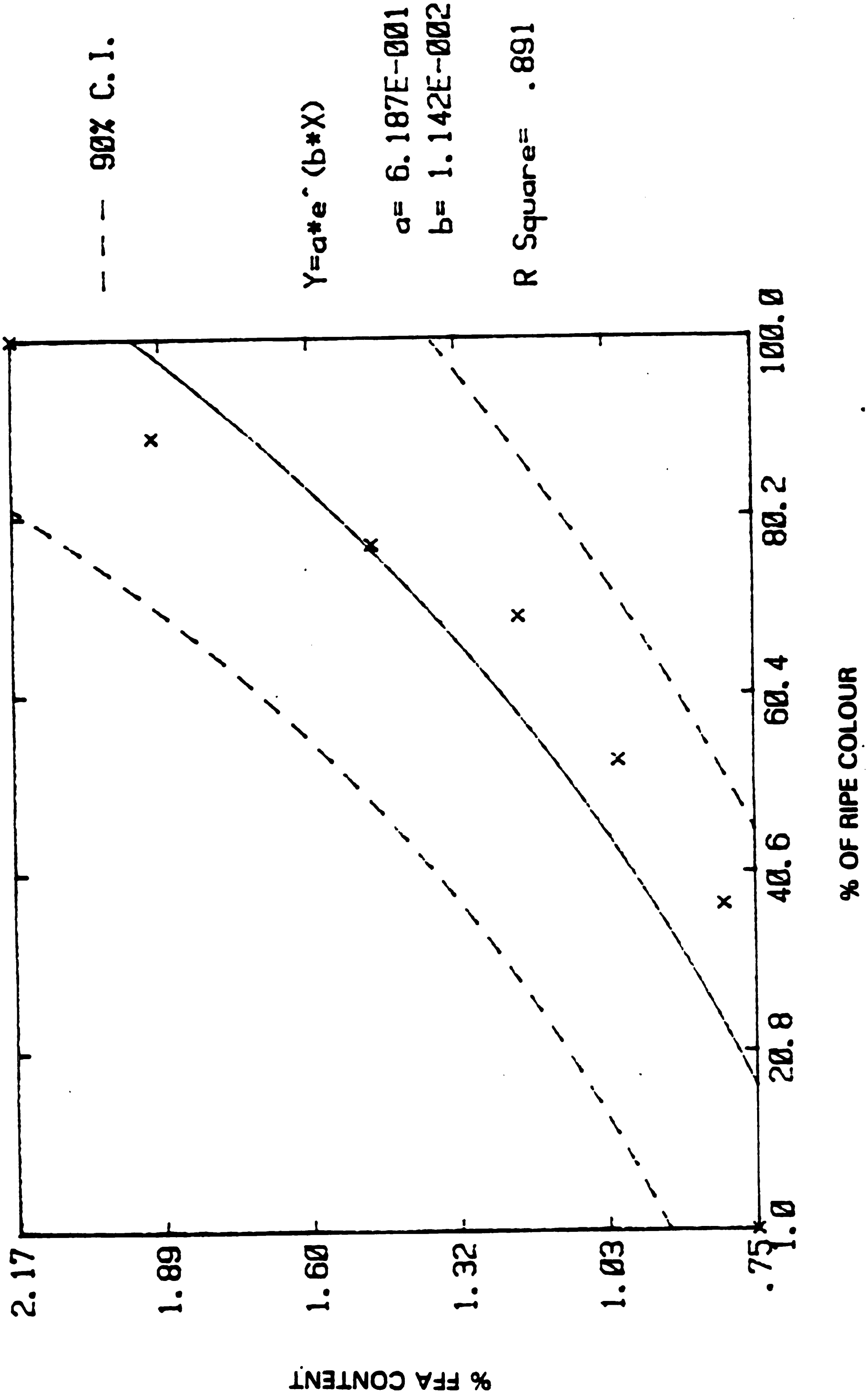
TENERA: %FFA VS. %DETACHED FRUIT LOCATION C

APPENDIX 19



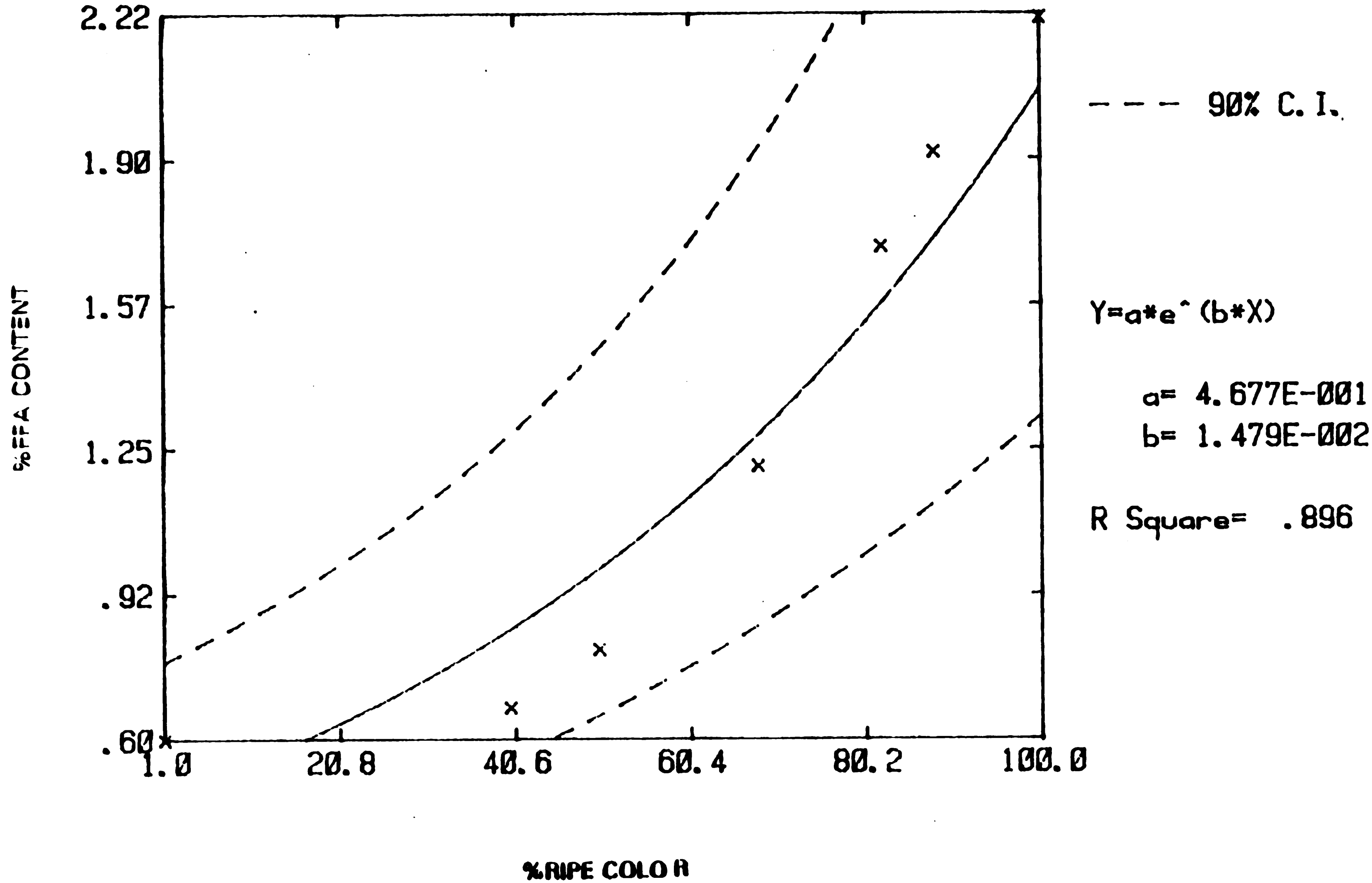
TENERA: %FFA VS %RIPE COLOUR LOCATION A

APPENDIX 19



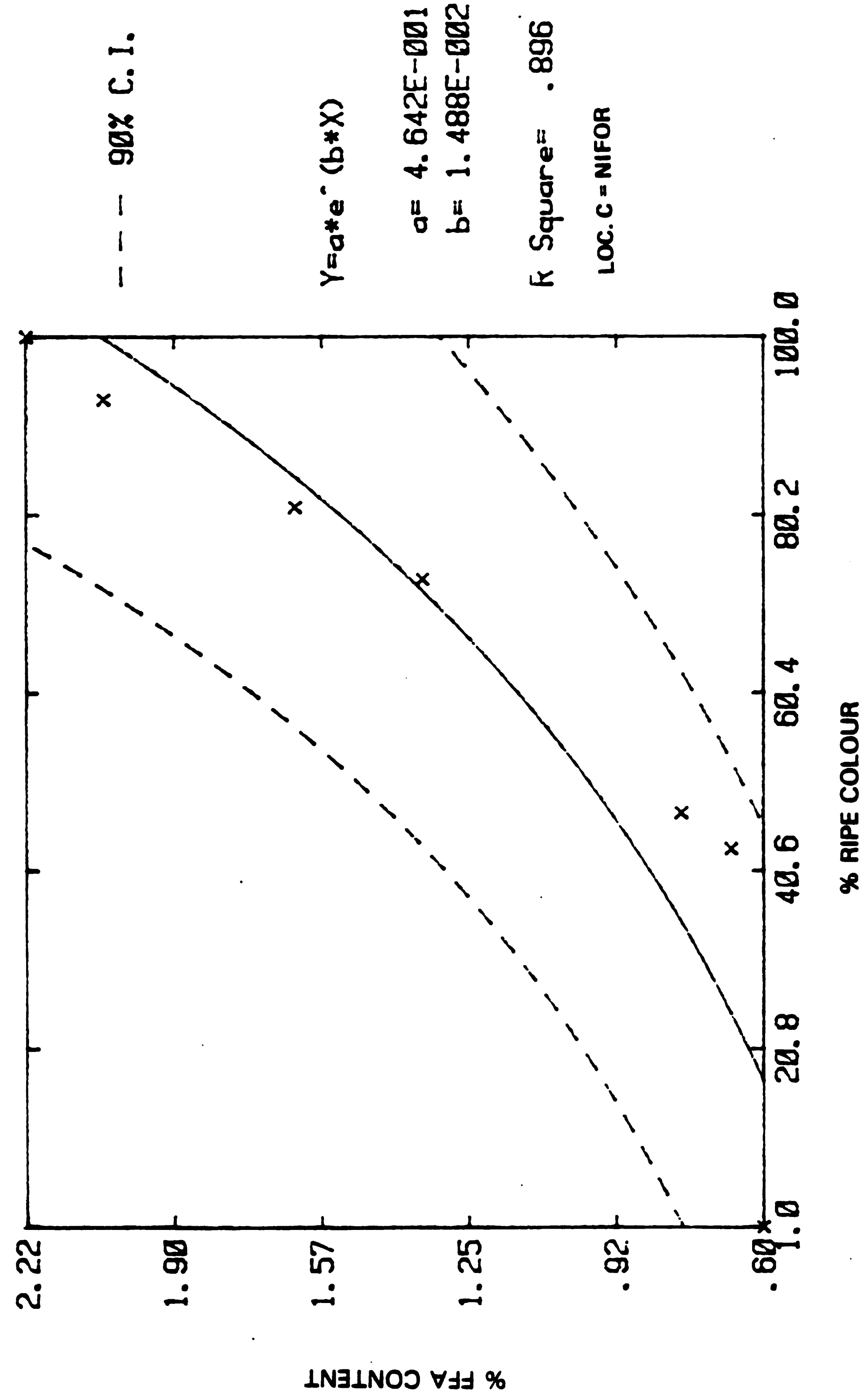
TENERA: %FFA VS %RIPE COLOUR LOCATION A

APPENDIX 20



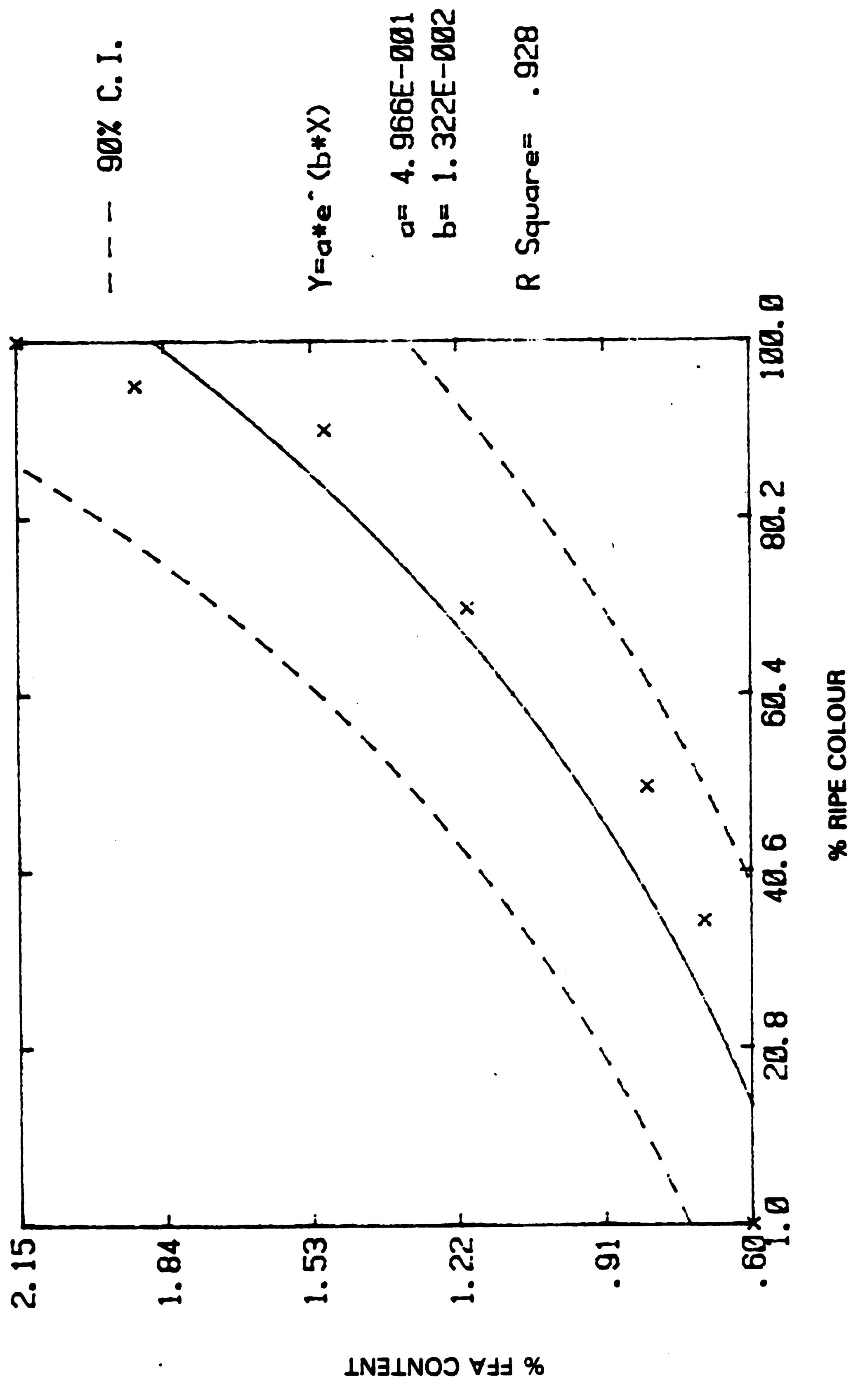
TENERA: %FA VS %RIPE COLOR · LOCATION B

APPENDIX 21



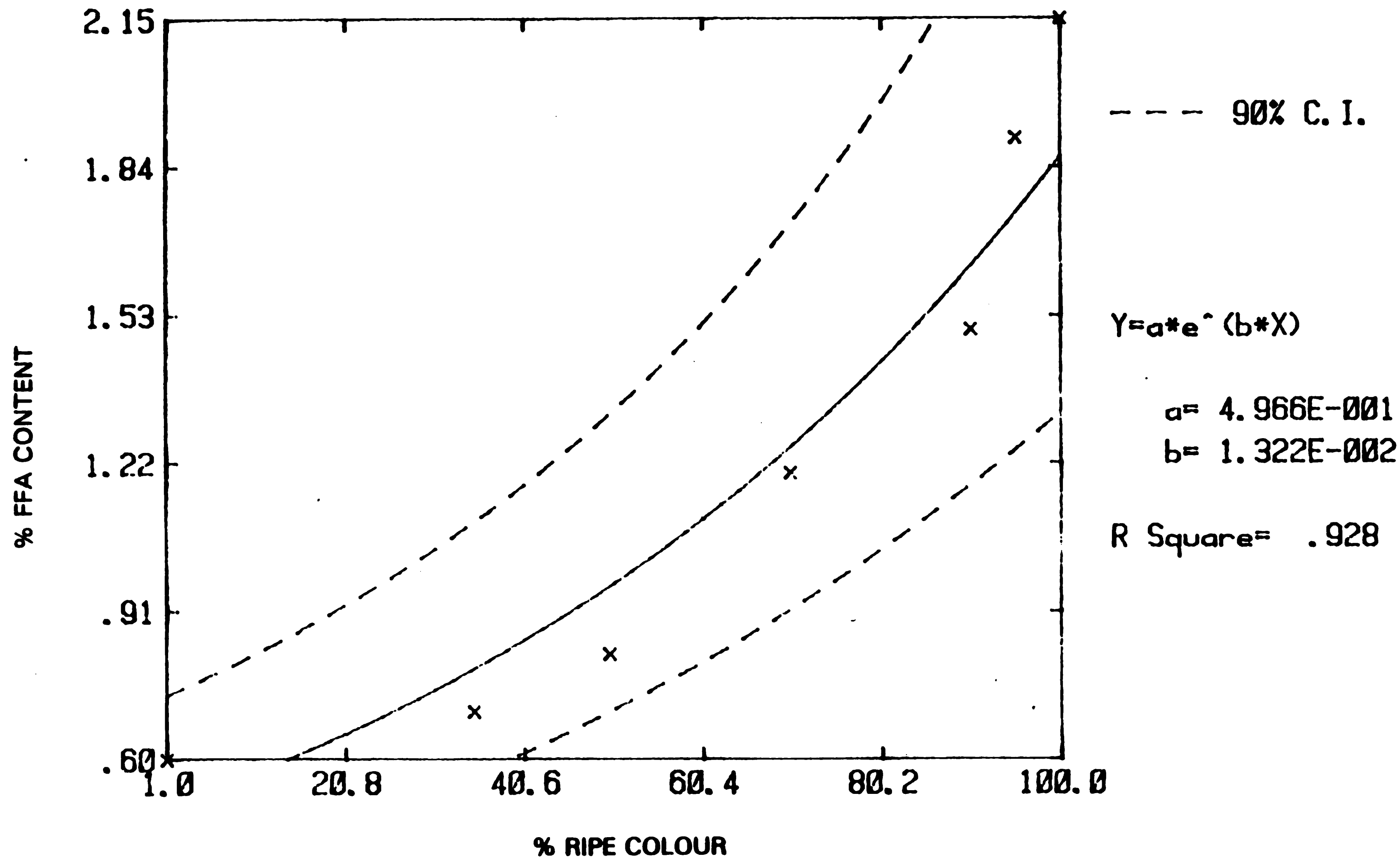
TENERA: %FFA VS %RIPE COLOUR LOCATION C

APPENDIX 22



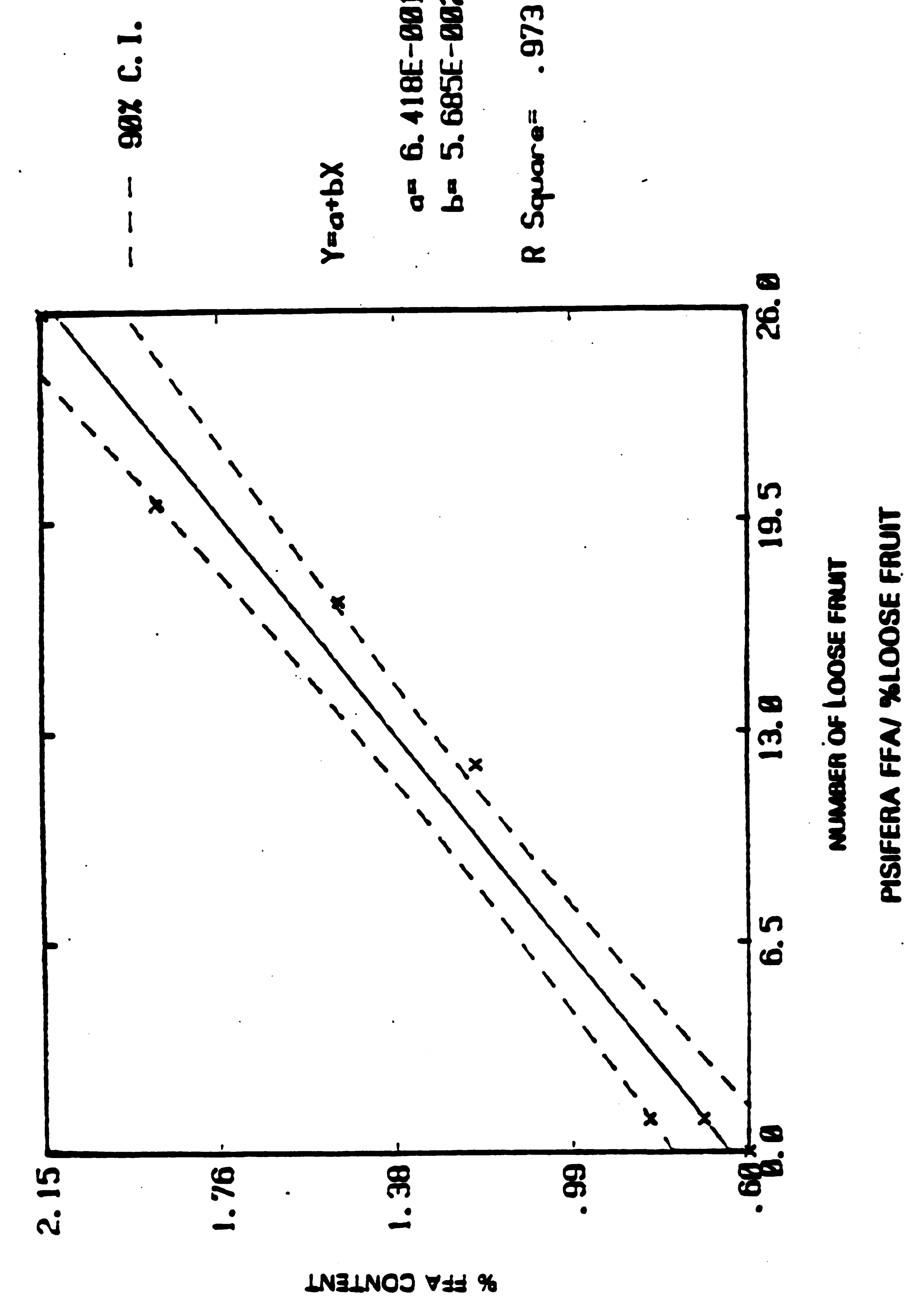
PISIFERA: %FFA & %RIPE COLOUR

APPENDIX 22



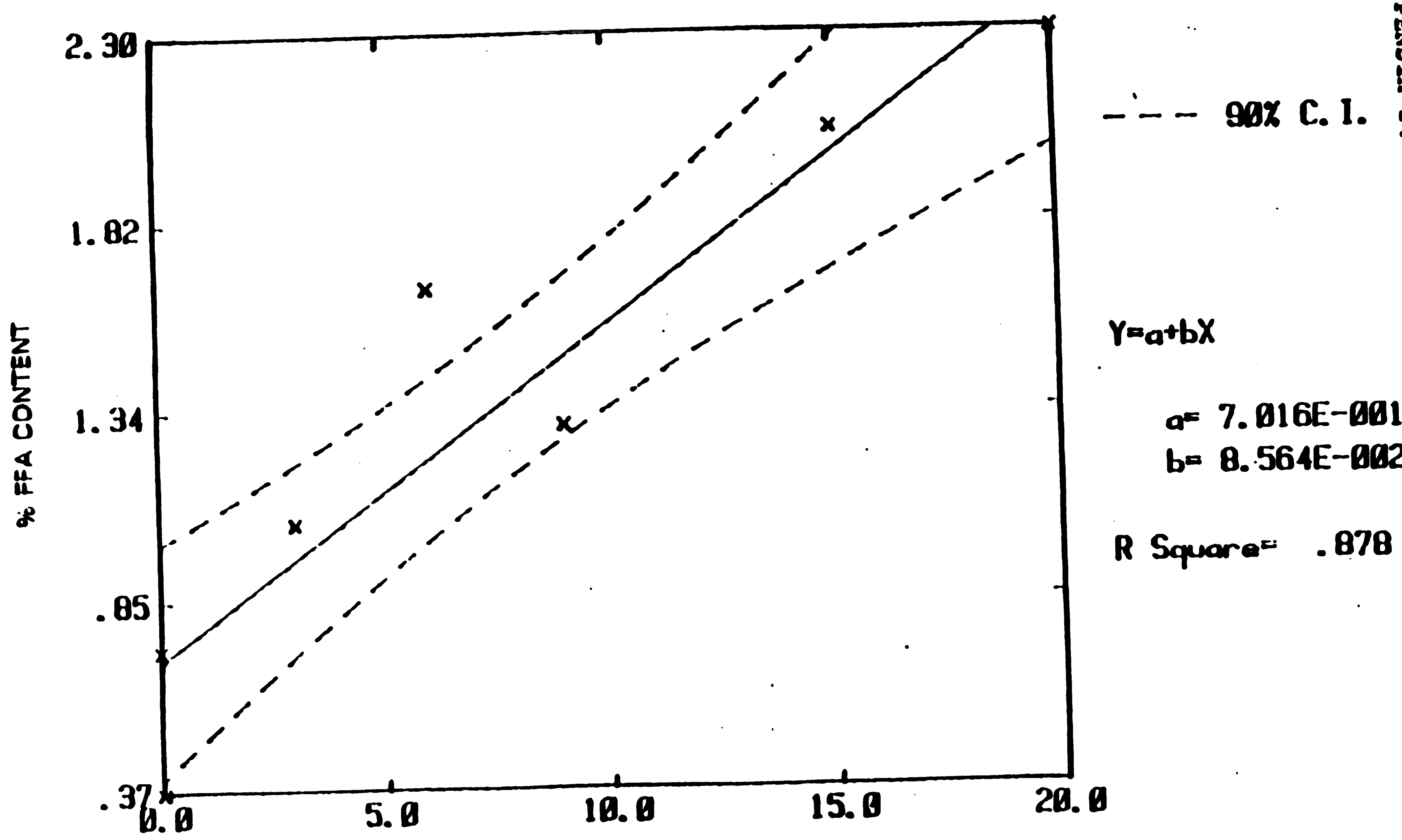
PISIFERA: %FFA & %RIPE COLOUR

APPENDIX 23

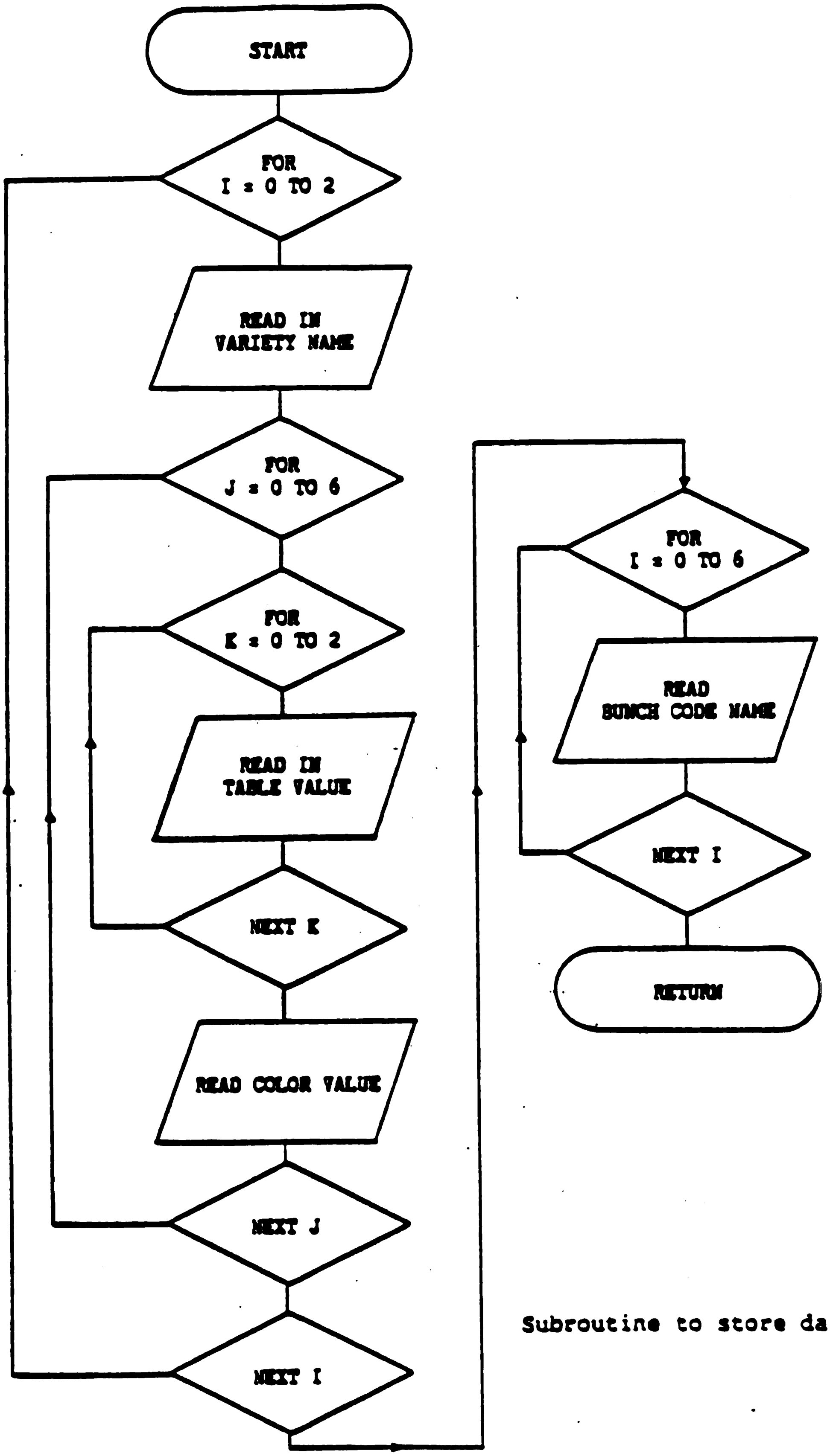


- - - 90% C.I.
Y=a+bX
a= 6.418E-001
b= 5.685E-002
R Square= .973
2.15
1.76
1.38
.99
.60
0.0
6.5
13.0
19.5
26.0
% FFA CONTENT
NUMBER OF LOOSE FRUIT
PISIFERA FFA/ %LOOSE FRUIT

APPENDIX 24

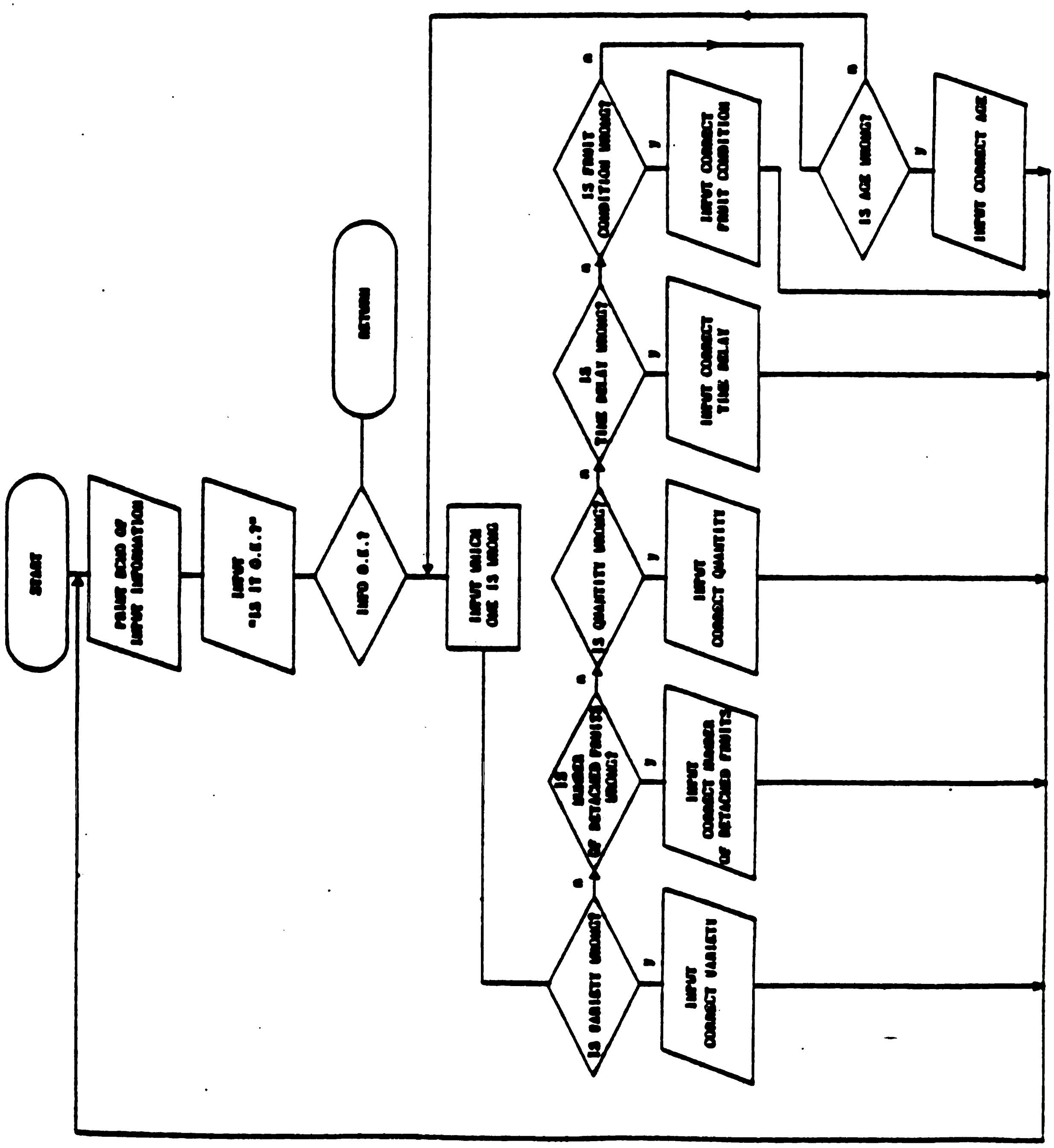


DURA FFA/ NO. OF LOOSE FRUIT



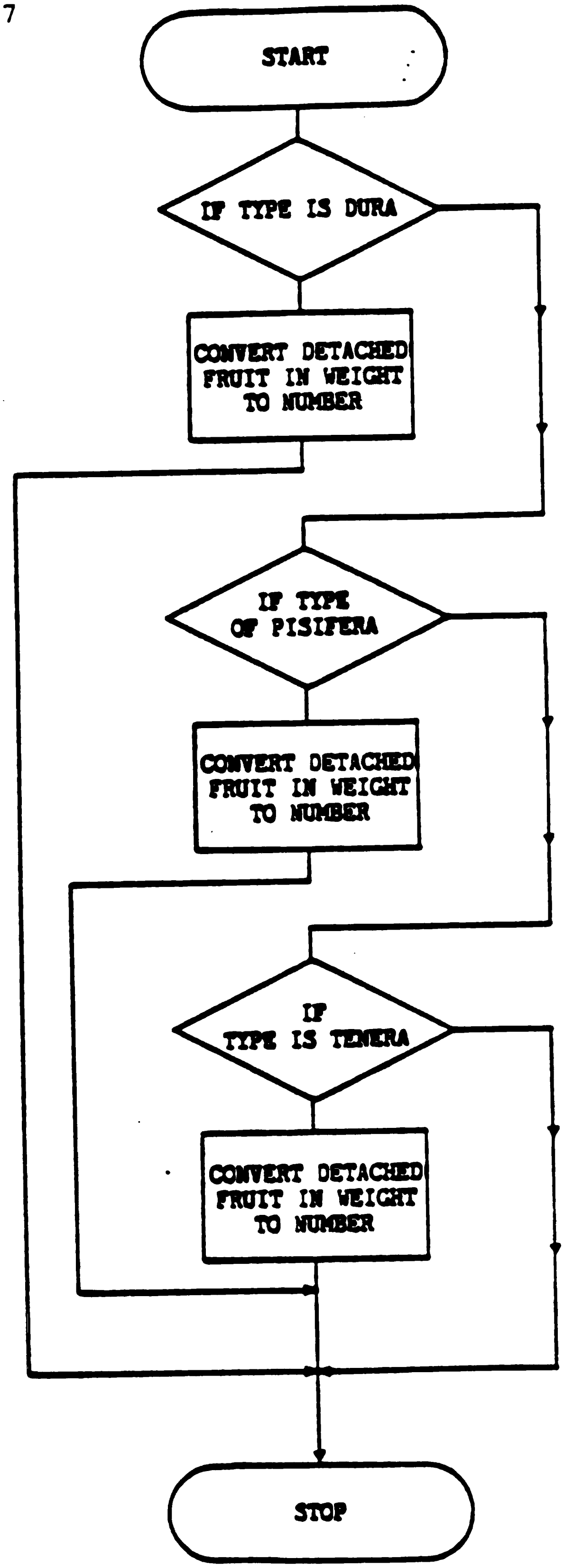
Subroutine to store data in arrays.

Appendix 26



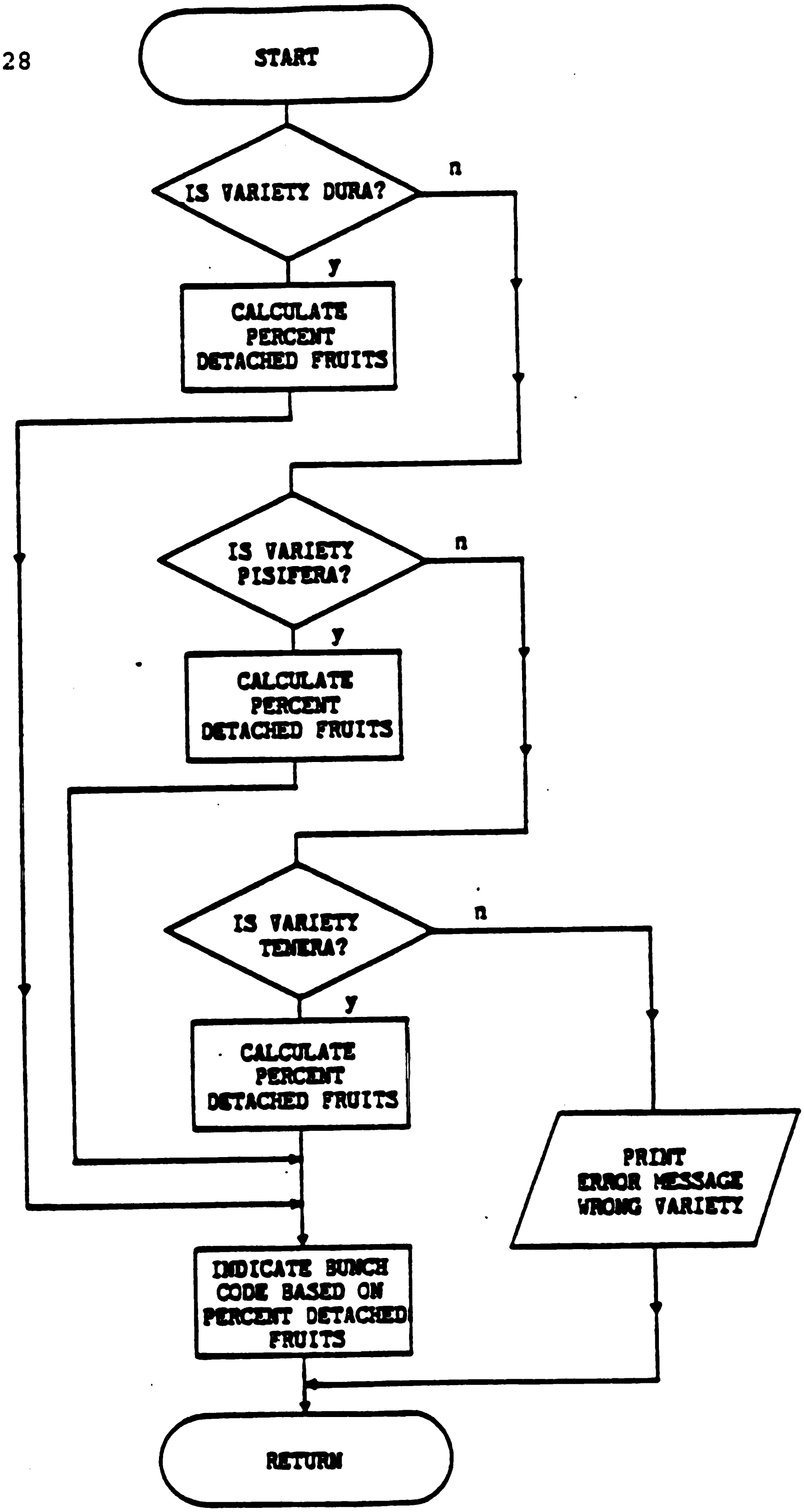
Subroutine to echo input to check values.

Appendix 27

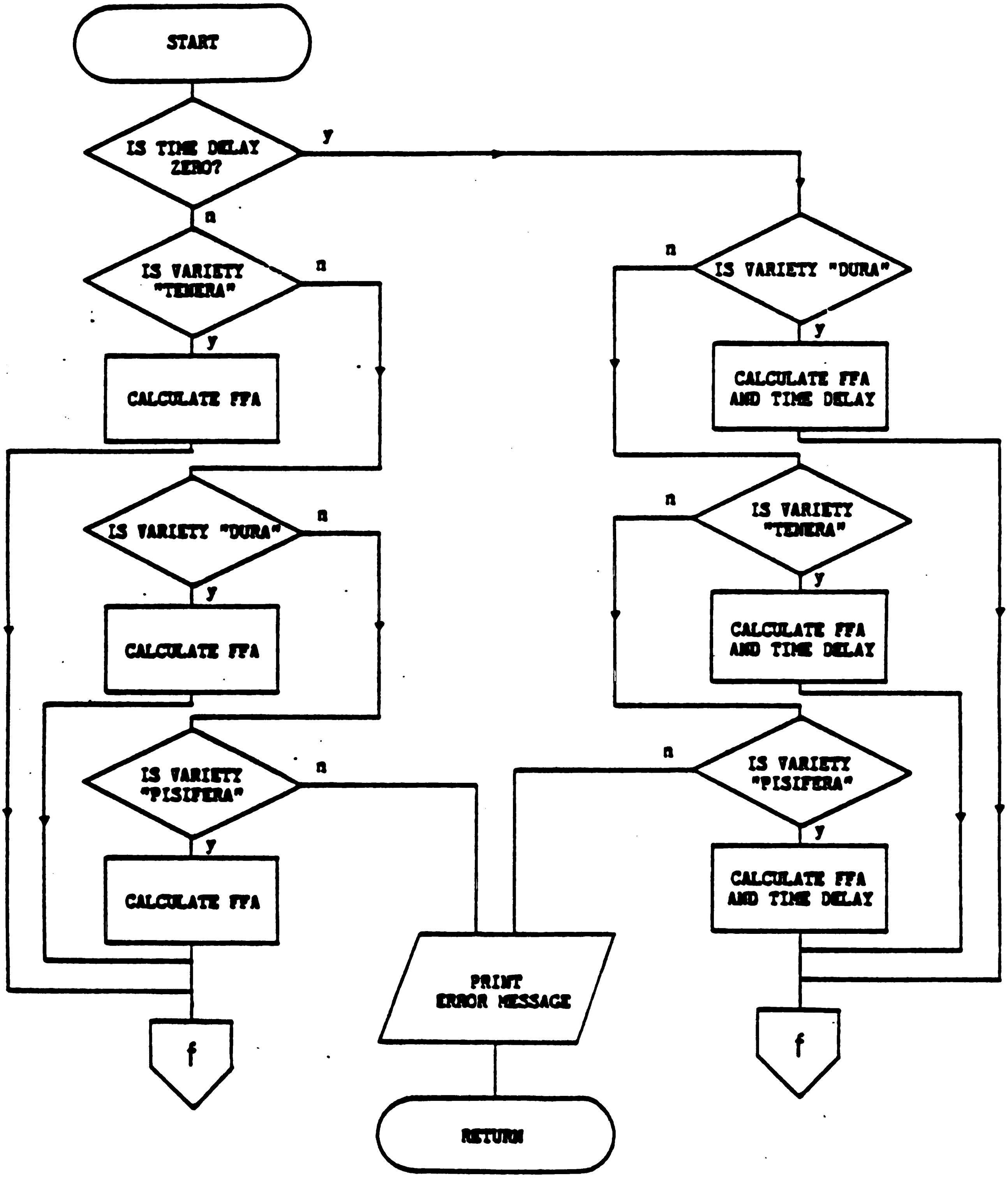


Subroutine to convert detached fruit in weight to number.

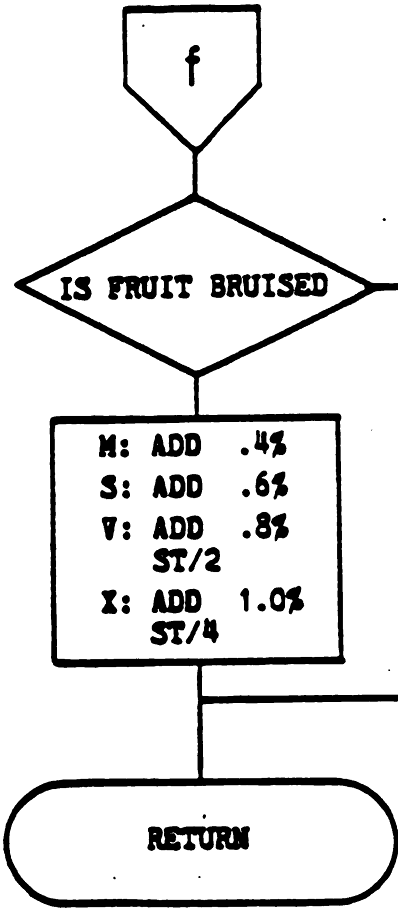
Appendix 28



Subroutine to calculate percent detached fruit and indicate bunch code.

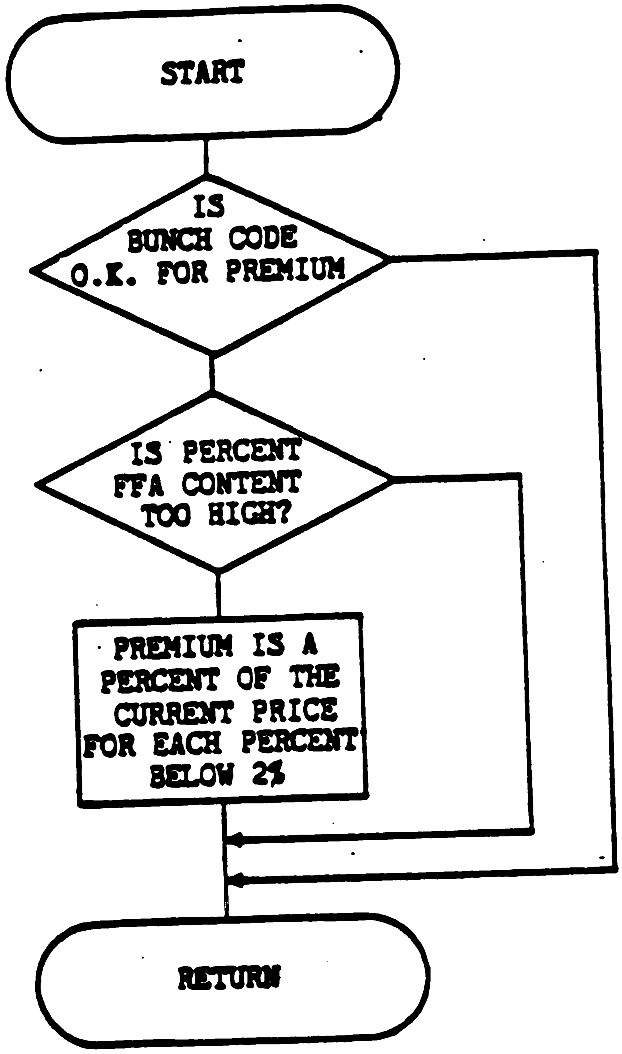

START
IS TIME DELAY ZERO?
y
n
IS VARIETY "TENERA"
n
y
CALCULATE FFA
IS VARIETY "DURA"
n
y
CALCULATE FFA
IS VARIETY "PISIFERA"
n
y
CALCULATE FFA
f
IS VARIETY "DURA"
n
y
CALCULATE FFA AND TIME DELAY
IS VARIETY "TENERA"
n
y
CALCULATE FFA AND TIME DELAY
IS VARIETY "PISIFERA"
n
y
CALCULATE FFA AND TIME DELAY
f
PRINT ERROR MESSAGE
RETURN

Appendix 29



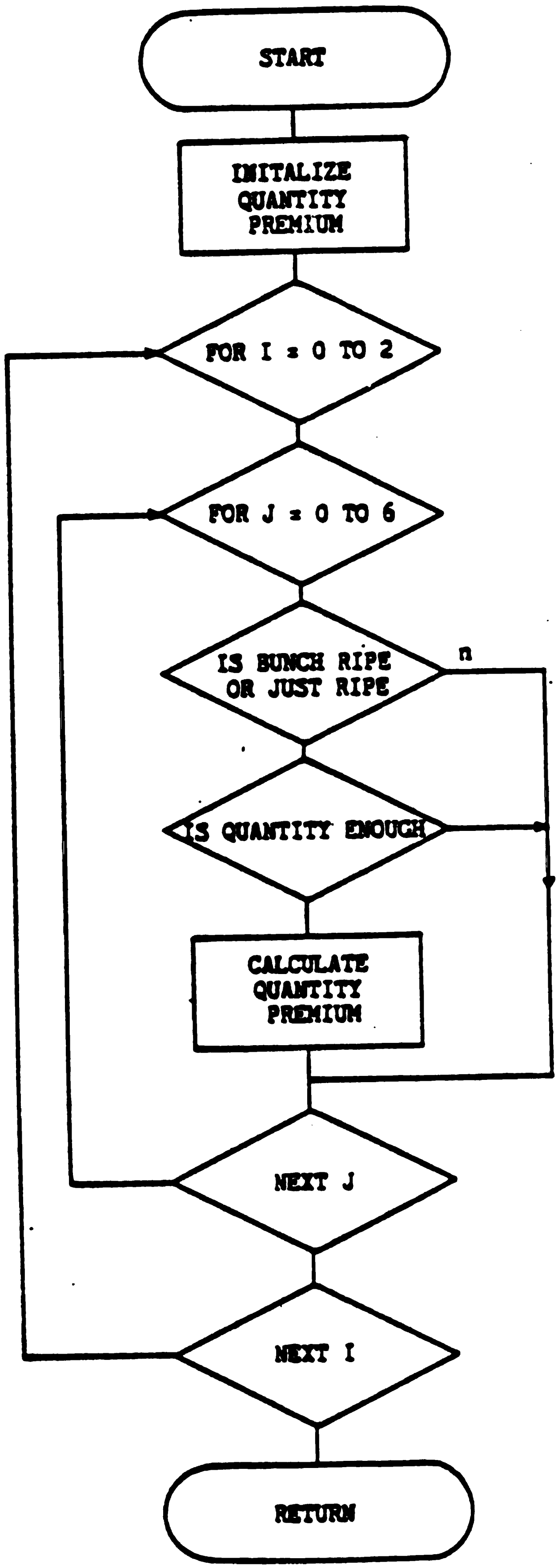
Subroutine to calculate fatty free acid.

Appendix 30



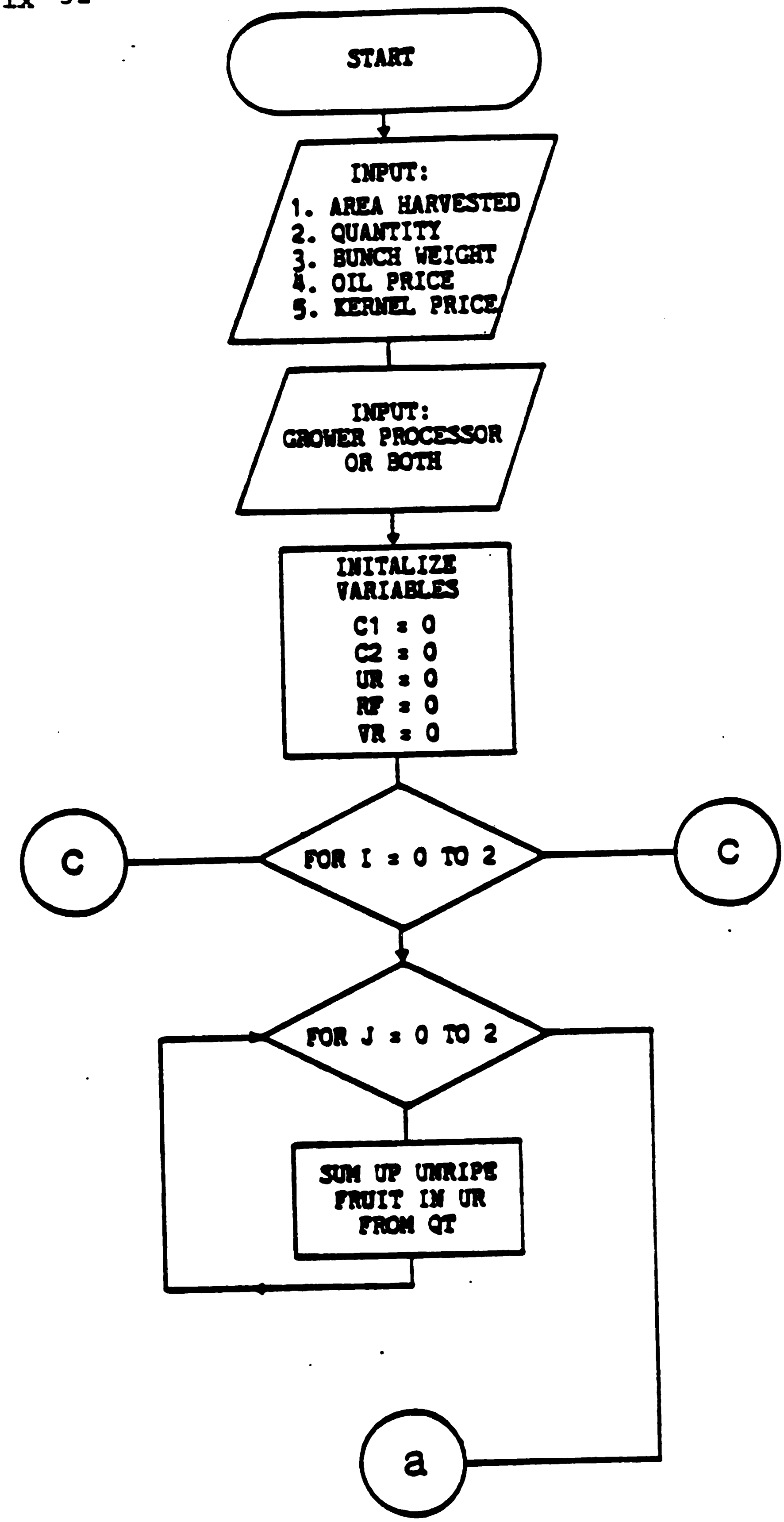
Subroutine to calculate standard premium.

Appendix 31

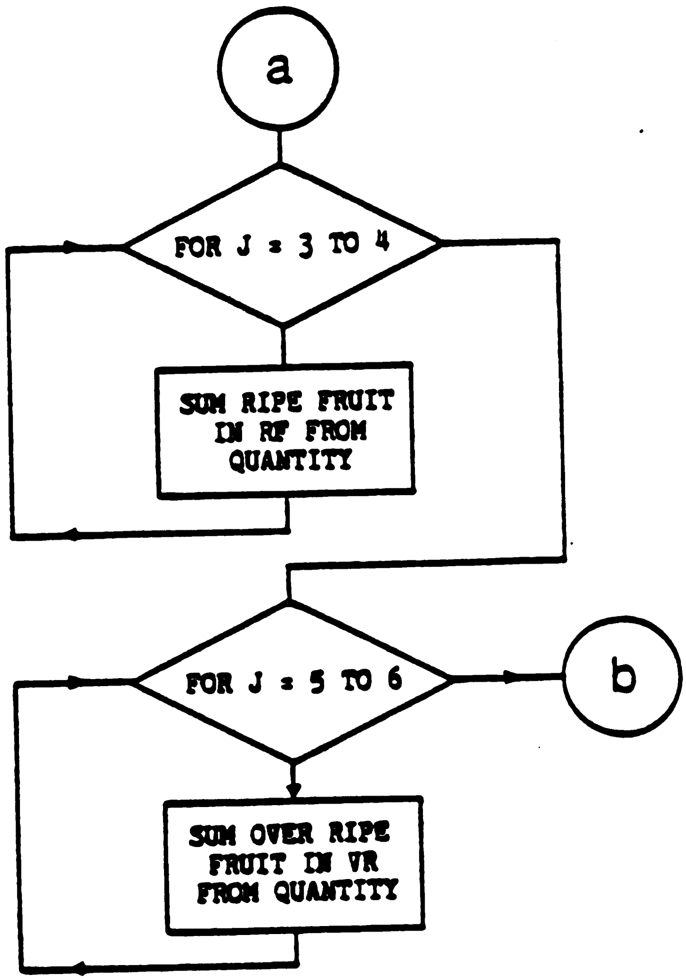


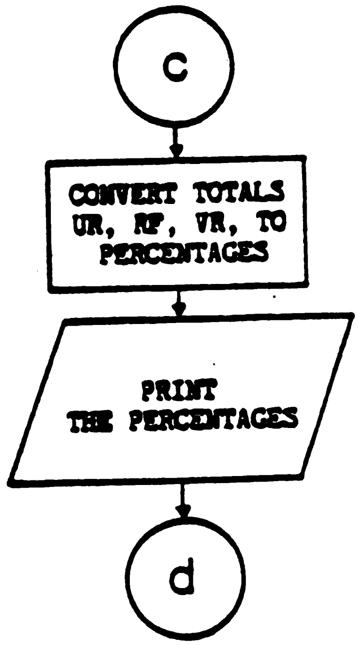
Subroutine to calculate quantity premium.

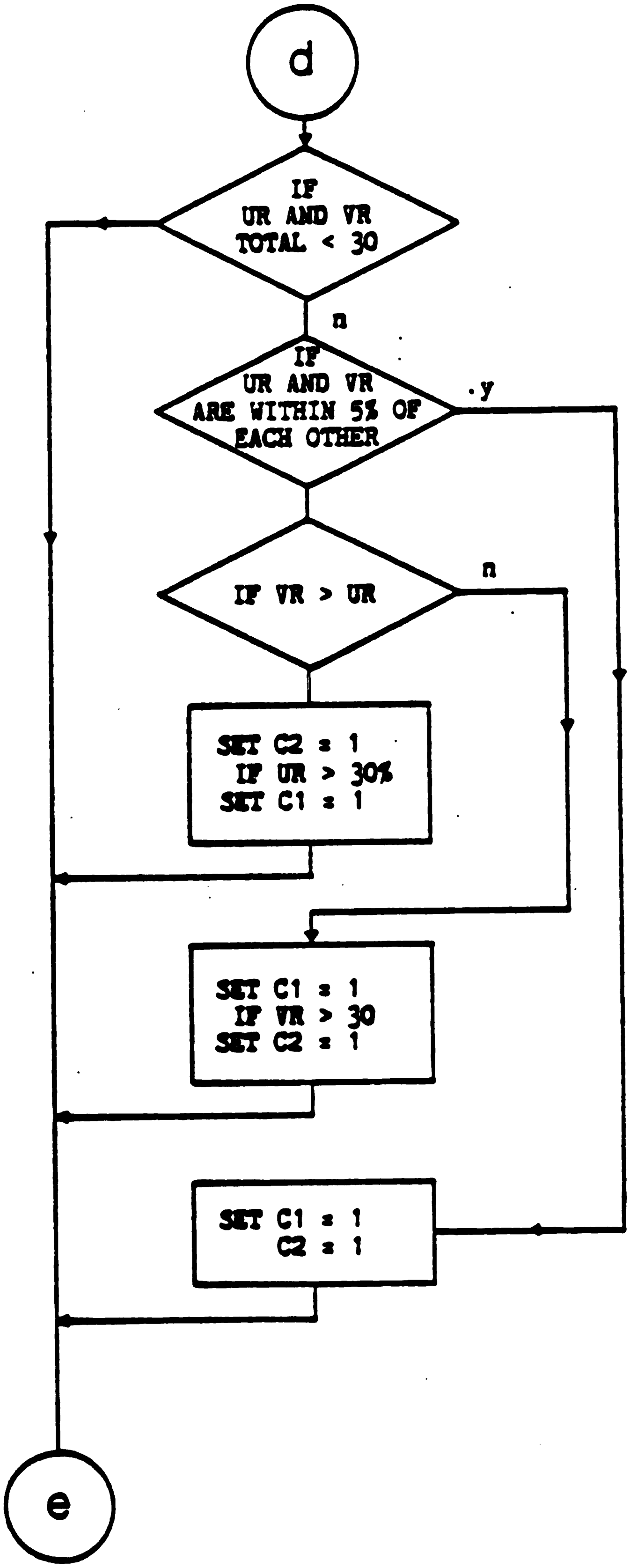
Appendix 32

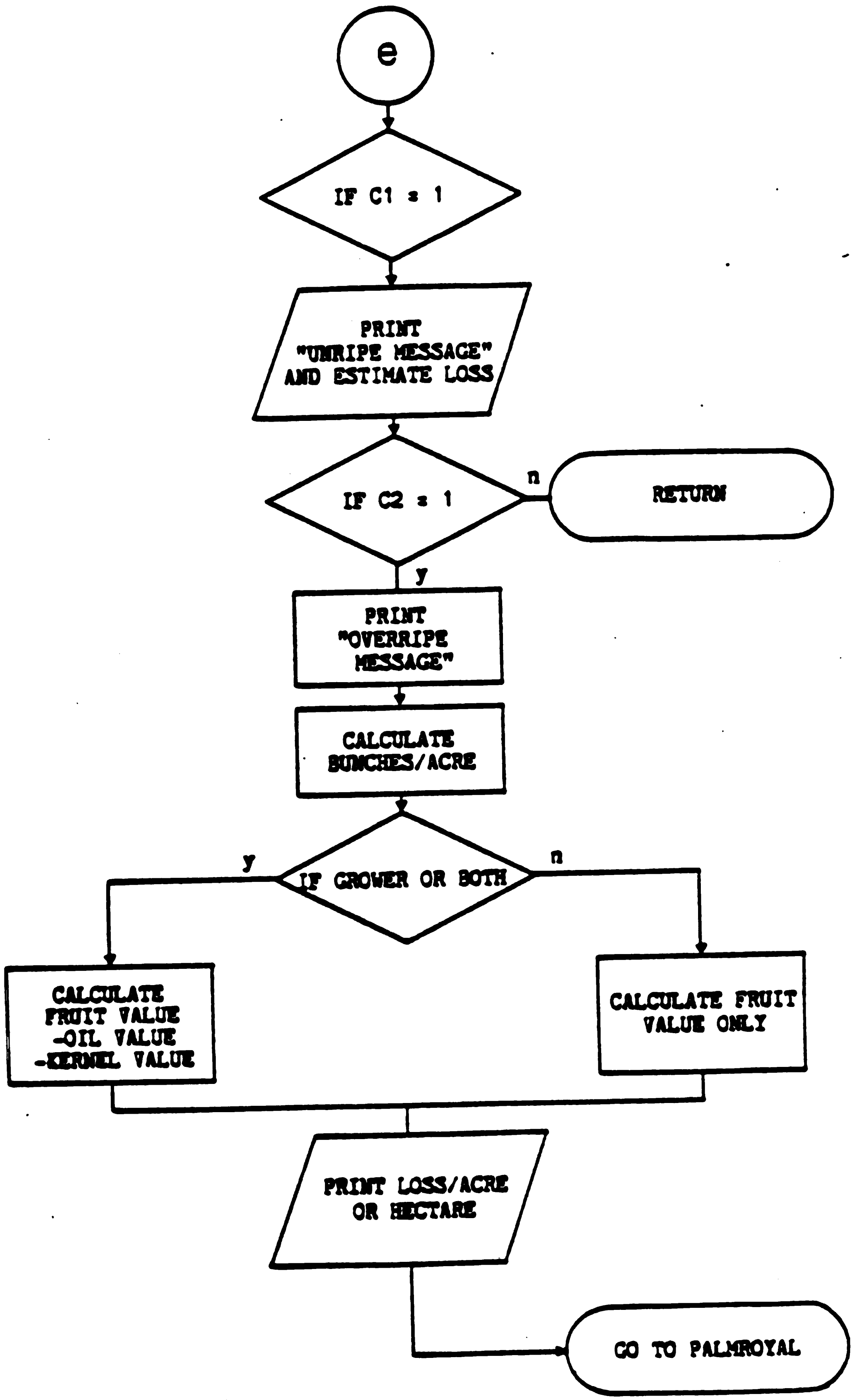


Subroutine for calculation of loss and harvest composition.

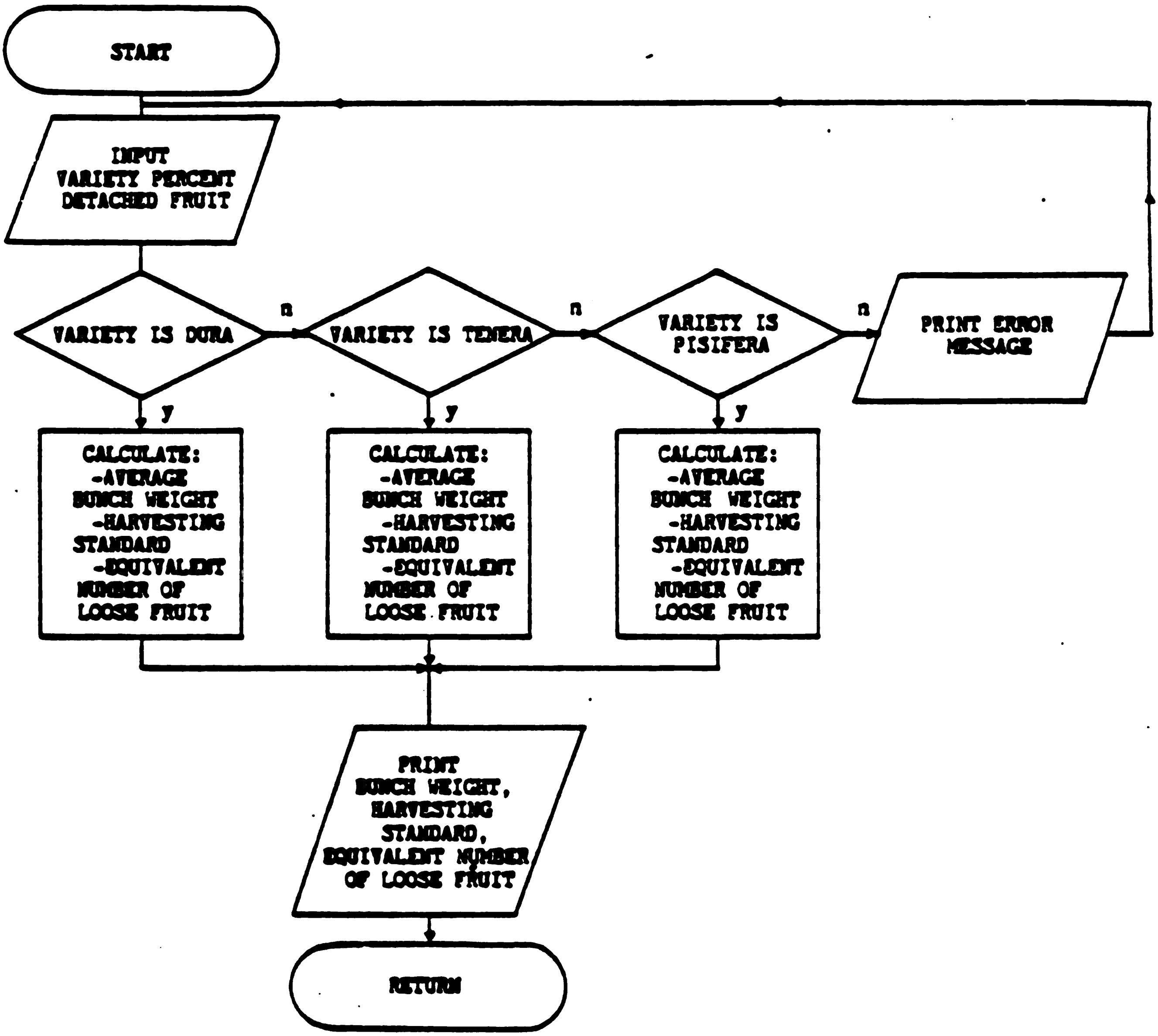

a
FOR J = 3 TO 4
SUM RIPE FRUIT IN RF FROM QUANTITY
FOR J = 5 TO 6
b
SUM OVER RIPE FRUIT IN VR FROM QUANTITY


c
CONVERT TOTALS UR, RF, VR, TO PERCENTAGES
PRINT THE PERCENTAGES
d

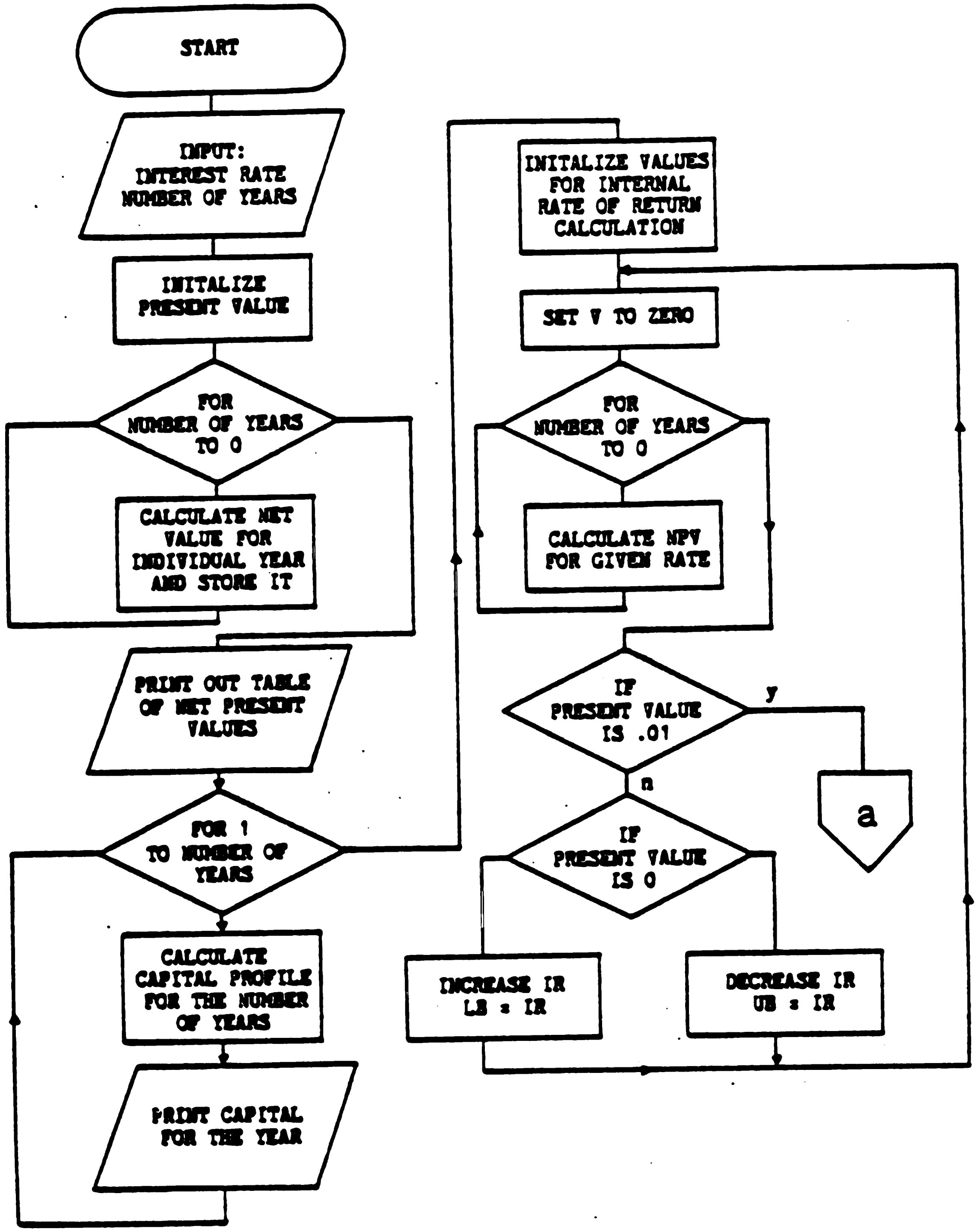

d
IF
UR AND VR
TOTAL < 30
n
IF
UR AND VR
ARE WITHIN 5% OF
EACH OTHER
y
IF VR > UR
n
SET C2 = 1
IF UR > 30%
SET C1 = 1
SET C1 = 1
IF VR > 30
SET C2 = 1
SET C1 = 1
C2 = 1
e

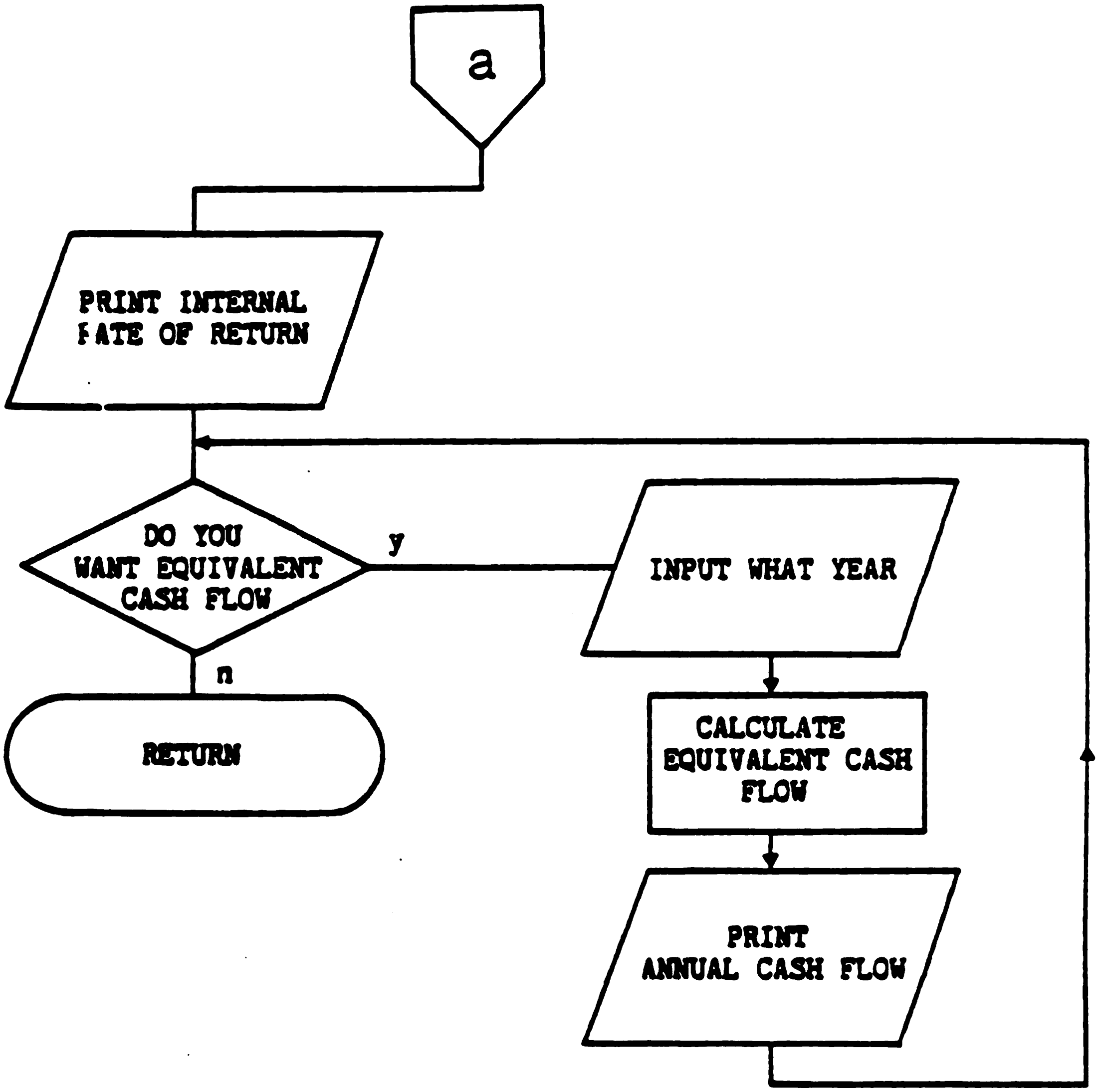

e
IF C1 = 1
PRINT "UNRIPE MESSAGE" AND ESTIMATE LOSS
IF C2 = 1
n
RETURN
y
PRINT "OVERRIPE MESSAGE"
CALCULATE BUNCHES/ACRE
y
IF GROWER OR BOTH
n
CALCULATE FRUIT VALUE -OIL VALUE -KERNEL VALUE
CALCULATE FRUIT VALUE ONLY
PRINT LOSS/ACRE OR HECTARE
GO TO PALMROYAL

Appendix 33



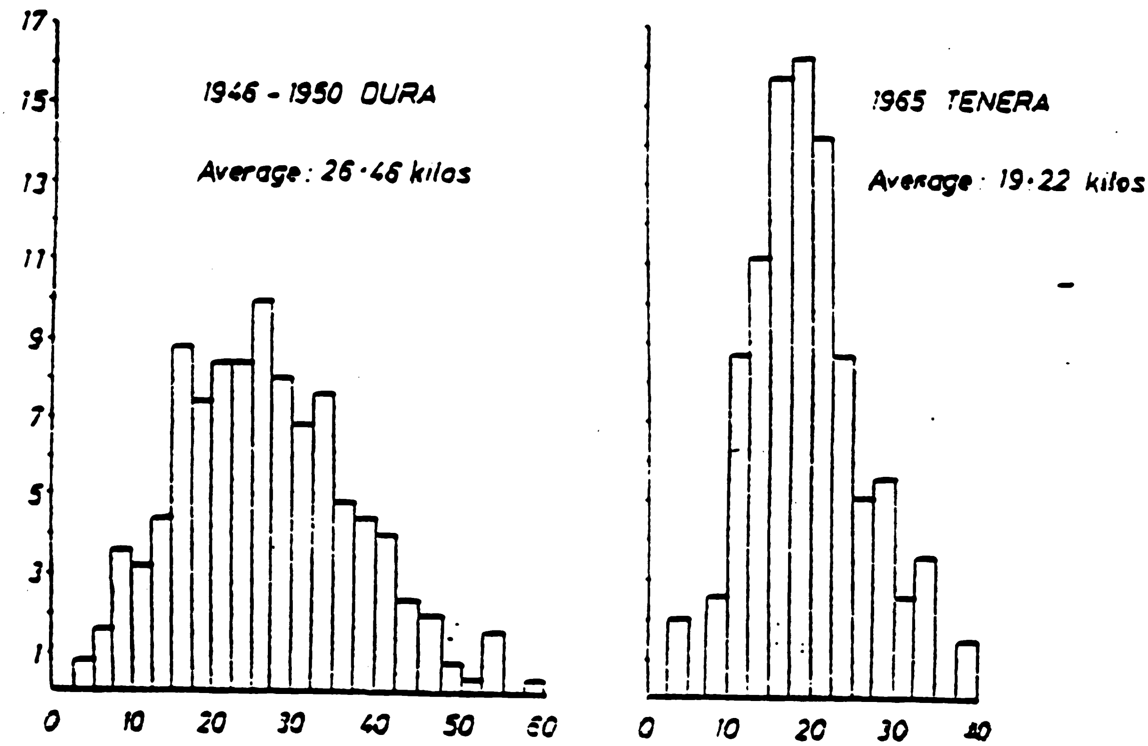
'Palmkey' subroutine to aid in adjustment of harvesting system.


START
INPUT:
INTEREST RATE
NUMBER OF YEARS
INITALIZE
PRESENT VALUE
FOR
NUMBER OF YEARS
TO 0
CALCULATE NET
VALUE FOR
INDIVIDUAL YEAR
AND STORE IT
PRINT OUT TABLE
OF NET PRESENT
VALUES
FOR 1
TO NUMBER OF
YEARS
CALCULATE
CAPITAL PROFILE
FOR THE NUMBER
OF YEARS
PRINT CAPITAL
FOR THE YEAR
INITALIZE VALUES
FOR INTERNAL
RATE OF RETURN
CALCULATION
SET V TO ZERO
FOR
NUMBER OF YEARS
TO 0
CALCULATE NPV
FOR GIVEN RATE
IF
PRESENT VALUE
IS .01
y
n
a
IF
PRESENT VALUE
IS 0
INCREASE IR
LB = IR
DECREASE IR
UB = IR



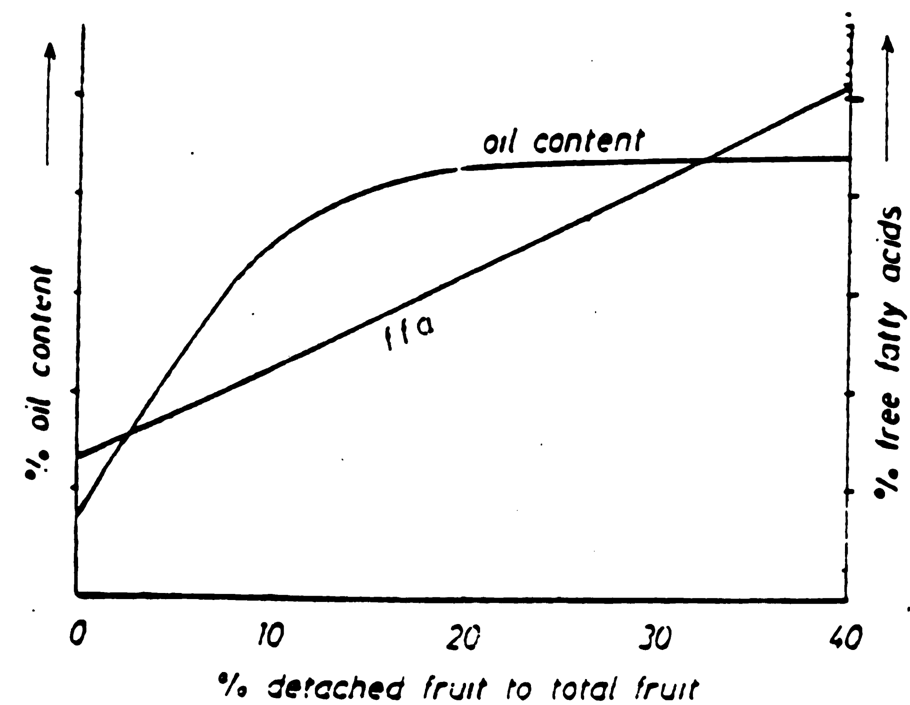
'PALMROYAL' subroutine for calculation of internal rate of return, and equivalent annual cash flow.

Appendix 35



DISTRIBUTION OF BUNCHES BY WEIGHT IN MATURE DURA AND TENERA AREAS
(AFTER A. SOUTHWORTH 1973)

Appendix 36



PROBABLE RELATIONSHIP BETWEEN OIL CONTENT AND OIL QUALITY AND PERCENTAGE DETACHED FRUIT.

(AFTER A. SOUTHWORTH 1973)

Appendix 37

Oil Palm Quality Control Program

```
]LIST

10  DIM TB(2.6.3)
11  DIM PL(500.6)
12  DIM C$(2.6)
15  DIM QT(2.6)
16  DIM M(35).PV(35)
18  REM  DICITONARY OF VARIABLES
19  REM  A    - VALUE OF OIL
20  REM   AC  - AGE OF PALM TREE
21  REM  AR   - AREA HARVESTED
23  REM  B    -VALUE OF KERNAL
24  REM   BC$ - BUNCH CODE NAME
25  REM   BW  - INDIVIDUAL BUNCH WT
30  REM  C    - FLAG VARIABLE
40  REM  C$   - ARRAY OF COLOURS
41  REM  D    - BUNCHES PER ACRE
42  REM  DF$  - DETACHED FRUIT (W OR N)
45  REM  C1   - PRINT FLAG (UNRIPE)
46  REM  C2   - PRINT FLAG (OVERRIPE)
48  REM  F$   - FARMER'S NAME
50  REM  FC$  - FRUIT CONDITION
52  REM  FF   - % FFA CONTENT
53  REM  FV   - FRUIT VALUE
60  REM  I    - INDEX VARIABLE
65  REM  I%   - INCORRECT ITEM NUM
67  REM  IR   - INTERNAL RATE OF RETURN
70  REM  J    - INDEX VARIABLE
73  REM  KP   - KERNAL PRICE (N/TON)
74  REM  KR   - AMT KERNAL / FRUIT
75  REM  K    - INDEX VARIABLE
76  REM   LF  - LOOSE FRUIT
77  REM  LB   - LOWER BOUND (IRR CALC)
78  REM  M    - MARGIN
79  REM  N    - TEMPORARY STORAGE VAR
80  REM  NV   - EQUIVALENT CASH FLOW
81  REM  O    - AMT OF OIL/FRUIT
82  REM  OK$  - FLAG VARIABLE
83  REM  OP   - OIL PRICE (N/TON)
85  REM    P    - PRICE(S2+Q2+PRICE(TABLE)
90  REM  PC%  - BUNCH CODE
95  REM  PL   - PRINT LISTING
97  REM    PM   - PREMIUM AWARD BASED ON % DETACHED FRUIT
100  REM  PN$ - PLANTATION NAME
110  REM  PR  - PREMIUM RATE
112  REM  PT% - POINTER INTO PL
113  REM  PV  - PRESENT VALUE
115  REM   Q   - QUANTITY(SUM OF BUNCH WT.IN KG.)
117  REM  QT  - QUANTITY TOTALS
120  REM  Q2  - QUANTITY PREMIUM
123  REM  Q3  - QUANTITY PREMIUM CALC
125  REM  R   - PERCENT DETACHED
127  REM  RF  - TOTAL WT RIPE FRUIT
130  REM  SN$ - STATE NAME
135  REM  ST  - SUBTOTAL
140  REM  S2  - STANDARD PREMIUM
145  REM  T   - TOTAL FOR FARMER
150  REM  TB  - TABLE OF VALUES
155  REM  TD  - TIME DELAY (DAYS)
```

```
156  REM  TF  - TOTAL FRUIT WT
157  REM  UB  - UPPER BOUND (IRR CALC)
158  REM  UR  - TOTAL WT UNRIPE FRUIT
159  REM  V   - PRESENT VALUE
160  REM  VB  - BUNCH WEIGHT (LB)
161  REM  V$  - VARIETY NAME
163  REM  V%  - VARIETY NUMBER
165  REM  VN$ - VARIETY NAME TABLE
166  REM  VR  - TOTAL WT OVERRIPE FRUIT
167  REM  W   - WT OR NUM DETACHED FRUIT
169  REM  Y   - FRUIT PER BUNCH
170  REM  YR  - YEAR (IRR CALC)
171  REM  Z$  - CORRECT? VARIABLE
172  HOME
174  PRINT  TAB( 10);"OIL PALM QUALITY CONTROL"
176  PRINT
178  PRINT
180  PRINT  TAB( 18);"BY"
182  PRINT : PRINT
184  PRINT  TAB( 10);"ERNEST MESHACK-HART"
186  PRINT : PRINT
188  PRINT : PRINT
190  INPUT "HIT RETURN TO BEGIN.";K$
191  HOME
193  PRINT : PRINT "WELCOME!THIS PROGRAM PREDICTS THE % FFA"
194  PRINT "AND OTHER FIELD FACTORS SUCH AS DEGREE OF BRUISING AND TIME DELAY"
196  PRINT "THE PERCENT DETACHED FRUIT IS CALCULATED BY RELATING THE WEIGHT OF DETACH
 THE TOTAL FRUIT WEIGHT."
198  PRINT : PRINT
200  PRINT : PRINT
202  PRINT "THIS PROGRAM ALSO PERFORMS HARVEST COMPOSITION ANALYSIS"
203  PRINT "THE HARVEST COMPOSITION IS CATEGORIZED INTO UNRIPE,RIPE,OVER-RIPE"
204  PRINT : PRINT "YOU WILL ALSO BE ASKED TO EVALUATE THE CONDITION OF THE FRUITLET"
205  PRINT "IF BRUISED,WHAT IS THE DEGREE OF BRUISING"
206  PRINT "WHENEVER IN DOUBT REFER TO THE 'HELP'MENU"
230  REM  *** BEGIN PROG ***
240  PRINT : PRINT : PRINT : PRINT
250  INPUT "ENTER PREMIUM: ";PR
260  GOSUB 1000
265  PRINT : PRINT : PRINT : PRINT
270  PRINT "ENTER FARMER'S NAME "
280  INPUT "'QUIT' TO FINISH DAY:  ";F$
290  IF F$ = "QUIT" THEN  GOTO 9000
300  INPUT "ENTER STATE NAME:       ";SN$
310  INPUT "ENTER PLANTATION NAME: ";PN$
320  LET PT% = 0
330  LET ST = 0.0
340  LET T = 0
350  PRINT : PRINT "ENTER VARIETY"
353  PRINT "(DURA, PISIFERA, TENERA)"
357  INPUT "'END' TO END CUSTOMER:      ";V$
358  IF V$ = "END" GOTO 600
360  PRINT "ENTER NO. DETACHED FRUITS"
362  INPUT "OR WEIGHT DETACHED FRUIT:  ";W
365  INPUT "NUMBER OR WEIGHT (N,W)?    ";DF$
370  INPUT "ENTER BUNCH WEIGHT (KG):   ";Q
380  INPUT "ENTER TIME DELAY (DAYS):   ";TD
390  PRINT "ENTER FRUIT CONDITION"
400  INPUT "(U, M, S, V, X, OR HELP):  ";FC$
405  IF FC$ = "HELP" THEN  GOSUB 1500
```

```
410  INPUT "ENTER AGE OF PALM (YEARS)  ",AG
415  REM  GOTO ACCURACY CHECK
417  GOSUB 7000
420  IF DF$ = "W" THEN  GOSUB 5000
433  GOSUB 2000
434  IF C =  - 1 THEN  GOTO 350
435  REM  GOTO FFA CALC
436  GOSUB 4000
439  REM  GOTO STANDARD PREM CALC
440  GOSUB 3000
460  LET PT% = PT% + 1
465  IF PT% = 500 THEN  GOTO 600
470  LET P = TB(V%,PC%,0) + S2 + Q2
480  LET ST = Q * P
482  IF FC$ <  > "V" GOTO 485
485  IF FC$ <  > "X" GOTO 490
489  REM  STORE INFORMATION FOR PRINTING LATER
490  LET PL(PT%,0) = V%
500  LET PL(PT%,1) = PC%
510  LET PL(PT%,2) = FF
520  LET PL(PT%,3) = S2
530  LET PL(PT%,4) = ST
540  LET PL(PT%,5) = Q
550  PRINT
560  GOTO 350
600  REM  PRINT RESULTS
610  PRINT : PRINT : PRINT : PRINT
620  PRINT "FARMER'S NAME: ";F$
630  PRINT "ESTATE:        ";PN$
640  PRINT "STATE:         ";SN$
650  PRINT
655  IF PT% = 0 GOTO 999
660  FOR I = 1 TO PT%
670  PRINT "PRESS (SPACE) TO CONTINUE": GET Z$
680  PRINT "VARIETY:               ";VN$(PL(I,0))
690  PRINT "DEGREE OF RIPENESS:  ";BC$(PL(I,1))
700  PRINT "%FFA:                  ";PL(I,2)
710  PRINT "PROBABLE COLOR:        ";C$(PL(I,0),PL(I,1))
720  PRINT "STANDARD PREMIUM:      ";PL(I,3)
730  PRINT "SUBTOTAL:              ";PL(I,4)
740  LET T = T + PL(I,4)
750  PRINT
755  IF PL(I,2) < 2 THEN  GOTO 780
760  PRINT "GOOD FARMERS SUPPLY FRESH FRUIT WITH"
770  PRINT "FFA LESS THAN 2%."
780  PRINT
790  PRINT "EXTRA AMOUNT DUE TO PREMIUM IS: ";PL(I,3) * PL(I,5)
800  PRINT
810  REM  TOTAL QUANTITIES FOR PREMIUM CALC
820  LET QT(PL(I,0),PL(I,1)) = QT(PL(I,0),PL(I,1)) + PL(I,5)
830  NEXT I
860  PRINT
870  REM  GOSUB QUANTITY PREMIUM CALC
880  GOSUB 6000
890  PRINT "QUANTITY PREMIUM: ";Q3
900  PRINT "TOTAL DUE FARMER: ";Q3 + T
950  INPUT "DO YOU NEED AN ECONOMIC ANALYSIS OF YOUR HARVEST COMPOSITION (Y/N)? ";Z
960  IF Z$ = "Y" OR Z$ = "YES" THEN  GOSUB 8000
965  PRINT
970  INPUT "DO YOU WANT ADVICE ON YOUR HARVESTING SYSTEM (Y/N)? ";Z$
```

```
975  IF Z$ = "Y" OR Z$ = "YES" THEN  GOSUB 3500
980  PRINT
999  GOTO 265
1000  REM  SUBROUTINE TO LOAD TABLES
1001  FOR I = 0 TO 2
1005  READ VN$(I)
1010  FOR J = 0 TO 6
1020  FOR K = 0 TO 2
1030  READ TB(I,J,K)
1040  NEXT K
1045  READ C$(I,J)
1050  NEXT J
1060  NEXT I
1070  FOR I = 0 TO 6
1080  READ BC$(I)
1090  NEXT I
1100  FOR I = 0 TO 2
1110  FOR J = 0 TO 6
1115  REM  CONVERT PRICE PER TON TO PRICE PER KILOGRAM
1120  LET TB(I,J,0) = TB(I,J,0) / 1000
1130  NEXT J
1140  NEXT I
1150  FOR X = 1 TO 11
1160  READ M(X)
1170  NEXT X
1180  FOR X = 12 TO 35
1190  LET M(X) = 260.52
1200  NEXT X
1210  RETURN
1500  REM  HELP SUBROUTINE
1510  PRINT
1520  PRINT "********************"
1530  PRINT
1540  PRINT "FRUIT CONDITION SHOULD BE CATEGORIZED"
1550  PRINT "ALONG THE FOLLOWING LINES."
1560  PRINT
1570  PRINT "1. UNBRUISED (NO BRUISING)"
1580  PRINT "2. MODERATELY BRUISED (LESS THAN 20% BRUISED)"
1590  PRINT "3. SEVERELY BRUISED (20-50% BRUISED)"
1600  PRINT "4. VERY SEVERELY BRUISED (50-75% BRUISED)
1605  PRINT "5. EXTREMELY SEVERELY BRUISED (>75% BRUISED)
1610  PRINT
1620  PRINT "ENTER 'U' FOR UNBRUISED"
1630  PRINT "       'M' FOR MODERATELY BRUISED"
1640  PRINT "       'S' FOR SEVERELY BRUISED"
1650  PRINT "       'V' FOR VERY SEVERELY BRUISED."
1655  PRINT "  OR  'X' FOR EXTREMELY BRUISED."
1660  PRINT
1670  PRINT "********************"
1680  PRINT
1690  INPUT "ENTER FRUIT CONDITION (V, M, S, X, OR V): ";FC$
1900  RETURN
2000  REM  SUBROUTINE TO CALCULATE % DETACHED FRUIT.
2010  REM  AND ALSO INDICATE WHAT CODE THE BUNCH BELONGS.
2020  IF V$ < > "DURA" THEN  GOTO 2100
2030  REM  VARIETY IS DURA
2040  REM  65% OF BUNCH WT.IS FRUIT AND
2050  REM  AVE.WT. OF EACH FRUIT IS .017LB(C.W.S HARTLEY)
2060  LET Y = .65 * Q
2070  LET LF = (Y * 2.2) / .017
```

```
2080  LET R = (W / LF) * 100
2090  LET V% = 0
2095  GOTO 2400
2100  IF V$ <  > "PISIFERA" GOTO 2200
2110  REM  VARIETY IS PISIFERA
2120  REM  62% OF BUNCH WT IS FRUIT AND
2130  REM  AVE WT OF EACH FRUIT IS .015LB(C.W.S HARTLEY)
2140  LET Y =  .62 * Q
2150  LET LF = (Y * 2.2) / .015
2160  LET R = (W / LF) * 100
2170  LET V% = 1
2180  GOTO 2400
2200  IF V$ <  > "TENERA" THEN  GOTO 2300
2210  REM  VARIETY IS TENERA
2220  REM  60% OF BUNCH WT IS FRUIT AND
2230  REM  AVE WT OF EACH FRUIT IS .013LB(C.W.S HARTLEY)
2240  LET Y =  .6 * Q
2250  LET LF = (Y * 2.2) / .013
2260  LET R = (W / LF) * 100
2270  LET V% = 2
2280  GOTO 2400
2300  REM
2310  REM  VARIETY IS NOT "DURA","PISIFERA",OR "TENERA"
2320  PRINT "INVALID FRUIT VARIETY"
2330  PRINT "MUST BE EITHER 'DURA', 'PISIFERA', OR 'TENERA'"
2340  LET C =  - 1
2350  GOTO 2600
2400  REM  INDICATE BUNCH CODE
2410  REM  BASED ON % DETACHED FRUIT
2420  LET PC% = 0
2430  IF R > 0 THEN PC% = 1
2440  IF R > 10 THEN PC% = 2
2450  IF R > 20 THEN PC% = 3
2460  IF R > 40 THEN PC% = 4
2470  IF R > 60 THEN PC% = 5
2480  IF R > 80 THEN PC% = 6
2600  RETURN
3000  REM  SUBROUTINE TO CALCULATE STANDARD PREMIUM
3010  REM
3020  LET S2 = 0
3050  REM  FFA CONTENT IS GOOD
3060  REM  PREMIUM IS .104 OF THE CURRENT PRICE FOR EACH PERCENTAGE POINT BELOW 2%
3070  REM
3080  REM
3090  LET S2 = (2 - FF) * (TB(V%,PC%,0) * .104)
3100  IF TB(V%,PC%,1) = 1 AND S2 > 0 THEN S2 = 0
3400  RETURN
3500  REM  SUBROUTINE FOR HARVESTING SYSTEM ANALYSIS
3530  PRINT "ENTER VARIETY YOU HARVEST"
3540  INPUT "(DURA, PISIFERA, OR TENERA): ";V$
3550  INPUT "ENTER %DETACHED FRUIT OF YOUR HARVEST COMPOSITION: ";R
3560  IF V$ <  > "DURA" GOTO 3600
3570  LET BW = .1779 + 1.233 * AG
3575  LET LF =  - .553 + .2110 * R
3580  LET MS = LF / BW
3590  GOTO 3700
3600  IF V$ <  > "TENERA" GOTO 3640
3610  LET BW =  - .0257 + 1.291 * AG
3615  LET LF =  - .124 + .4003 * R
3620  LET MS = LF / BW
```

```
3621  LET PM = 0 0013 / (0 0065886 + (0.00004784 * R))
3624  INPUT "PRICE OF OIL: ";OP
3626  LET N = OP * (1 + 1.386 * PM - 0.0184 * PM * R) * (0.0456 + 0.0013 * R)
3630  GOTO 3700
3640  IF V$ ( ) "PISIFERA" GOTO 3680
3650  LET BW = .7326 + 1.192 * AG
3655  LET LF = - 415 + 2965 * R
3660  LET MS = LF / BW
3670  GOTO 3700
3680  PRINT "TYPE SHOULD BE DURA. PISIFERA. OR TENERA "
3690  GOTO 3530
3700  PRINT  PRINT "LIKELY AVERAGE BUNCH WEIGHT. ";BW
3710  PRINT "MIN HARVESTING STANDARD:      ";MS
3715  PRINT "THE EQUIVALENT LOOSE FRUIT"
3716  PRINT "LOOSE FRUIT BEFORE CUTTING THE BUNCH IS: ".LF
3717  PRINT
3720  PRINT "IF HARVESTING INTERVAL IS SEVEN DAYS."
3721  PRINT "THE MAX PREMIUM IS: ".PM
3724  PRINT "THE REVENUE DUE FARMER IS  ";N
3900  RETURN
4000  REM  SUBROUTINE FOR RATE OF
4010  REM  ACIDIFICATION CALCUATION
4100  IF TD = 0 THEN  GOTO 4400
4110  REM  CALCULATE FFA BASED ON TIME DELAY
4120  IF V$ ( ) "TENERA" THEN  GOTO 4200
4130  LET FF = .724 + (.663 * TD)
4135  LET FF = (FF + ( 614 + (.0184 * R))) / 2
4140  GOTO 4800
4200  IF V$ ( ) "DURA" THEN  GOTO 4300
4210  LET FF = .726 + (.654 * TD)
4215  LET FF = (FF + (.601 + ( 0195 * R))) / 2
4220  GOTO 4800
4300  IF V$ ( ) "PISIFERA" THEN  GOTO 4350
4310  LET FF = .784 + ( 521 * TD)
4315  LET FF = (FF + (.601 + (.0173 * R))) / 2
4320  GOTO 4800
4350  REM  VARIETY TYPE IS NOT
4360  REM  "DURA"."PISIFERA". OR "TENERA"
4370  PRINT "UNRECOGNIZED TYPE"
4380  GOTO 4990
4400  REM  TIME DELAY IS ZERO
4410  REM  CALCULATE FFA BASED ON
4420  REM  PERCENTAGE DETACHED FRUIT
4430  IF V$ ( ) "DURA" THEN  GOTO 4500
4440  LET FF = .601 + (.0195 * R)
4450  GOTO 4800
4500  IF V$ ( ) "TENERA" THEN  GOTO 4600
4510  LET FF = .614 + (.0184 * R)
4520  GOTO 4800
4600  IF V$ ( ) "PISIFERA" THEN  GOTO 4350
4610  LET FF = .601 + (.0173 * R)
4620  GOTO 4800
4800  REM  IF FRUIT IS BRUISED.
4810  REM  ADD .4% TO THE FFA VALUE
4820  IF FC$ ( ) "M" GOTO 4840
4830  LET FF = FF + .4
4840  IF FC$ ( ) "S" GOTO 4860
4850  LET FF = FF + .6
4860  IF FC$ ( ) "V" GOTO 4880
4870  LET FF = FF + .8
```

```
4880  IF FC$ < > "X" GOTO 4990
4890  LET FF = FF + 1 0
4990  RETURN
5000  REM  SUBROUTINE TO CALCULATE
5010  REM  THE NUMBER DETACHED FRUITS
5020  REM  FROM WEIGHT OF LOOSE FRUITS
5030  IF V$ < > "DURA" THEN  GOTO 5100
5040  LET W = (W * 2 2) /  017
5050  GOTO 5400
5100  IF V$ < > "PISIFERA" THEN  GOTO 5200
5110  LET W = (W * 2 2) /  015
5120  GOTO 5400
5200  IF V$ < > "TENERA" THEN  GOTO 5300
5210  LET W = (W * 2 2) /  013
5220  GOTO 5400
5300  RETURN
5400  RETURN
5410  RETURN
5500  REM  PALM KEY
5510  REM  ROOM FOR PRINT STATEMENTS
5520  REM
5530  PRINT
5540  PRINT "CALCULATION OF OIL PER MESOCARP. FFA, DETACHED FRUIT "
5550  PRINT
5560  INPUT "ENTER TYPE (DURA. PISIFERA. TENERA)  ".V$
5570  PRINT
5580  INPUT "% UNRIPE FRUIT   ".UR
5590  INPUT "% RIPE FRUIT     ".RF
5600  INPUT "% OVERRIPE FRUIT ".VR
5610  PRINT
5620  REM  CALC OF OPM AND FFA
5630  LET DF = 0
5640  LET DF =  1 * UR
5650  LET DF = DF + ( 3 * RF)
5660  LET DF = DF + ( 45 * VR)
5670  IF V$ < > "TENERA" GOTO 5720
5680  LET FF =  613 +  0184 * DF
5690  LET OM = 45 59 +  13 * DF
5710  GOTO 5820
5720  IF V$ < > "DURA" GOTO 5760
5730  LET FF =  601 +  0194 * DF
5740  LET OM = 45 59 +  13 * DF
5750  GOTO 5820
5760  IF V$ < > "PISIFERA" GOTO 5800
5770  LET FF =  601 +  0173 * DF
5780  LET OM = 45 59 +  13 * DF
5790  GOTO 5820
5800  PRINT "TYPE MUST BE DURA. PISIFERA. OR TENERA "
5810  GOTO 5550
5820  PRINT
5830  PRINT "OPM"."FFA"."DF"
5840  PRINT OM.FF.DF
5850  PRINT
5870  INPUT "WOULD YOU LIKE TO TRY ANOTHER COMBINATION".Z$
5880  IF Z$ = "YES" OR Z$ = "Y" GOTO 5550
5900  RETURN
6000  REM  SUBROUTINE TO CACULATE
6010  REM  QUANTITY PREMIUM
6020  LET Q3 = 0
6030  FOR I = 0 TO 2
```

```
6040 FOR J = 0 TO 6
6050 IF TB(I.J.1) = 1 THEN  GOTO 6080
6060 IF TB(I.J 2) ) QT(I.J) THEN  GOTO 6080
6070 LET Q2 = (PR * TB(I.J.0))
6072 LET Q3 = QT(I.J) * Q2 + Q3
6080 NEXT J
6090 NEXT I
6120 RETURN
6300 REM  SUBROUTINE PALM ROYAL
6310 PRINT
6320 REM  ROOM FOR PRINT STATEMENTS
6330 REM
6340 INPUT "ENTER RATE OF INTEREST  ".IR
6350 INPUT "ENTER NUMBER OF YEARS   ".YR
6360 PRINT
6370 LET N = IR
6380 LET PV(YR) = 0
6390 FOR X = (YR - 1) TO 0 STEP  - 1
6400 LET PV(X) = (PV(X + 1) + M(X)) / (1 + IR)
6410 NEXT X
6420 PRINT
6430 FOR X = 0 TO (YR - 1)
6440 PRINT "PRESENT VALUE FOR YEAR ".X."  ".PV(X)
6450 NEXT X
6460 PRINT
6470 INPUT "PRESS (RETURN) TO CONTINUE".Z$
6480 PRINT
6490 REM  CAPITAL PROFILE
6500 LET C = 0
6510 FOR X = 1 TO YR
6520 LET C =  - M(X) + C * (1 + IR)
6530 PRINT "CAPITAL FOR YEAR ".X."  ".C
6540 NEXT X
6550 INPUT "PRESS (RETURN) TO CONTINUE".Z$
6560 PRINT
6570 LET IR =  15
6580 LET LB =  -  3
6590 LET UB =  3
6600 LET V = 0
6610 FOR X = (YR - 1) TO 0 STEP  - 1
6620 LET V = (V + M(X)) / (1 + IR)
6630 NEXT X
6640 IF  ABS (V) (  01 GOTO 6740
6650 IF V ( 0 GOTO 6700
6660 REM  V ) 0. INCREASE IR
6670 LET LB = IR
6680 LET IR = ((UB - LB) / 2) + LB
6690 GOTO 6600
6700 REM  V ( 0. DECREASE IR
6710 LET UB = IR
6720 LET IR = ((UB - LB) / 2) + LB
6730 GOTO 6600
6740 PRINT "INTERNAL RATE OF RETURN  ".IR
6750 PRINT
6760 PRINT "DO YOU WANT THE EQUIVALENT CASH FLOW"
6770 PRINT "OF THE NET PRESENT VALUE".
6780 INPUT Z$
6790 LET IR = N
6800 IF Z$ (  ) "YES" AND Z$ (  ) "Y" GOTO 6900
6810 INPUT "FOR WHAT YEAR?".YR
```

```
6820  LET NV = PV(YR) * IR * ((1 + IR) ^ YR)
6830  LET NV = NV / (((1 + IR) ^ YR) - 1)
6840  PRINT
6850  PRINT "ANNUAL CASH FLOW  " NV
6860  GOTO 6760
6900  RETURN
7000  REM  SUBROUTINE TO CHECK
7010  REM  INPUT ERRORS
7020  REM  ECHO PRINT
7040  PRINT   PRINT
7050  PRINT "IS THIS INFORMATION CORRECT?"
7060  PRINT
7070  PRINT "1  VARIETY              " V$
7080  PRINT "2  DETACHED FRUIT       ".W
7085  PRINT "3  WEIGHT OR NUMBER     ".DF$
7090  PRINT "4  BUNCH WEIGHT         " Q
7100  PRINT "5  TIME DELAY           " TD
7110  PRINT "6  FRUIT CONDITION      " FC$
7120  PRINT "7  PALM TREE AGE        ".AG
7130  PRINT
7140  PRINT "CORRECT (Y/N)? "  GET OK$
7150  IF OK$ = "Y" OR OK$ = "YES" THEN  GOTO 7700
7200  PRINT "WHICH ITEM IS INCORRECT (1-7)? "  GET I$
7205  LET I% =  VAL (I$)
7210  IF I% (  ) 1 THEN  GOTO 7250
7220  PRINT "ENTER VARIETY"
7230  INPUT "(DURA. PISIFERA. TENERA)  ".V$
7240  GOTO 7000
7250  IF I% (  ) 2 THEN  GOTO 7285
7260  PRINT "ENTER NUMBER OF DETACHED FRUITS"
7270  INPUT "OR WEIGHT DETACHED  ".W
7280  GOTO 7000
7285  IF I% (  ) 3 THEN  GOTO 7300
7290  INPUT "WEIGHT OR NUMBER (W,N) ".DF$
7295  GOTO 7000
7300  IF I% (  ) 4 THEN  GOTO 7350
7310  INPUT "ENTER QUANTITY (KG)  " Q
7320  GOTO 7000
7350  IF I% (  ) 5 THEN  GOTO 7400
7360  INPUT "TIME DELAY (DAYS)  ".TD
7370  GOTO 7000
7400  IF I% (  ) 6 THEN  GOTO 7450
7410  PRINT "ENTER FRUIT CONDITION"
7420  INPUT "(U. M. S. V. X. OR HELP)  ".FC$
7425  IF FC$ = "HELP" THEN  GOSUB 1500
7430  GOTO 7000
7450  IF I% (  ) 7 THEN  GOTO 7500
7460  INPUT "ENTER AGE OF PALM (YEARS)  ".AG
7470  GOTO 7000
7500  PRINT "ITEM NUMBER MUST BE A NUMBER FROM 1 TO 7 "
7510  GOTO 7200
7700  IF V$ = "DURA" OR V$ = "PISIFERA" OR V$ = "TENERA" GOTO 7740
7705  PRINT
7710  PRINT "VARIETY MUST BE 'DURA'. 'PISIFERA'. OR 'TENERA' "
7720  PRINT "PLEASE CHECK VARIETY "
7730  GOTO 7000
7740  IF DF$ = "W" OR DF$ = "N" GOTO 7780
7745  PRINT
7750  PRINT "ITEM NUMBER THREE (WEIGHT OR NUMBER)"
7760  PRINT "MUST BE EITHER 'W' OR 'N'. "
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7770  PRINT "PLEASE CHECK WEIGHT OR NUMBER "
7775  GOTO 7000
7780  IF FC$ = "U" OR FC$ = "M" OR FC$ = "S" OR FC$ = "V" OR FC$ = "X" GOTO 7900
7785  PRINT
7790  PRINT "FRUIT CONDITION MUST BE 'U' FOR UNBRUISED,"
7800  PRINT "'M' FOR MODERATELY BRUISED, 'S' FOR"
7810  PRINT "SEVERELY BRUISED  'V' FOR VERY SEVERELY"
7815  PRINT "BRUISED, OR 'X' FOR EXTREMELY BRUISED "
7820  PRINT "PLEASE CHECK FRUIT CONDITION "
7830  GOTO 7000
7900  RETURN
8000  REM  SUBROUTINE FOR COST ANALYSIS
8010  REM  COLLECT ADDITIONAL INFORMATION
8015  INPUT "ENTER VARIETY YOU HARVEST             ",V$
8020  INPUT "ENTER AREA HARVESTED (ACRES)          ",AR
8030  INPUT "ENTER QUANTITY HARVESTED (TONS)       ",Q
8040  INPUT "ENTER BUNCH WEIGHT (LBS)              ",VB
8045  INPUT "ENTER FRUIT WEIGHT (G)                ",FW
8050  INPUT "ENTER CURRENT OIL PRICE (N/TON)       ",OP
8060  INPUT "ENTER CURRENT KERNAL PRICE (N/TON)    ",KP
8070  PRINT
8080  INPUT "ARE YOU A GROWER, PROCESSOR, OR BOTH? ",Z$
8090  PRINT
8093  LET C1 = 0
8097  LET C2 = 0
8100 UR = 0
8110 RF = 0
8120 VR = 0
8130  FOR I = 0 TO 1
8140  FOR J = 0 TO 2
8150  REM  TOTAL UNRIPE FRUIT
8160  LET UR = UR + QT(I,J)
8170  NEXT J
8190  FOR J = 3 TO 4
8200  REM  TOTAL RIPE FRUIT
8210  LET RF = RF + QT(I,J)
8230  NEXT J
8240  FOR J = 5 TO 6
8250  REM  TOTAL OVERRIPE FRUIT
8260  LET VR = VR + QT(I,J)
8263  NEXT J
8265  NEXT I
8267  LET TF = UR + RF + VR
8268  LET UR = (UR / TF) * 100
8270  LET RF = (RF / TF) * 100
8275  LET VR = (VR / TF) * 100
8279  PRINT
8280  PRINT "PERCENTAGE UNRIPE FRUIT    ",UR
8282  PRINT "PERCENTAGE RIPE FRUIT      ",RF
8284  PRINT "PERCENTAGE OVERRIPE FRUIT  ",VR
8286  PRINT
8287  GOSUB 9500
8288  REM  DECIDE WHICH MESSAGE IS APPROPRIATE
8290  IF (UR + VR) < 30 THEN  GOTO 8330
8293  IF  ABS (UR - VR) < 5 THEN  GOTO 8320
8296  IF UR > VR THEN  GOTO 8310
8299  REM  OVERRIPE > UNDERRIPE
8300  LET C2 = 1
8304  IF UR > 30 THEN  LET C1 = 1
8306  GOTO 8330
```

```
8310  REM  UNDERRIPE > OVERRIPE
8312  LET C1 = 1
8315  IF VR > 30 THEN  LET C2 = 1
8317  GOTO 8330
8320  REM  PRINT BOTH MESSAGES
8324  LET C1 = 1
8327  LET C2 = 1
8329  REM  PRINT MESSAGES
8330  IF C1 <  > 1 THEN  GOTO 8360
8333  PRINT   PRINT "MUCH OIL IS LOST BY HARVESTING UNRIPE BUNCHES "
8340  PRINT "THE PREMIUM OBTAINED FOR LOWER FFA%"
8345  PRINT "CANNOT OFFSET THIS LOSS "
8350  PRINT   PRINT "ANNUAL LOSS PER HECTARE FOR UNRIPE BUNCHES  ".2 5 * (( 018 * Q) * OP) / AR.
" N/HECTARE"
8360  IF C2 <  > 1 THEN 8800
8365  PRINT
8370  PRINT "EXCESSIVE LOOSE FRUITS AND BUNCHES ARE MORE PRONE"
8380  PRINT "TO DAMAGE. LEADING TO HIGH FFA% OIL CONTENT."
8390  PRINT "WHICH YIELDS POOR OIL QUALITY "
8500  REM  CALCULATE LOSS PER ACRE
8510  REM  CALCULATE BUNCHES LOST PER ACRE
8520  LET L = Q / ((VB *  45) / 1000)
8550  IF Z$ <  > "PROCESSOR" AND Z$ <  > "P" AND Z$ <  > "B" AND Z$ <  > "BOTH" GOTO 8650
8560  REM  CUSTOMER IS A PROCESSOR
8570 O = FW *  367
8580  LET A = OP * (O / 1000000)
8590 KR = FW *  075
8600  LET B = KP * (KR / 1000000)
8610  LET FV = A + B
8650  IF Z$ <  > "GROWER" AND Z$ <  > "G" GOTO 8700
8660  REM  CUSTOMER IS A GROWER
8670  INPUT "ENTER FRUIT PRICE (TON)  ".FP
8680  LET D = FP * (FW / 1000000)
8690  LET FV = D
8700  PRINT   PRINT "ANNUAL LOSS PER HECTARE FOR OVERRIPE BUNCHES  ".2 5 * (FV * L)." N/HECTARE"
8800  PRINT   PRINT
8805  GOSUB 6300
8810  INPUT "DO YOU WANT AN AID IN ADJUSTING YOUR HARVESTING SYSTEM (Y/N)? ".Z$
8820  IF Z$ = "Y" OR Z$ = "YES" THEN  GOSUB 5500
8990  FOR I = 0 TO 2
8991  FOR J = 0 TO 6
8994 QT(I.J) = 0
8996  NEXT J
8997  NEXT I
8999  RETURN
9000  PRINT   PRINT
9010  PRINT "PROGRAM ENDED "
9020  STOP
9500  REM  CALCULATE OIL PER MESOCARP AND FFA
9520  LET DF = 0
9530  REM  10% OF UNRIPE IS DETACHED
9540  LET DF = .1 * UR
9550  REM  30% OF RIPE IS DETACHED
9560  LET DF = DF + ( 3 * RF)
9570  REM  40% BUT NOT MORE THAN 50% IS DETACHED
9580  LET DF = DF + ( 45 * VR)
9590  IF V$ <  > "TENERA" GOTO 9630
9600  LET FF = .613 +  0.84 * DF
9610  LET OM = 45 59 +  13 * DF
9620  GOTO 9750
```

```
9630  IF V$ < > "DURA" GOTO 9670
9640  LET FF = .601 + .0194 * DF
9650  LET OM = 45.59 + .13 * DF
9660  GOTO 9750
9670  IF V$ < > "PISIFERA" GOTO 9710
9680  LET FF = .601 + .0173 * DF
9690  LET OM = 45.59 + .13 * DF
9700  GOTO 9750
9710  PRINT "VARIETY MUST BE DURA, PISIFERA, OR TENERA "
9720  RETURN
9750  PRINT "OIL PER MESOCARP",,"FFA"
9760  PRINT OM,,FF
9780  PRINT
9800  RETURN
10000  REM  DATA FOR TABLE
10010  REM  TB(2,6,2)
10020  DATA  "DURA"
10030  DATA  0,1,0,"BLACK"
10040  DATA  10,1,0,"BLACK"
10050  DATA  40,1,0,"BLACK"
10060  DATA  75,0,20,"SHINY BLACK"
10070  DATA  75,0,20,"SHINY BLACK"
10080  DATA  40,1,0,"SHINY BLACK"
10090  DATA  10,1,0,"SHINY BLACK"
10100  DATA  "PISIFERA"
10130  DATA  0,1,0,"GREEN"
10140  DATA  10,1,0,"YELLOW GREEN OR 35% RIPE COLOUR"
10150  DATA  40,1,0,"YELLOW ORANGE OR 50% RIPE COLOUR"
10160  DATA  75,0,20,"ORANGE OR 70% RIPE COLOUR"
10170  DATA  75,0,20,"RED ORANGE OR 90% RIPE COLOUR"
10180  DATA  40,1,0,"RED OR 95% RIPE COLOUR"
10190  DATA  10,1,0,"RED OR 100% RIPE COLOUR"
10200  DATA   "TENERA"
10230  DATA  0,1,0,"GREEN"
10240  DATA  10,1,0,"YELLOW GREEN OR 40% RIPE COLOUR"
10250  DATA  40,1,0,"YELLOW ORANGE OR 50% RIPE COLOUR"
10260  DATA  75,0,20,"ORANGE OR 70% RIPE COLOUR"
10270  DATA  75,0,20,"RED ORANGE OR 80% RIPE COLOUR"
10280  DATA  40,1,0,"RED OR 90% RIPE COLOUR"
10290  DATA  10,1,0,"RED OR 100% RIPE COLOR"
10300  DATA   "VERY UNRIPE"
10310  DATA   "UNRIPE"
10320  DATA   "UNDER RIPE"
10330  DATA   "JUST RIPE"
10340  DATA   "RIPE"
10350  DATA   "OVER RIPE"
10360  DATA   "VERY OVER RIPE"
10370  REM  TABLE FOR IRR CALC
10400  DATA  -1067.45
10410  DATA  -220.99
10420  DATA  -128.09
10430  DATA  -36.47
10440  DATA  25.02
10450  DATA  109.02
10460  DATA  134.52
10470  DATA  218.52
10480  DATA  260.52
10490  DATA  260.52
10500  DATA  260.52
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