FEASIBILITY STUDY
ON
THE ESTABLISHMENT OF A CITRIC ACID PLANT
IN
THE REPUBLIC OF ZIMBABWE

MARCH 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Republic of Zimbabwe, the Government of Japan decided to conduct a feasibility study on the Citric Acid Plant in Zimbabwe and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Zimbabwe a study team headed by Mr. Nobuo Ishii, Techno Consultants, Inc., twice between May 1991 and January 1992.

The team held discussions with the officials concerned of the Government of Zimbabwe, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Zimbabwe for their close cooperation extended to the team.

March, 1992

Kensuke Yanagiya

KensukeYanagiya
President
Japan International Cooperation Agency

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Chapter 1 Outline of the Study

1–1 Preface

Citric acid has a clean and refreshing acid taste which makes it one of the most popular of the acidulants used for food and pharmaceuticals. Citric acid is completely non-toxic and quite safe for humans. Citric acid is an international trade commodity and it is relatively inexpensive. Therefore, citric acid is used in a wide variety of food and pharmaceutical products. The largest usage of citric acid is as an acidulant for beverages where it provides a clean acid taste. Citric acid accounts for approximately 75 percent of the acidulants used for beverages and it is used in many soft drinks. However, some soft drinks use other acidulants, for example, phosphoric acid is used in colas and tartaric acid in association with grape-flavored drinks. After beverages, the next largest use of citric acid is in foodstuffs such as jams, candies, and sauces. It is also used widely as a preservative for various foodstuffs. In the field of pharmaceuticals, citric acid is used in antacids, analgesics and vitamin C tablets for the purpose of softening the bitter taste of medicines and providing a good flavor. In industry, it is used in detergents as a builder, or washing agent, and is included in certain kinds of water treatment. Sodium tripolyphosphate (STPP) has been used in detergents as a builder, but STPP presented a serious environmental problem as it caused eutrophication of lakes and marshes. In recent years, there has been interest in the use of citric acid as a replacement for STPP as a detergent builder and citric acid has now been accepted by the major detergent producers in the U.S.A.

In Zimbabwe, the demand for citric acid for industrial uses is very low. However, citric acid is widely used, mainly in the field of beverages and to a lesser extent in food stuffs and pharmaceuticals. The rate of growth of demand for beverages in Zimbabwe has exceeded the rate of increase of population and the rate of growth of GDP and it is expected that the demand for beverages will increase steadily in the future. With the increase in demand for beverages, it is forecast that the demand for citric acid will also increase steadily. Citric acid is not produced in Zimbabwe at present and the total quantity imported is about 600 tons per year. Since Zimbabwe is a landlocked country and the cost of transporting imported goods is high, citric acid is relatively expensive, compared with the international market price. Under these circumstances, domestic users of citric acid have great expectations for the domestic production and supply of citric acid.

Citric acid is produced by a fermentation process using carbohydrates such as molasses (waste liquor after extracting sugar), glucose solution from starch, cornstarch and sweet potato starch extraction residues as the raw material. Agriculture is prosperous in Zimbabwe and Zimbabwe has established its own status as a food supplying country in Africa for a number of years. Large amounts of maize and suger, which are sources of raw materials for citric acid, are produced and some of these produces are exported to foreign countries. Furthermore, Zimbabwe is the second most industrialized country, after the Republic of South Africa, among sub-Sahara African countries. The electric power supply which is one of the key factors for establishing a citric acid industry is extremely good in Zimbabwe.

World demand for citric acid is currently about 500,000 tons per year, more than 80 percent of which is produced in Europe and North America. In Africa and the Near and Middle East, citric acid is produced in Israel and Turkey but their total production is only 3 to 4 percent of the world production. The world's five biggest producers (the citric acid majors), namely, Haarmann & Reimer (a subsidiary of Bayer, Germany), Jungbunzlauer (Austria), Archer Daniels Midland (U.S.A), Roche (Switzerland) and Pfizer (U.S.A) account for apporoximately 75 percent of the total world production of citric acid. Under an oligopolistic market structure, the fundamental strategy of the citric acid majors is the sale of the product and usually they do not intend to sell or supply their production technology. There is only one Austrian engineering firm, Vogelbusch, which sells the technology for citric acid production. In Japan, citric acid producers have developed their own process technology. The quality of citric acid produced in Japan is as high as any in the world.

Under these circumstances, the Government of Zimbabwe requested the Government of Japan to conduct an investigation into the viability of establishing a citric acid plant using agricultural products harvested in Zimbabwe as the raw material. This project meets the objectives of the industrial development plan promoted by the Government of the Republic of Zimbabwe in terms of utilization of indigenous resources,reducing the outflow and increasing the inflow of foreign currency and relatively low capital investment. The above is the background of this feasibility study.

1-2 Objective of the Study

The objective of this study is to investigate and evaluate the viability of citric acid production using raw materials locally available at present, or in the near future, from the technical, financial and economical viewpoints and formulate all of the findings in the form of a study report. In accordance with the Scope of Work agreed and signed between the preliminary survey team of JICA (Japan International Cooperation Agency) and their Zimbabwe counterpart IDC (the Industrial Development Corporation of Zimbabwe Limited) and MIC (Ministry of Industry and Commerce), the following items have been studied and analyzed:

(1) Study on the background and relevant conditions of the project

(2) Agricultural situation

(3) Market study of citric acid and its by-products

(4) Study of raw materials

(5) Fermentation test of Zimbabwean raw materials

(6) Study of the plant site, environment and infrastructure

(7) Formulation of basic plans and conceptual designs for the projected plant

(8) Financial analysis and economic evaluation

(9) Conclusions and recommendations

1-3 Method of the Study

Citric acid is produced by a fermentation process using carbohydrates as raw material. Since the fermentation process utilizes the activities of micro organisms, fermentation performance is affected to a great extent by the combinations of raw materials, fungus and fermentation conditions. If an existing fermentation process (fungus and fermentation conditions) is applied regardless of the properties of the raw materials, fermentation will result in a low output. Therefore, in this study, appropriate combinations of fermentation processes and raw materials were studied by fermentation tests actually conducted in Japan using the following raw materials which were collected during the field survey:

– Cornstarch (2 kinds)	:	10 kgs each
– Dry sweet potato chips (dried in sunlight after slicing)	:	24 kgs
– Dry cassava chips (dried in sunlight after slicing)	:	3 kgs
– Crude sugar	:	3 kgs

– Affination syrup : 3kgs

(syrup which is collected during the refining process of crude sugar)

– Condensed sugarcane juice : 5 kgs

– Process molasses : 3 kgs

(molasses collected during the refining process of crude sugar)

– "B" molasses : 5kgs

(mother liquor after extracting crude sugar, twice by crystalisation)

– Bagasse (used as a carrier) : 12kgs

– White maize (for analysis of starch content) : 1kg

– Yellow maize (for analysis of starch content) : 1kg

Based on the results of the fermentation tests and taking into consideration the raw material situation (price and availability), the appropriate size of the plant as determined by the market study, and the plant site, the most feasible project scheme was established as shown below:

<<Project Scheme>>

– Plant capacity : 3,000 tons per year (operation: 333 days per year)

– Fermentation process : Submerged culture fermentation process (number of fermenters: 3 units, 240m^3 each)

– Product specification : Citric acid monohydrate (BP specification)

– Raw material : Cornstarch made from Zimbabwe maize (consumption: about 4,100 tons per year)

– Plant site : Mukuvisi area, approximately 10km east of Harare city.

A conceptual design of the plant, construction cost estimates, financial and economic analyses of the project were carried out for the selected project scheme.

1–4 Field Survey

The Japan International Cooperation Agency dispatched a field survey study team to the Republic of Zimbabwe from May 30 to June 25, 1991. The list of members of the field survey team and their schedule are shown in Appendix–I.

Chapter 2 Executive Summary

Chapter 2 Executive Summary

2–1 Economic and Industrial Situations in Zimbabwe

The scale of the economy and industry of Zimbabwe is the second largest in sub-Sahara countries after the Republic of South Africa. Infrastructure is well developed and the industries are very diversified so that the economy can be self-supporting. Most industries, however, have an oligopolistic or monopolistic structure, and the rationalization and modernization of the industries are lagging behind. Utilization of factory capacities, in general, fell to 40 to 70 percent after independence due to the shortage of foreign currency and import restrictions on capital goods and raw materials. The average annual rate of real economic growth was only 2.7 percent in the past decade; when the larger population growth rate of Zimbabwe (about 3.0%) is considered, it is effectively a negative growth per capita.

To deal with the above, the government of Zimbabwe is undertaking economic reform programs, including trade liberalization and deregulation of domestic price controls. The programs are intended to improve the competitiveness of domestic corporations, raise the living standards of the people and eliminate poverty from the country. In addition to the reform programs, the government is facing higher rates of inflation and unemployment.

2–2 Citric Acid and Its Production Technology

Citric acid is versatile and widely used in beverages and food for which its principle application is as an acidulant, pharmaceuticals, detergents, and other industrial applications. The main forms of citric acid are anhydrous and monohydrate and the quality is specified in the standards of major countries.

Currently, commercial production of citric acid is made by the following three fermentation methods:

(1) Surface culture: Liquid culture solution is fermented in shallow pans.

(2) Submerged culture: Liquid culture solution is agitated with enough aeration by sterilized air in a fermentation vessel.

(3) Solid (or semi-solid) culture: Solid culture medium is filled into open trays for fermentation in fermentation rooms.

The main method used at present is the submerged culture fermentation method. Although many kinds of carbohydrate materials (starch and sugar) can technically be used, in practice, beet molasses, cane molasses, starch syrup, cornstarch, sweet potato residues and so forth are utilized for commercial production of citric acid. In the fermentation process, the retention of the citric acid yield by the fungi is the prime concern. As the fermentation yield largely depends on the type of fungi selected to meet the process to be used and the raw material, the combinations of raw material, process and fungi are very important.

2–3 Citric Acid Markets

The current world demand for citric acid is about 500,000 tons per year and the actual plant production capacity is estimated to be 550,000 to 600,000 tons per year. There has been a trend for major citric acid producers to be changed from pharmaceuticals and chemical manufacturers to grain processing manufacturers, or to raw materials suppliers. Current international export prices (fob) of citric acid are between 1.3 and 1.5 US$/kg. Citric acid demand in Zimbabwe is about 620 tons at present. Of the demand, 87 percent is for soft drinks and 9 percent for food processing. Current domestic price (delivery base) is 7.0 to 9.0 Z$/kg (2.2 to 2.9 US$/kg). It is forecast that the domestic citric acid demand will grow at the rate of 6.7 percent until the end of this century.

Current citric acid demand in the Southern Africa region is estimated to be 4,620 tons. The Republic of South Africa accounts for 60 percent of the demand, Swaziland for 16 percent, Zimbabwe for 13 percent, and other countries for 11 percent. The demand growth rate for citric acid in the region will be 5.1 percent and the demand will reach about 6,200 tons in the middle of the 1990s. Because citric acid major suppliers are well entrenched into the biggest market in the region, the Republic of South Africa, it will be difficult to cover more than half the citric acid market in the region. Potential sales by a Zimbabwean citric acid producer will be about 3,000 tons in the middle of the 1990s. Thus, the plant capacity of 3,000 tons/y is determined in this study.

2–4 Agriculture in Zimbabwe

About 70 percent of the Zimbabwe population, 9.12 million in 1988, is engaged in agriculture. The major agricultural products of Zimbabwe, are grains including maize, wheat and sorghum, which amount to 2 to 3 million tons per year, creating some surplus in general. The domestic demand for maize

is about 1.7 million tons and the amount needed to provide the people's staple food has been secured except in drought years.

Farming zones suited for upland crops (maize, sweet potato, etc.) are those with an annual average temperature from 17.5 to 20 degrees centigrade and an annual rainfall of 650 to 1,000 mm. These zones consist of various types of soils ranging from sand to clay loam. Drought damage happens once in four years due to the shallow ploughing depth and the low content of readily available moisture. As ways of alleviating drought damage, it will be most practical and effective to proceed with such countermeasure as soil improvement by fertilizers, deep ploughing, increasing available moisture in soils, effective use of rainfall and minimizing of evaporation and transpiration.

2–5 Raw Materials

The following candidate raw materials were selected for citric acid production in this study:

(1) Sweet potato starch residues

(2) Cassava starch residues

(3) Cornstarch

(4) Sugar materials including raw sugar, molasses, etc.

Of the above materials, the domestic production of sweet potatoes and cassavas is very small and no sweet potato starch or cassava starch markets exist in Zimbabwe. There is no proven commercial plant using raw sugar in the world. Cane molasses are fully utilized for ethanol production in Zimbabwe. So the possibility of using sugar materials is very low. Although the current production of cornstarch is not so large, an expansion of cornstarch production is very realistic as the raw material, maize, is abundant and domestic demands for cornstarch and its derivatives are very high. Hence, cornstarch has been determined as the raw material for citric acid production.

Of the several subsidiary materials used in the citric acid process, ammonium nitrate and sulfuric acid are produced in Zimbabwe, whereas slaked lime, activated carbon, filter aid and potassium dehydrogen phosphate will have to be imported.

2–6 Plant Site and Infrastructure

The location next to Zimbabwe Phosphate Industries in Mukuvisi district was selected to be the most suitable site for establishing the citric acid plant. There are plenty of advantages in this location, such as firm soil foundation, easy availability of the raw material (cornstarch) and subsidiary materials, better transportation routes, well maintained infrastructures like electric power supply, water and sewage systems, and being near to the major domestic markets for citric acid.

2–7 Environmental Protection

As this plant will produce citric acid using food, cornstarch, based on fermentation by microorganism, it will have almost no effect on the environment. However, this plant will create organic waste water from the fermentation process and waste gas from the steam boiler, certain environmental measures are required. For the waste water treatment, an improved batch type lagoon facility is to be installed, and for the waste gas treatment, cyclones are to be furnished. Also other wastes, such as mycelium and gypsum, are effectively utilized as far as possible.

2–8 Citric Acid Fermentation Tests

Several kinds of raw material were collected in Zimbabwe and a series of fermentation tests was carried out in Japan using the raw materials. The following summarizes the fermentation test results for the submerged culture using cornstarch and for the solid culture using sweet potato starch residues and cassava residues:

(1) Fermentation test results using cornstarch (jar tests)

Raw Material	Yield against total sugar	Yield against consumed sugar
– STARCON	81.98%	89.71%
– STARTEX-45	80.45%	90.09%
(Japanese starch	83.98%	90.14%)

(2) Fermentation test results using sweet potato/cassava residues

Raw Material	Yield against total sugar
– Sweet potato residues + rice bran + bagasse	80.20%
– Cassava residues + rice bran + bagasse	87.70%
(Commercial production using Japanese sweet potato residues	about 85.00%)

Both fermentation tests resulted in similar yields to those obtained in commercial production in Japan. Above all, it is concluded that citric acid production, using Zimbabwean cornstarch and sweet potato/ cassava starch residues, is possible.

2–9 Project Scheme

(1) Product : Citric acid monohydrate (complying with BP standards)

(2) Production capacity : 3,000 tons/year

(3) Raw material : Cornstarch made in Zimbabwe
(Consumption : 4,100 tons/year)

(4) Process : Submerged culture fermentation process

2–10 Conceptual Design of the Plant

The citric acid plant consists of a fermentation process and a separation process. In the fermentation process, a pure strain of citric acid generating fungus is cultured at a plant laboratory and then planted and cultured in three different sizes of fermenters in sequence so that a commercial quantity of citric acid accumulates in the liquid culture medium. In this process, the sterilization of the raw material by steam and prevention of contamination by miscellaneous fungi are very important. It is the nature of this process that heat is generated as fermentation progresses, so that cooling with a considerable amount of water is required. The plant is designed to be equipped with 3 main fermenter units, one first seed tank and one second seed tank. The operation of fermentation takes place in 3 batches every 7 days. The operating cycles for the first and second seed tanks are 48 and 72 hours respectively to meet the operating cycle for the main fermenters.

In the separation process, citric acid is first crystallized and separated as calcium citrate which has low solubility. This calcium citrate is then decomposed by sulfuric acid to obtain citric acid solution, which is concentrated to separate citric acid crystals thereafter. In designing the separation process, it

is intended that the loss of citric acid should be minimized by circulating mother liquor and washing water as much as possible.

2–11 Construction Work and Construction Costs

The fermentation process uses several items of equipment which are only used for biotechnology, and which are made of stainless steel for the purpose of preventing contamination by bacteria and corrosion by citric acid. As far as procurement of equipment and materials are concerned, those made in Zimbabwe will be used as much as possible, except for the main fermenters, continuous sterilization units, evaporators, centrifuges, air compressors and major laboratory equipment which are to be imported.

The construction period will be 2 years after the conclusion of construction agreement. A general contractor in Zimbabwe will be the prime contractor for the work which will be conducted under the guidance of supervisors dispatched by a licenser.

The construction costs for the plant are estimated to be US$24.3 million of which the foreign currency portion is 38% and the remaining domestic currency portion is 62%.

2–12 Implementation of the Project

The plant is designed for 333 days of continuous batch operations. The remaining 32 days are used for preventive maintenance and preparation work for normal operation after the maintenance outage. In the period just after commencement of plant operation, annual sales of 3,000 tons of citric acid can not be expected from the viewpoint of initial mechanical failures and lack of experience on the part of the operators as well as marketing prospects. Thus, in this study plant utilization has been estimated to be 76% for the first year, 97% for the second year, and 100% for the third year and thereafter and the corresponding number of batches per year is 109, 139, and 143 respectively.

The total number of employees will be 115, including 91 persons for production, 10 persons for maintenance, 13 persons for administration, and one plant manager.

2–13 Total Capital Requirements

In principle, total capital consists of plant construction costs, preoperation costs, initial working capital and interest during construction. Sources for the capital required are equity (one third of the

total), a foreign bank long-term loan for the foreign currency portion, and a domestic bank long-term loan for the domestic currency portion. In the case where the interest rate for the foreign long-term loan is 10.75%, the total capital is calculated to be about US$26.49 million, of which the interest during construction amounts to US$1.32 million.

2–14 Financial Analysis

In the financial analyses, production cost tables, income statements, fund flow tables and balance sheets were made to evaluate the profits from operations and funds required for the operations based on estimated capital requirements, operation costs, sales amount, etc. Then, the internal rate of return (IRR) from 20 years of operation was calculated using the discounted cash flow method.

For foreign loans, two interest rate cases were simulated; one was 10.75% (Case 1) and the other 4.50% (Case 2). For the domestic long term loan, an interest rate of 20% was determined from discussions with IDC. The high rate of inflation in Zimbabwe is reflected in this high rate of interest. As the exchange rate of the Zimbabwe dollar against the U.S. dollar has fallen at an average rate of about 15.4% a year in the past decade, the interest rate after conversion into U.S. dollars will be 4.6%.

The following summarizes the results of the financial analysis:

	Case–1	Case–2
– Sales price : (average for 20 years)	1.81 US$/kg	1.81 US$/kg
– Production cost : (average for 20 years)	1.87 US$/kg	1.75 US$/kg
– Accumulated profit :		
(before tax)	–US$6.55 million	US$3.44 million
(after tax)	–US$6.55 million	US$1.98 million
– Accumulated cash : (in the 20th year)	–US$0.26 million (debt)	US$8.30 million (cash)
– IRROI (before tax) :	2.9%	2.9%
– IRROI (after tax) :	1.5%	1.5%
– IRROE (before tax) :	–	0.9%
– IRROE (after tax) :	–	–0.1%

Subsequently, a sensitivity analysis was conducted on the basis of Case 2 above, by changing the product price, operation costs and plant costs as shown in Table 2–1.

Table 2–1 Summary of Sensitivity Analysis

	Base Case	Product Price 20% up	Operation Cost 20% down	Plant Cost 30% down
IRROI(b/tax)	2.9%	7.9%	6.5%	7.2%
IRROI(a/tax)	1.5%	4.9%	3.9%	4.5%
IRROE(b/tax)	0.9%	10.8%	8.2%	9.5%
IRROE(a/tax)	–0.1%	7.0%	5.1%	6.2%
Production Cost	1.75US$/kg	1.75US$/kg	1.50US$/kg	1.54US$/kg
Total Profit after Tax	2.0MMUS$	14.8MMUS$	10.8MMUS$	9.5MMUS$
Cum. Cash Surplus at 20th year	8.3MMUS$	21.1MMUS$	17.2MMUS$	14.0MMUS$

2–15 Economic Analysis

In the economic analysis, the appropriateness of the project was evaluated in terms of the national economy of Zimbabwe. The evaluation was made for an economic internal rate of return, which is calculated based on the discounted cash flow method after the calculation of economic benefits and costs, and the foreign currency benefit resulting from the implementation of the project. In this study, economic benefits, economic capital costs and economic operation costs are calculated from the benefits and costs employed in the financial analysis by introducing the two parameters of a shadow exchange rate and a shadow wage rate. A foreign currency premium of 1.5, for the calculation of the shadow exchange rate, and a shadow wage rate of 0.37 are used in the base case study.

Based on the above premises, the economic internal rate of return was calculated to be 5.5% which is slightly better than the financial internal rate of return. When the foreign currency premium was changed to 1.33 and 2.0, the economic internal rate of return became 3.7% and 9.4% respectively.

The foreign currency balance resulting from the implementation of the project is calculated as follows:

– In the case of a commercial loan : plus US$56.83 million

– In the case of a soft loan : plus US$63.92 million

The largest economic benefits derived from this project will be the saving of foreign currency for domestic citric acid consumption and the earning of foreign currency from exports. The amount of foreign currency earned will be 2.3 times the plant costs in the case of a commercial bank loan and 2.6 times in the case of a soft loan. It is expected that this kind of relatively low capital investment project should be promoted in order to contribute to the earning of foreign currency since the shortage of foreign currency limits the development of the national economy of Zimbabwe.

2–16 Conclusion and Recommendations

It became clear that the production of citric acid is technically possible using cornstarch made in Zimbabwe from the results of the fermentation tests. Also, there are no obstacles to establishing a citric acid industry in Zimbabwe in terms of technical transfer, supplies of materials and utilities, environmental measures and plant construction. Estimated annual demands for citric acid in the middle of the 1990s (1996) will be 6,200 tons in total in southern Africa; 900 tons in Zimbabwe, 4,700 tons in the Republic of South Africa, 110 tons in Zambia and so on. As European citric acid producers are well entrenched with major citric acid consumers in the Republic of South Africa, more than half the market in South Africa cannot be considered as being accessible to a proposed Zimbabwean citric acid producer. Also, exports to Europe cannot be considered because of the geographical location of Zimbabwe. So the plant capacity of this project has to be 3,000 tons, which is far smaller than the minimum size of a commercial plant which is said to be around 10,000 tons.

The world citric acid industry is now under the pressure of very fierce competition and restructuring of the industry is underway because major producers have established large capital intensive facilities and producers in developing countries have entered into the market. Major citric acid producers in the world tend to be changing from chemical companies to grain processing companies, which can provide the raw material cheaply. Recently even in China which supplies citric acid cheaply, small scale producers have stopped their production because of a cut in export subsidies by the government. Under the circumstances, it is said that only large scale plants of a few tens of thousand tons capacity, of which the facilities are already depreciated, or plants, where very cheap raw materials and labor costs are available, can make reasonable or marginal profits in the citric acid business.

The results of the financial analysis do not show such a good profitability for the project. This is mainly attributed to the following inherent features of the industry in Zimbabwe as well as the world market situations and limited market size mentioned above:

(1) Zimbabwean industry is diversified since the economy of Zimbabwe has been headed towards self-sufficiency. Most of the industry, however, has a monopolistic or oligopolistic structure and prices of materials for citric acid production are considerably higher than international prices. For instance, the sulfuric acid price in Zimbabwe (194 US$/ton) is as much as 2.59 times that in USA, the slaked lime price in Zimbabwe (98 US$/ton, imported from Zambia) 2.04 times that in USA, and the coal price (42.32 US$/ton) 4.45 times that in the Republic of South Africa.

(2) Transportation of equipment and materials is expensive because of the inland location.

(3) Personnel wages in Zimbabwe are not necessarily low when compared to those in other developing countries.

Thus, the entry of a new Zimbabwean company into the citric acid industry with a 3,000 ton plant will not be so easy and careful consideration must be given to the implementation of the project.

On the other hand, regarding the sales in the domestic market, when this project is considered for the purpose of import substitution, expensive transportation costs and a high rate of commission charged by the domestic suppliers act favorably to maintain domestic citric acid prices at a high level. However, the sales volume of this portion is about one third of the total sales and the remaining two thirds have to be sold competitively in foreign market.

To make the project financially feasible, the following measures can be considered:

(a) To exempt surtaxes on imported equipment and materials used for the plant construction.

(b) To reduce interest costs by the government having a share of the equity capital or by a government loan.

(c) To receive the most beneficial loan conditions from abroad.

(d) To find the best method for the supply of the equipment and materials necessary for the plant construction.

(e) To make the raw material costs close to international market costs by further promoting corporate rationalization through the ongoing trade liberalization program and price decontrol.

(f) To provide a subsidy for citric acid exports to neighboring countries, if necessary.

(g) To consider capital sharing from consumers in other Southern African countries to make the citric acid industry stable in the region.

However, it will be very difficult to realize all of the above measures. It is concluded that the project is not feasible.

Chapter 3 Present Socio – Economic Conditions in the Republic of Zimbabwe

Chapter 3 Present Socio-Economic Conditions in the Republic of Zimbabwe

3-1 Basic Data

Country Name : The Republic of Zimbabwe

Date of Independence : April 18, 1980

Land Area : 390,759 km^2
(a bit larger than the land area of Japan, 370,000 km^2)

Location : Southern Part of African continent
Latitude 15° 30' to 22° 30' south
Longitude 25° 00' to 33° 10' east

Population : 9,369,000 (1990 estimate)

Major Cities :

Harare	658,000 (in 1982)
Bulawayo	495,000
Chitungwiza	172,000
Gweru	79,000
Mutare	75,000
Kwekwe	48,000
Kadoma	45,000
Hwange	39,000

Climate : Sub-Tropical
Zimbabwe's climate belongs to the tropical zone. However, as almost all the country is over 1,000 m in altitude, the climate is effectively sub-tropical.

Capital City	:	Harare (located at an altitude of 1,472 m)
Climate at Harare	:	Hot season: From October to November Average temperature varies between 16°C and 27°C. Cool season: June to July Average temperature varies between 7°C and 21°C. Driest Month: July (average rainfall is 1 mm/month) Wetest Month: January (average rainfall is 196 mm/month)
Languages	:	English (official language), Shona and Ndebele
Religion	:	Christianity and Animish
Races	:	Shona – 7,000,000 (1990 estimated figure) Ndebele – 2,000,000 White – 100,000 Mixed – 20,000 Asian (mainly Indian) – 10,000
Measurement	:	Metric System
Currency	:	Zimbabwe Dollar: Z$1 = 100 Zimbabwe cent Exchange Rate: US$1 = Z$3.15 in June, 1991
Fiscal Year	:	Begins in July and ends in June

3–2 Political Background

3–2–1 Historical Sketch

In 1890, Cecil Rhodes, a British businessman, established a "British Southern African Company" in current Zimbabwe as his private colonization company. When Cecil Rhodes died, the United Kingdom incorporated this land into the British colonies and named it "Rhodesia", after him.

3–2–2 The Road to Independence

After World War II, independence movements in African countries increased. First the Republic of Ghana succeeded in achieving independence, and was followed by other African countries. The native population in Rhodesia also showed its enthusiasm for independence. However, the "Rhodesia Front" headed by Prime Minister Ian Smith repressed political activities towards independence and finally made a Unilateral Declaration of Independence (UDI) on November 11, 1965, breaking away from the UK and naming the country the "Republic of Rhodesia". This action brought global censure, and the United Nations decided to operate mandatory economic sanctions based on the Charter No.7 in 1967. Prime Minister Smith, however, stayed in power for another 15 years, securing the co-operation of whites together with the support of countries such as South Africa and Portugal, which openly ignored the UN resolution.

In 1975, Angola and Mozambique achieved independence, and the anti-government movement in this country became very active. In these circumstances, many white people gave up the idea of a future in Rhodesia and migrated abroad. Prime Minister Smith could not maintain his position and finally had to allow nominal participation of the native population in the government and appointed Bishop Abel Muzorewa as a governor who represented the most moderate group. He intended to change the name of the country to "Zimbabwe-Rhodesia". In opposition to this government, the Patriotic Front was organized by linking ZANU (Zimbabwe African National Union led by Mr. Robert Mugabe) and ZAPU (Zimbabwe African People's Union led by Mr. Joshua Nkomo), and their activities developed significantly, although both parties had been active separately since 1972. The government of Muzorewa lost control of the country within one year.

In 1979, Prime Minister M. Thatcher of the United Kingdom proposed and convened a constitutional conference of all parties concerned at Lancaster House, London. As a result of free and fair elections, Mr. Robert Mugabe was victorious, and independence was officially attained under the new name of "The Republic of Zimbabwe".

3–2–3 Political Movements after Independence

The Zimbabwe parliament had a lower house and an upper house in the Westminster style, with 80 members representing Africans and 20 members representing whites in the lower house and 30 members for Africans and 10 members for whites in the upper house. In September 1987, Prime Minister Mugabe revised the constitution of the lower house and abolished the white seats after the expiration of the Lancaster House agreement. In March, 1990, the second national election since independence was held and ZANU-PF won a sweeping victory, and then the upper house was abolished. Results for the 1980, 1985 and 1990 elections are shown in Table 3–1.

Table 3–1 Election Results for 1980, 1985 and 1990

	1980		1985		1990	
	Seats (no.)	Votes (%)	Seats (no.)	Votes (%)	Seats (no.)	Votes (%)
Common roll:						
Zanu-PF	57	63	63	76	116	77
Zapu	20	24	15	18	–	–
Zanu-Sithole	–	2	1	1	1	...
UANC	3	11	–	3	–	...
ZUM	–	–	–	–	2	... (*)
Vacant	–	–	1	–	1	–
White roll:						
Conservative Alliance of Zimbabwe (CAZ)(RF)	20	...	15	53	–	–
Independent Zimbabwean Group	–	–	4	...	–	–
Independent	–	...	1	...	–	–

Note: * Estimates range from 15 to 20 percent

In the general election of 1990, the president was elected by popular vote for the first time since independence. Mr. Robert Mugabe won with 78% of the votes and was re-elected as president of Zimbabwe for a 6 year term.

3–2–4 Present Political Organization

Zimbabwe is a republican country headed by President Mugabe with a Marxist-Leninist ideology. In June 1991, at the general conference of ZANU-PF, President Mugabe called for a study to be made concerning the need to reconsider the present ideology.

As for the political parties of Zimbabwe, President Mugabe has the intention to govern by single party (ZANU-PF) rule, and actually succeeded in unifying ZANU-PF and ZAPU in December 1987. In other African countries, some democratic movements with multi-party political systems have appeared following the current political trend in USSR and east European countries. Under these circumstances, there are still several political parties besides ZANU-PF, i.e., ZANU-Sithole, CAZ and ZUM (Zimbabwe Unity Movement-headed by Mr. Edger Tekere).

3–2–5 International Relations

After independence in 1980, Zimbabwe's international relations normalized but at the same time political relations with the Republic of South Africa became cool.

Zimbabwe is one of the most important members of SADCC (Southern African Development Coordination Conference) which had been established in July, 1979 with the main purpose of lessening economic dependence on the Republic of South Africa (member countries: Tanzania, Zambia, Botswana, Mozambique, Angola, Lesotho, Swaziland, Malawi, Namibia and Zimbabwe-10 countries), and also PTA (Preferential Trade Area), founded in July 1984, with the ultimate aim of establishing "The Economic Community of South-East Africa" (member countries: Burundi, Comoros, Djibuti, Ethiopia, Kenya, Lesotho, Malawi, Mauritius, Rwanda, Somalia, Swaziland, Uganda, Zambia, Tanzania, Mozambique, Sudan, Angola and Zimbabwe-18 countries), and has maintained close relations with these neighboring countries. In particular, the clearing house of the PTA is located inside the Zimbabwe Reserve Bank and commenced operations in 1984.

Diplomatically Zimbabwe takes an anti-South Africa position. However in economic terms, relations with South Africa have been preserved since Zimbabwe is located inland and has to use foreign sea ports for international trade. The most economical transportation route is through the Mozambique port of Beira. But the Beria-Corridor railway line (from Beira to Mutare, Zimbabwe) has often been disrupted by the RENOMO (Resistance in Mozambique) guerillas. So, a substantial volume of goods, about 65-70 percent of trade, is routed through Durban in the Republic of South Africa. Industries in

Zimbabwe developed in a self-sufficient economy during the period of UDI due to economic sanctions and Zimbabwe was largely dependent on South Africa for capital and technology.

In trade relations with other countries, trade with South Africa accounted for the largest total of exports and imports in 1987. Zimbabwe maintains good relations with the United Kingdom as well as with other EC countries, as Zimbabwe is an active member of OAU (Organization of African Unity) and is the party concerned with the Lome Convention. Relations with both USSR and USA were once cool. Zimbabwe accused USSR for the invasion of Afghanistan, and also expressed opposition to USA for the invasion of Grenada and its policy towards Nicaragua. However Zimbabwe has now restored good relations with both countries. Zimbabwe is on good terms with such countries as Bulgaria, Rumania, China and North-Korea.

3–3 Major Socio–Economic Indicators

In this section, major socio-economic indicators are introduced. These data are essential for the analysis of the present situation and the economic programs shown in "A Framework for Economic Reform (1991-95)" in Section 5.

3–3–1 Gross Domestic Products

The GDP is shown in Table 3–2, broken down by industry and given both in current monetary terms and also in constant (1980) prices. The trends of total and per capita GDP are given in Table 3–3.

The industrial share of GDP and its annual average growth rate in 1984 and 1989 are shown in Table 3–4 and 3–5 respectively.

Table 3–2 Gross Domestic Product by Industry

(Unit: Z$ million)

Item	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
At Current Prices												
Agriculture & Forestry	289	321	451	640	669	544	748	1,038	1,121	951	1,309	1,408
Mining & Quarrying	156	226	285	252	217	393	320	335	446	529	629	793
Manufacturing	515	625	802	1,016	1,121	1,441	1,475	1,488	1,832	2,098	2,394	2,946
Electricity & Water	62	71	70	78	73	195	142	144	229	302	314	391
Construction	67	92	91	138	190	258	205	154	168	175	200	190
Finance & Insurance	105	123	159	185	228	275	282	343	366	461	542	649
Real Estate	45	44	43	55	55	59	60	68	75	94	100	105
Distributions, Hotels & Restaurants	356	425	451	603	741	783	742	777	971	912	1,061	1,202
Transport & Communications	178	188	211	306	365	403	434	431	582	644	726	829
Public Administration	239	270	291	309	367	398	444	476	518	603	731	881
Education	86	98	169	215	309	343	416	520	610	676	829	1,001
Health	54	60	71	82	106	108	116	143	164	197	242	285
Domestic Services	52	53	65	72	85	88	87	96	129	142	167	201
Other Services, n.e.s.	120	136	173	219	277	317	346	419	372	397	495	587
Less Imputed Banking Service Charge	–69	–82	–108	–121	–146	–173	–168	–205	–233	–270	–309	–340
Gross Domestic Product	2,255	2,650	3,224	4,049	4,657	5,432	5,649	6,227	7,350	7,911	9,433	11,128
At Constant [1980] Prices												
Agriculture & Forestry	444	444	451	515	478	403	496	614	576	472	592	602
Mining & Quarrying	292	292	285	278	284	280	291	288	283	300	295	303
Manufacturing	629	697	802	881	877	852	809	902	933	949	996	1,074
Electricity & Water	70	64	70	70	63	68	70	79	94	123	127	149
Construction	91	89	91	105	101	93	86	64	69	64	67	58
Finance & Insurance	169	155	159	174	208	203	189	187	181	198	208	224
Real Estate	54	48	43	43	43	44	44	44	45	45	46	47
Distributions, Hotels & Restaurants	329	339	451	456	451	392	366	386	418	408	444	469
Transport & Communications	167	173	211	221	226	224	226	237	244	234	248	251
Public Administration	277	277	291	339	333	338	364	372	370	386	409	423
Education	127	127	169	236	284	310	335	358	375	386	391	412
Health	68	68	71	76	88	89	93	97	100	99	104	107
Domestic Services	69	65	65	63	61	60	59	60	60	61	61	62
Other Services, n.e.s.	165	165	173	186	204	215	217	235	247	245	235	240
Less Imputed Banking Service Charge	–88	–90	–108	–106	–112	–110	–105	–125	–123	–132	–134	–131
Gross Domestic Product	2,863	2,913	3,224	3,537	3,589	3,461	3,540	3,798	3,882	3,838	4,089	4,290

Source: Central Statistical Office, Quarterly Digest of Statistics, Dec. 1990

Table 3–3 Trend of Gross Domestic Product

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Total (Z$ million)										
Current Price	3,224	4,049	4,657	5,432	5,649	6,227	7,350	7,911	9,433	11,128
Constant (1980) Price	3,224	3,537	3,589	3,461	3,540	3,798	3,882	3,838	4,089	4,290
Real Change (%)*	10.7	9.7	1.5	▲3.7	2.3	7.3	2.2	▲1.1	6.5	4.9
Per Head (Z$)										
Current Price	438	533	612	703	711	762	874	916	1,062	1,220
Constant (1980) Price	438	465	472	448	445	465	462	444	451	470
Real Change (%)*	7.4	6.2	1.5	▲5.1	▲0.7	4.5	▲0.6	▲3.9	1.6	4.2

Note : * Calculated by Study Team

Source : CSO, Quarterly Digest of Statistics, Dec. 1990

Table 3–4 Industrial Share of Gross Domestic Product at Current Prices

	1983		1989	
	Z$ million	%	Z$ million	%
Agriculture & Forestry	544	10.0	1,408	12.7
Mining & Quarrying	393	7.2	793	7.1
Manufacturing	1,441	26.5	2,946	26.5
Construction	258	4.7	190	1.7
Electricity & Water	195	3.6	391	3.5
Transportation & Communications	403	7.4	829	7.4
Distribution, Hotels, etc	783	14.4	1,202	10.8
Finance & Real Estate	334	6.1	754	6.8
Public Administration & Defence	398	7.3	881	7.9
Services & Other	683	12.6	1,734	15.6
Total	5,432	100.0	11,128	100.0

Source : CSO, Quarterly Digest of Statistics. Dec. 1990

Table 3–5 Industrial Share of Gross Domestic Product at 1980 Prices

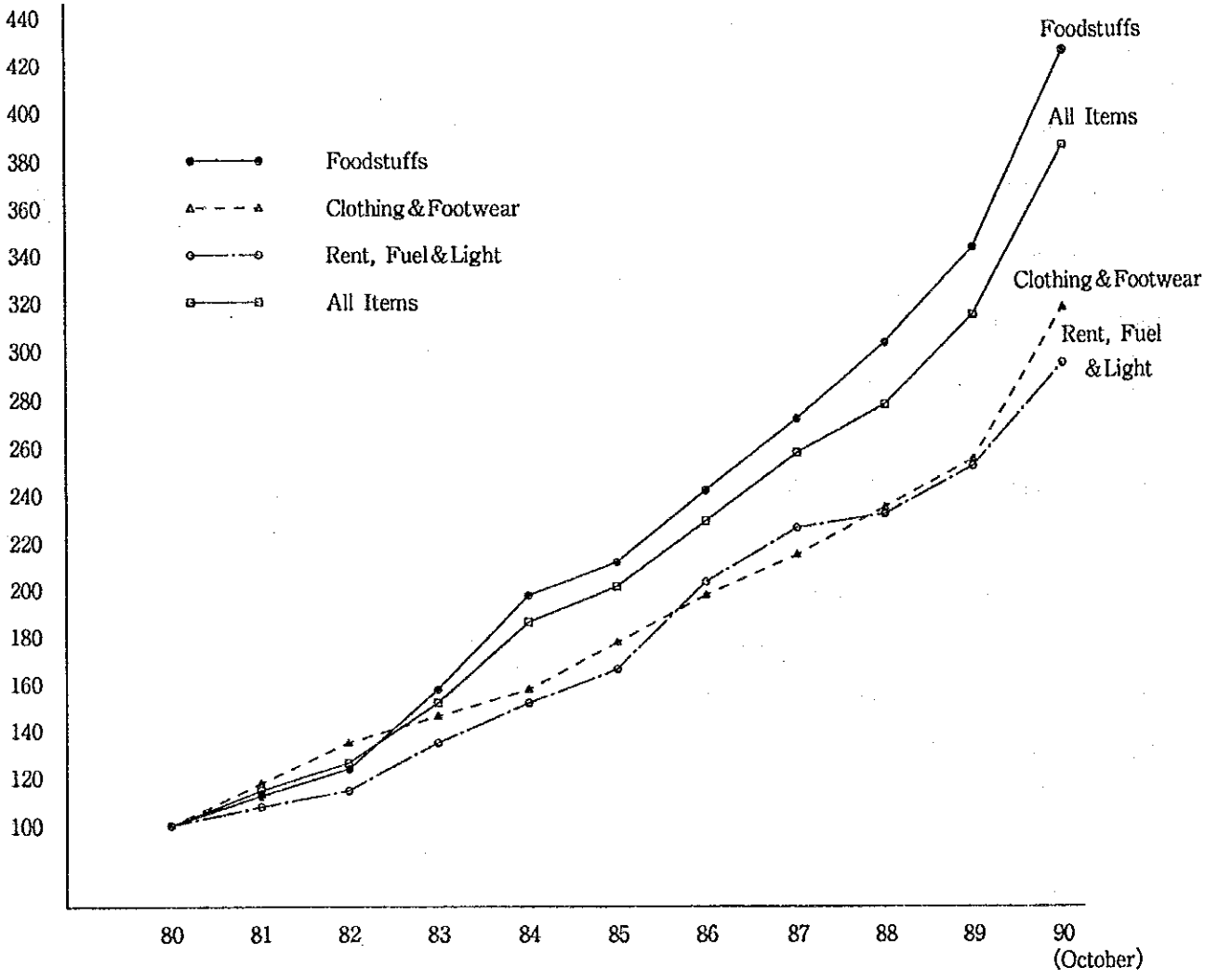
(Unit: Z$ million)

	1983	1989	Average Annual Growth Rate 1983–1989(%)
Agriculture & Forestry	403	602	6.9
Mining & Quarrying	280	303	1.3
Manufacturing	852	1,074	3.9
Construction	93	58	–7.6
Electricity & Water	68	149	14.0
Transportation & Communications	224	251	1.9
Distribution, Hotels, etc	392	469	3.0
Services & Other	1,259	1,515	3.1
Imputed Bank Charges	–110	–131	–3.0
Total	3,461	4,290	3.6

Source : CSO, Quarterly Digest of Statistics. Dec. 1990

3–3–2 Consumer Price Index

The statistical method for calculating the consumer price index in Zimbabwe follows on from that of the Rhodesian period in which calculations were made for Urban Families in the Higher Income Group (Europeans) and Lower Income Group (Africans). Figure 3–1 shows the consumer price index (for clothing, foodstuffs, housing and total) for the Lower Income Group. The index is a weighted average for four cities with weighting percentages as follows: Harare 56%, Bulawayo 32%, Gweru 6% and Mutare 6%.



Source : CSO, Quarterly Digest of Statistics, Dec. 1990
Compiled by Study Team

Figure 3–1 Consumer Price Index for Lower Income Group

3–3–3 Wages

The number of employees and their wages by industrial sector were obtained from the statistics of the CSO (Central Statistical Office). The wages for each industrial sector are shown in Table 3–6. It should be noted that the amount for 1990 is for only half a year; the estimated amount is arrived at by doubling the half year's figures. It is assumed that the high level of wages in the finance, insurance and real estate sectors is a result of the highly educated background of employees engaged in these sectors. The minimum wage system has been abolished and wages are to be fixed by collective bargaining.

Table 3–6 Wages by Industrial Sector

(Unit : Z$)

	AGRICUL-TURE FORESTRY & FISHING	MINING & QUARRY-ING	MANUFAC-TURING	FINANCE INSURANCE & REAL ESTATE	PUBLIC ADMINIS-TRATION	TOTAL
1980	458	1,757	2,521	6,280	3,703	1,863
1981	744	2,306	3,117	7,196	3,375	2,307
1982	919	2,805	3,609	7,959	4,054	2,789
1983	1,061	3,085	4,093	8,747	4,215	3,067
1984	1,177	3,560	4,586	9,624	4,399	3,358
1985	1,247	4,074	5,225	10,627	4,730	3,771
1986	1,376	4,444	5,655	11,948	5,127	4,160
1987	1,466	4,790	6,331	13,393	5,871	4,640
1988	–	5,494	7,115	15,442	6,384	–
1989	–	6,160	7,986	17,211	6,969	–
1990[1/2]	–	3,393	4,318	9,671	3,615	–
(estimate)	–	6,786	8,636	19,342	7,230	–

Source : CSO, Quarterly Digest of Statistics, Dec. 1990
Compiled by Study Team

3–3–4 Agriculture

Table 3–7 and 3–8 show the volume in tons and the values of various agricultural products.

Table 3–7 Volume of Crop Sales to/through Marketing Authorities in tons

Year	Maize	Groundnuts (unshelled)	Sorghum	Soya beans	Coffee	Wheat	Cotton	Flue-cured tobacco	Burley tobacco	Sun-flower
1980/81	819168	17425	17803	93636	5630	163040	182037	122572	2466	
1981/82	2013758	20037	30393	65319	4904	200904	200812	69795	2017	
1982/83	1391265	15905	19150	84340	6906	212945	157673	86949	3653	
1983/84	616749	9329	5347	74438	9727	124250	167280	94295	4631	4726
1984/85	941590	5706	19949	89775	10720	98530	250072	119636	5236	86663
1985/86	1827768	7858	81981	85340	11354	205528	297538	106010	3127	14083
1986/87	1594322	18905	73605	83421	13486	248346	252737	114304	2644	19845
1987/88	402495	16996	3662	102675	11599	229084	232826	127996	3463	23256
1988/89	1196655	23217	22665	122585	12627	256924	324497	119913	3755	46393
1989/90	900230	19155	8892	138047	14601	283965	264409	129952	5207	36898

Source : CSO, Quarterly Digest of Statistics, Dec. 1990

Table 3–8 Value of Crop Sales to/through Maketing Authorities, Z$ thousand

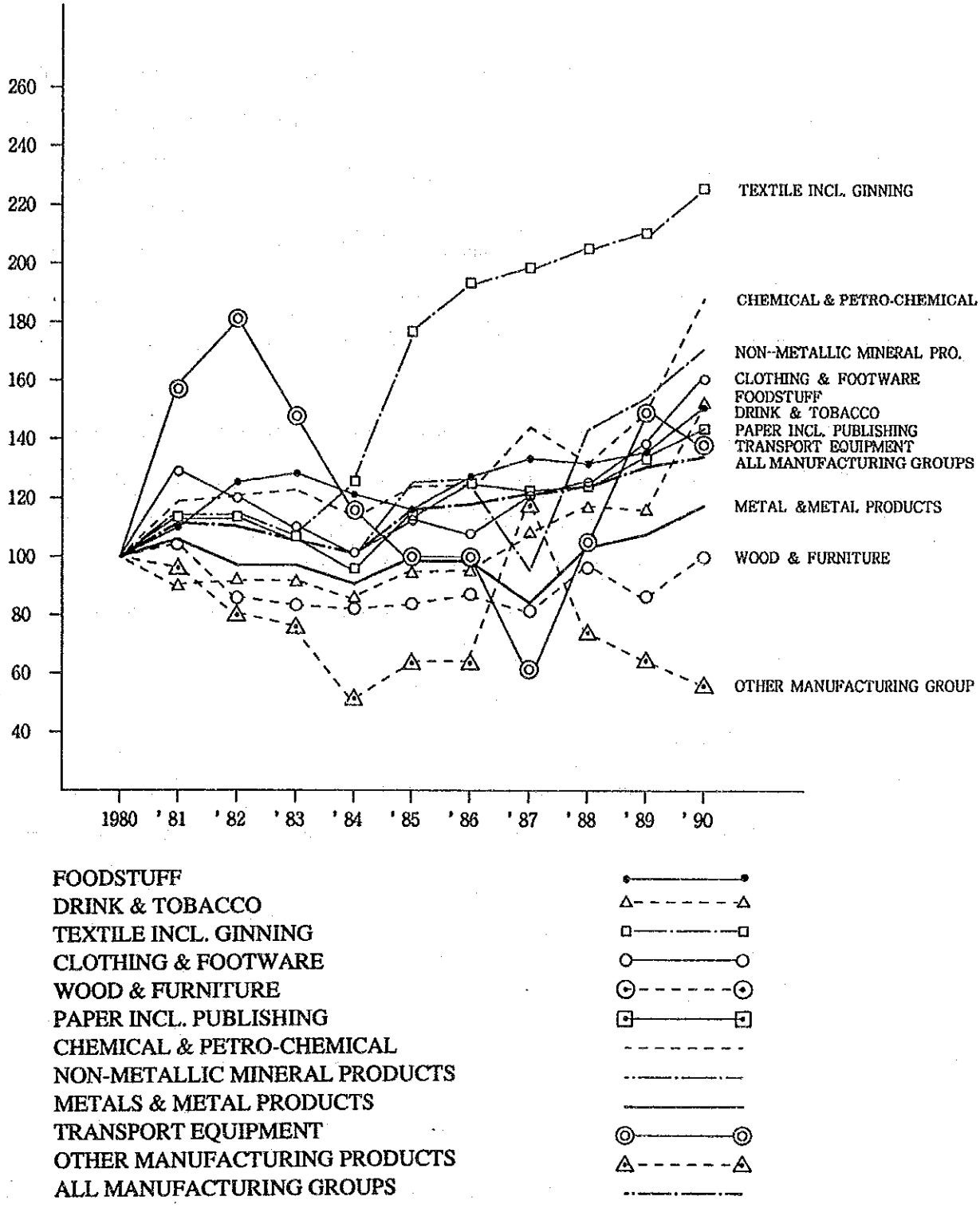
Year	Maize	Ground-nuts	Sorghum	Soya beans	Coffee	Wheat	Cotton	Flue-cured tobacco	Burley tobacco	Sugar	Sun-flower	Total
1980/81	72062	4513	1741	14944	12385	22112	70515	97438	2119	76613		374442
1981/82	239778	5312	3182	11069	7417	34735	76752	127527	3179	82421		591372
1982/83	166431	4432	2014	16788	12003	39892	79339	145811	5998	77966		550674
1983/84	73753	2591	582	19123	20886	27296	83413	177797	6730	93956	1162	507289
1984/85	131439	1742	2760	25665	32034	24536	137953	247118	7538	113835	3242	729188
1985/86	326990	3582	14083	27223	43914	58320	193213	284524	5747	117552	4151	1093926
1986/87	283586	8631	13657	28059	73890	74107	183919	358206	6829	146940	6593	1192373
1987/88	60186	9042	533	39301	34601	75442	174582	278938	8075	157050	8697	859054
1988/89	231216	11800	2114	51062	38609	93023	257744	471837	13770	171435	19435	1382191
1989/90	247970	12009	1620	59550	53761	113170	232542	558459	18308	207100	22631	1530620

Source : CSO, Quarterly Digest of Statistics, Dec. 1990

3–3–5 Industry

The manufacturing sector accounted for 26.5% of GDP in 1989 as shown in Table 3–4.

Production records for each industry are given in Figure 3–2.



Source : CSO, Quartery Digest of Statistics, Dec. 1990
Compiled by Study Team

Figure 3–2 Index of Manufacturing Production (1980 = 100)

From the figure, it can be clearly seen that the output of Zimbabwe industries has changed remarkably each year. These changes have been caused by the constraints in utilizing industrial capacity due to the lack of raw materials and spare parts. It is reported that industry has utilized only 40 to 70 percent of available capacity. On the other hand, it has been pointed out that the industrial structure is of an oligopolistic or monopolistic nature. Most of the monopolies are said to export their products at lower prices and cover their losses with high prices in the domestic market, so as to obtain import quotas equivalent to their exports. It is urged that manufacturers endeavour to minimize and rationalize their production costs.

Under these circumstances, the government decided to proceed with the Trade Liberalization Program through the OGIL system (Open General Import License system) and the deregulation of investments, so as to promote "free competition" and consequently to reduce sales prices. For this purpose, the Zimbabwe government announced a new investment promotion policy in April, 1989 as described in Section 3–4, and also a new policy named "A Framework for Economic Reform (1991–95)" in January, 1991 as summarized in Section 3–5.

3–3–6 Foreign Trade

The latest statistics for Zimbabwe's foreign trade are from 1987. Exports and imports of major commodities in 1982 and 87 are shown in Tables 3–9 and 3–10. Table 3–11 shows the major trading countries in 1981 and 87.

Table 3–9 Exports by Commodity

(Z$ million)

Item	1982	1987
Tobacco	194.7	430.6
Gold	140.5	413.0
Ferro-Alloys	77.2	249.5
Cotton	52.8	123.1
Nickel	45.5	92.9
Asbestos	60.9	91.6
Iron & Steel	41.2	88.0
Textile & Clothing	13.1	82.2
Sugar	52.3	78.8
Meat	7.1	78.4
Maize	39.9	66.3
Copper	21.7	49.0
Coffee	14.7	46.5
Tea	6.1	17.9
(sub-total)	(767.7)	(1,907.8)
Total Incl. Others	947.6	2,332.1

Note : Re-export is not included
Source : CSO

Table 3–10 Imports by Commodity

(Z$ million)

Item	1982	1987
Chemicals	124.6	309.6
Transport Equipment	154.5	242.2
Petroleum Products	154.8	196.2
Food	10.6	24.4
Electricity	21.2	16.9
Sub-total	465.7	789.3
Total Incl. Others	1,081.8	1,741.7

Source : CSO

Table 3–11 Exports and Imports by Country

(%)

EXPORT	1981	1987	IMPORT	1981	1987
UK	6.9	12.9	South Africa	27.4	20.8
W-Germany	8.3	10.2	UK	10.0	11.5
South Africa	22.6	9.8	USA	7.3	9.4
USA	7.9	6.8	W-Germany	7.2	8.7
Botswana	3.2	5.5	Botswana	1.6	5.7
Japan	2.8	5.0	Japan	6.1	3.9
Italy	4.9	4.4	France	5.0	3.7
Netherlands	–	3.7	Italy	2.0	3.0
Belgium	2.6	3.7	Netherlands	1.7	2.8
Mozambique	...	3.7	Switzerland	2.1	2.2
Zambia	4.0	2.8			

Source : CSO

3–3–7 External Balance of Payment

Statistics for external balance of payments published by the Reserve Bank of Zimbabwe are the latest ones. The annual data from 1981 to 1988 are shown in Table 3–12. The external debt service ratio is shown in Table 3–13.

Table 3–12 Balance of Payments-Annual Data

(Z$ million)

	1981	1982	1983	1984	1985	1986	1987	1988[6]
Merchandise exports[2]	+ 1001.9	+ 998.2	+ 1173.9	+ 1483.7	+ 1811.2	+ 2206.4	+ 2416.2	+ 3006.2
Service receipts	+ 83.0	+ 115.6	+ 131.3	+ 156.8	+ 168.5	+ 231.6	+ 250.2	+ 327.0
Income receipts	+ 74.5	+ 83.1	+ 92.8	+ 100.7	+ 100.8	+ 111.2	+ 76.5	+ 48.2
Merchandise imports[2]	– 1059.4	– 1114.3	– 1086.6	– 1237.1	– 1485.6	– 1686.1	– 1782.1	– 2127.3
Service payments	– 345.6	– 307.8	– 392.7	– 400.5	– 466.0	– 485.0	– 514.1	– 684.3
Income payments	– 171.0	– 245.3	– 314.2	– 257.3	– 304.4	– 419.2	– 430.3	– 480.2
Unrequited transfers(net)	– 23.0	– 62.4	– 58.7	+ 16.3	+ 51.8	+ 53.7	+ 113.5	+ 107.0
Balance on current account	– 439.6	– 532.9	– 454.2	– 101.9	– 159.2	+ 12.6	+ 129.9	+ 196.6
Long term capital	+ 62.0	+ 281.9	+ 311.7	+ 214.1	158.2	+ 122.9	+ 111.7	+ 65.0
Official	(+ 68.1)	(+ 237.6)	(+ 294.5)	(+ 235.0)	(+ 174.6)	(+ 105.4)	(+ 156.4)	(+ 20.5)
Private	(– 6.1)	(+ 44.3)	(+ 17.2)	(– 20.9)	(– 16.4)	(+ 17.5)	(– 44.7)	(+ 44.5)
Short term capital [3]	+ 71.6	+ 60.7	– 25.8	+ 18.5	+ 121.5	+ 14.6	+ 3.6	+ 24.9
Balance on capital account	+ 133.6	+ 342.6	+ 285.9	+ 232.6	+ 279.7	+ 137.5	+ 115.3	+ 89.9
Net errors and omissions	+ 85.9	+ 66.0	+ 10.0	+ 33.6	+ 83.0	– 77.1	– 11.5	– 106.6
Balance on capital and current account	– 220.1	– 124.3	– 158.3	+ 164.3	+ 203.5	+ 73.0	+ 233.7	+ 179.9
Gold monetization/ demonetization	+ 15.2	+ 2.2	+ 41.5	+ 29.0	+ 22.5	– 62.3	– 40.3	– 8.6
Valuation factors[4]	– 28.0	+ 25.2	– 36.1	– 21.7	+ 11.2	+ 65.5	+ 82.3	+ 25.4
Use of IMF resources	+ 30.8	–	+ 162.2	+ 78.7	– 30.1	– 97.4	– 170.7	– 132.4
Extraordinary financing[5]	+ 218.3	+ 110.3	– 8.4	– 223.0	– 97.9	+ 43.0	– 28.6	– 3.2
Change in reserves	+ 16.2	+ 13.4	+ 0.9	+ 27.3	+ 109.2	+ 21.8	+ 76.4	+ 61.1

1. All figures except current account are net.
2. Includes timing adjustments, internal freight, gold sales, and gold swap transactions.
3. Capital movements not related to reserves, where period is less than one year.
4. Valuation changes relating to both gold and foreign assets.
5. Extraordinary financing represents borrowing related to reserves.
6. Provisional

Source : Reserve Bank of Zimbabwe Quarterly Economic and Statistical Review, Mar. 1991.

Table 3–13 External Debt and Debt Service Ratio

(Z$ million)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Government	73.2	74.3	183.9	278.4	264.6	418.9	621.2	584.5	571.0	814.9
Interest	23.2	40.4	89.3	121.1	133.3	145.7	167.5	172.1	193.2	295.6
Capital	49.9	33.9	94.6	157.3	131.3	273.2	453.7	412.4	377.8	519.3
Parastatals	2.7	70.4	113.2	140.8	278.6	269.8	236.0	264.4	239.8	287.6
Interest	2.0	32.8	79.5	77.4	117.5	94.8	76.4	93.7	103.1	107.4
Capital	0.7	37.6	33.7	63.4	161.1	175.0	157.6	170.7	136.7	180.2
Private	27.0	36.7	287.3	38.7	39.5	27.5	31.5	27.9	38.8	65.4
Interest	0.9	9.8	11.0	10.1	9.0	10.2	10.6	8.2	11.8	21.2
Capital	26.1	26.9	17.3	28.6	30.5	17.3	20.9	19.7	27.0	44.2
Total	102.9	181.4	325.4	457.9	582.7	716.2	888.7	876.8	849.6	1168.0
Interest	26.2	83.0	179.8	208.6	259.8	250.7	254.5	274.0	308.1	424.2
Capital	76.7	98.4	145.6	249.3	322.9	465.5	634.2	602.8	541.5	743.8
Total Export of Goods and Services	1084.7	1113.8	1323.0	1695.8	1979.7	2438.0	2666.4	3189.6	3983.4	4770.8
Debt Service Ratio %	9.5	16.3	24.6	27.0	29.4	29.4	33.3	27.5	21.3	24.5

Source : Reserve Bank of Zimbabwe, Quarterly Economic and Statistical Review, Mar. 1991.

3–3–8 Foreign Exchange Reserves

Table 3–14 shows the foreign exchange reserves of Zimbabwe as quoted from IMF statistics. It is to be noted that the figures for gold vary in accordance with the estimated market value.

Table 3–14 International Liquidity

(US$ million end year)

	1984	1985	1986	1987	1988	1989
Foreign exchange	43.1	78.8	100.2	143.0	178.0	93.8
SDRs	2.3	14.5	6.2	23.1	0.6	0.7
IMF reserve position	–	–	–	0.1	0.1	0.1
Total reserves excl. gold	45.4	93.4	106.4	166.1	178.6	94.6
Gold*	175.3	187.3	163.6	149.0	124.7	131.5

* Valued at 75 per cent of fourth quarter London price.
Source : IMF, International Financial Statistics.

3–3–9 Foreign Exchange Rates

Table 3–15 shows the devaluation trend of Zimbabwe dollars against several foreign currencies based on data from the Reserve Bank of Zimbabwe.

Table 3–15 Foreign Exchange Rates
Middle rates–foreign currency units per Zimbabwe dollar for spot transactions

End of[1]	U.S. dollar	Sterling	Rand	Deutsche mark	Japanese yen	Swiss franc	French franc	Italian lire	Mozambique metical	Botswana pula	Zambia kwacha	Tanzania shilling
1980.....	1.5859	0.664081	1.1835	3.1138	–	2.8173	7.1759	1472.0	52.4560	–	–	–
1981.....	1.3944	0.730052	1.3386	3.1388	–	2.5085	7.9829	1673.3	50.3588	1.2288	1.2334	11.6148
1982.....	1.0876	0.671047	1.1670	2.5896	–	2.1790	7.3195	1488.92	41.9340	1.1520	1.0082	10.3910
1983.....	0.9046	0.622574	1.1017	2.4564	–	1.9693	7.5082	1492.59	37.7001	1.0476	1.3576	11.3137
1984.....	0.6656	0.571085	1.3163	2.0872	166.60	1.7211	6.3848	1277.29	29.2604	1.0366	1.4721	12.0157
1985.....	0.6093	0.422684	1.5777	1.4992	122.26	1.2634	4.5987	1023.32	25.3390	1.3134	3.4551	10.0530
1986.....	0.5959	0.405512	1.3144	1.1605	95.34	0.9694	3.8439	808.34	23.3810	1.0982	7.5702	30.6173
1987.....	0.6013	0.323366	1.1611	0.9588	74.17	0.7757	3.2455	708.03	242.9252	0.9447	4.8381	49.9621
1988.....	0.5147	0.287446	1.2268	0.9195	64.71	0.7793	3.1379	676.57	322.3051	0.9963	5.1771	64.1415
1989.....	0.4405	0.274455	1.1172	0.7440	63.27	0.6781	2.5428	557.56	359.5058	0.8225	9.2599	83.9828
1990.....	0.3793	0.196783	0.9726	0.5665	51.15	0.4834	1.9316	427.28	395.9366	0.7128	17.8962	73.8896
1991.Mar.	0.3395	0.194556	0.9273	0.5795	47.36	0.4944	1.9676	431.17	378.6605	0.6731	18.6165	69.2859

Source : Reserve Bank of Zimbabwe, Quarterly Economic and Statistical Review, Mar, 1991.

3–3–10 Foreign Aid

After independence, foreign aid, worth Z$1.9 billion for the period 1981–83, was pledged to the economic development programs "ZIMCORD" announced in early 1981. However, only half the amount was provided due to changed circumstances in the donor countries.

The World Bank group lent US$541 million in the decade 1980-1990, and the group also committed loans for agricultural development projects amounting to US$146.3 million in early 1990. The African Development Bank and African Development Fund lent US$223 million to Zimbabwe during 1980–1990. ODA (Official Development Assistance) from the OECD and OPEC areas is as shown in Table 3–16.

Table 3–16 Gross Official Development Assistance from the OECD and OPEC Areas

(US$ Million)

	1983	1984	1985	1986	1987	1988
Bilateral	186.4	244.7	215.5	193.8	272.0	238.2
of which:						
West Germany	34.1	26.6	27.7	41.8	46.3	42.1
UK	22.1	17.0	24.9	15.7	16.7	31.2
Norway	8.6	13.7	8.3	16.4	22.0	23.7
Sweden	15.3	19.4	23.5	20.9	32.9	23.1
Netherlands	9.6	22.6	17.7	24.2	35.3	22.0
Multilateral	22.8	53.3	25.5	36.2	29.3	46.5
EC	10.4	25.9	3.9	3.9	7.0	16.0
Total	209.1	298.1	241.0	229.9	301.3	284.7
of which:						
grants	154.1	217.3	167.4	160.4	212.5	224.4

Source : OECD Development Assistance Committee, Geographical Distribution of Financial Flows to Developing Countries.

In the Paris Conference held in March, 1991, Zimbabwe succeeded in obtaining pledges totaling US$700 million for 1991 and the same amount for 1992, receiving the highest appreciation from all of the donor countries for "A Framework for Economic Reform (1991–95)".

3–4 Promotion Policy for Investment

The oligopolistic structure of industry is one of the crucial weaknesses of the Zimbabwe economy. It is said that many Zimbabwe industries have been enjoying secure, substantial profits with little effort at rationalization because there were no domestic competitors in a nearly monopolistic situation.

The government of Zimbabwe recently announced "The Promotion of Investment: Policy and Regulations" in April, 1989, as a substitute for "Foreign Investment: Policy Guidelines and Procedures" announced in September, 1982, with the intention of promoting more investment of both foreign and domestic capital.

The main objectives of the government's economic policy are summarized as follows:

(1) rapid growth of the economy,

(2) full employment,

(3) price stability,

(4) efficiency in resource allocation, and

(5) equitable distribution of benefits.

It advocates the necessity of vigorous investment from both abroad and domestically to facilitate the policy.

From the view-point of the importance of establishing integrated industrial bases and also of achieving transfer of technology and skills from abroad, priority is to be given to new intermediate and capital goods industries, and for substantial employment benefits, consumer goods industries are also to be encouraged. Among these sectors, export oriented industries are to be especially welcomed provided they are viable in the international markets.

As to treaties protecting foreign investors, the government announced that it would become one of the member countries of MIGA (Multilateral Investment Guarantee Agency) and would submit to arbitration for the settlement of any disputes according to the rules and procedures of UNCITRAL (United Nations Commission on International Trade Low) or the International Chambers of Commerce, which, in terms of safety, should be an attraction for foreign investors.

In order to facilitate quick decisions in applying investments, the investment center (ZIC), based within the Ministry of Finance, Economic Planning and Development, replaced the former FIC (Foreign Investment Committee) as the single interface organization.

3–5 A Framework for Economic Reform (1990–95)

At the Donor's Conference, held in March, 1991, in Paris, the government of Zimbabwe received the highest appreciation from all attendants for "A Framework for Economic Reform (1991-95)" which was announced in January 18, 1991.

These reform programs are to be the basis for "The Second Five-Year Plan for Zimbabwe Economic Development" announced in the middle of 1991.

The following sections describe the reform programs:

3–5–1 Recognition of Present Economics of Zimbabwe

The government recognized honestly that actual personal income had failed to grow in the past decade, and pointed out the necessity of the "Economic Reform" including trade liberalization and deregulation of domestic controls. In fact, since independence, Zimbabwe has achieved substantial successes in the fields of Socio-Politics such as education, health and population control, but not in economics.

The annual growth of GDP during the 1980's was only 2.7% which was much less than the increase in population. The growth of exports was only 3.4% per year in real terms during the same period. This slow economic performance had an unfortunate effect on debt service payments, which rose to a peak of 34% of exports in 1987. Unemployment increased to 26% in 1989 and the fiscal deficit exceeded 10% of GDP in almost every year during the 1980's. Inflation also averaged around 15% per annum during the same period, and private investment fell from 12% in 1982 to 8% of GDP in 1987. This decline in investment can be attributed to the following three factors:

(1) The risks associated with the fiscal deficit,

(2) Uncertainties of foreign exchange allocation, and

(3) A highly regulated business environment which included price controls, labor market restrictions and investment control procedures.

Recognizing the above, the government enforced the following five reforms in recent years:

(1) Devaluation of the Zimbabwe dollar (8% in 1989 and 12% in 1990),

(2) Official announcement to reduce the fiscal deficit to 5% of GDP by FY1994/95 (actually reduced from 13.1% in FY86/87 to 10.6% in FY90/91),

(3) Facilitation of an increase in investments, including

(a) establishment of ZIC (Investment Center) as a single interface for investment procedures,

(b) narrowing the definition of foreign companies,

(c) enabling 100% repatriation of profits compared with the previous 50%, and

(d) becoming a member country of MIGA (Multilateral Investment Guarantee Agent) and OPIC (Overseas Private Investment Corporation) to increase trustworthiness,

(4) Introduction of an export retention scheme to allow 5 or 7.5% of export earnings to be retained as an incentive for exports, and

(5) Expansion of the number of items which can be imported by registered users under OGIL (Open General Import Licence) system in October, 1990.

3–5–2 Objectives of Economic Reform

(1) The fundamental objectives of this economic reform are to improve living standards, and banish poverty from Zimbabwe.

(2) Real economic growth rate is targeted at 5% per annum by 1995, with 5.8% in industry, 3.2% in agriculture and 5% in the service sector.

(3) By 1995, GDP per capita as well as consumption per capita are projected to rise by about 2% per annum.

3–5–3 Strategies of Economic Reform

(1) Summary of adjustment

(a) Fiscal policies

Recognizing that the present level of taxation is high, the government intends to minimize the people's burden as much as possible. The revenue from tax is to be reduced from 35% of GDP in 1990 to about 33% by the end of 1995. The deficit of the central government is to be reduced to 5% of GDP by FY94/95 as stated before, by cutting unnecessary government expenditure and consolidating the Ministries, if areas of redundancy and duplication can be identified.

(b) Public enterprises

Direct subsidies to public enterprises in FY90/91 amounted to around Z$629 million. The government is to reduce this amount to Z$40 million in FY94/95.

(c) Monetary policy

During this program, the economy of Zimbabwe is to be liberalized and domestic regulations are to be decontrolled. At the same time, however, liberalization and deregulation might accelerate inflation. So the program also plans to reduce the rate of inflation to 10% by 1995. Under the circumstances, the Reserve Bank of Zimbabwe will be forced to exercise considerable judgment in the formulation of monetary policy.

Recognizing that the present direct method of controlling credit and the monetary supply should be changed to a more market oriented approach, the government adopted the BLR (Base Lending Rate) system from 1989, which provides for minimum interest rates on deposits and saving accounts. This caused deposit interest rates to tend to increase in response to market forces, and encouraged people to save. If the fiscal deficit reaches a sound level, the monetary policy also should be deregulated gradually by 1995.

The BLR system is to be influenced by foreign interest rates in addition to the existing criteria of FY91/92, and abolishment of this BLR system is to be announced during FY92/93 so as to complete the gradual liberalization of interest rates.

(2) Trade liberalization

The government committed itself to a gradual trade liberalization program in place of the current foreign exchange allocation system by 1995. This program includes the expansion of the OGIL items, tariff reform, supportive exchange rate policy and improved export provisions.

(a) OGIL system

With the exception of a few goods, i.e., those related to defense and safety of public interest, it will be possible to import all items under the OGIL system by 1995. This means that domestic industries will face external competition. To allow local industries enough time to adjust and modernize their equipment, the government made two basic categories of OGIL items; one is for all importers and the other is for registered end users.

In the early stage of the program, the OGIL items principally include raw materials to permit industries to fully use their existing capacity.

The schedule of import liberalization is shown in Table 3–17.

Table 3–17 Schedule of Import Liberalization

(Minimum Share of Imports on OGIL)(%)

OGIL \ YEAR	1989	1990	1991	1992	1993	1994	1995
Unristricted	6	6	30	45	60	75	85
End Use Specific	14	18	20	25	15	10	0
Total	20	24	50	70	75	85	85

(b) Import tariff reform

Once the foreign exchange allocation system is phased out, the import tariff will be the only measure for protecting local producers. Zimbabwe presently adopts three mechanisms for import tariffs, i.e., custom duties, surtax and import tax (equivalent to sales tax).

The schedule for reforming these three tariffs is shown in Table 3–18.

Table 3–18 Schedule of Tariff Reform

(%)

	1991	1992	1993	1994	1995
Customs duties					
– consumer goods	30	30	30	30	30
– raw materials	0	0	0	5	10
– intermediates	10	10	10	10	10
investment goods	5	5	5	10	10
Surtax	20	15	10	5	0
Sales tax					
– general	15	15	15	15	15
– capital goods	10	10	10	10	10
Average total					
– tax on imports	29.0	27.5	26.0	24.5	23.0

(3) Deregulation of domestic controls

The government recognizes that the Zimbabwe economy cannot be activated by means of trade liberalization alone and that this must be accompanied by simplifications of investment approvals and deregulation of prices, distribution, and labor and wages, etc.

(a) Investment approvals

To expedite investment approvals, the ZIC (Investment Center) was established as a "Single Interface" for approvals. ZIC can approve projects of less than Z$10 million, and can give strong recommendations for projects of more than Z$10 million. ZIC is to conduct investment approvals in terms of the feasibility of individual projects in addition to earnings or capabilities for saving foreign currency over a specific period.

(b) Deregulation of price controls

So far, the government has removed all price controls except for 10 products/services, i.e., bread, maize, beef, matches, cooking oil and fats, cement, steel (ZISCO products), fertilizers, petroleum fuel and bus/railway fares. Agricultural support prices are to remain under control with the aim of reducing the burden of budgetary subsidies, but it is intended to rationalize the pricing policies.

(c) Agricultural prices and marketing

The government continuously checks and reviews the activities of agricultural marketing agencies in order to eliminate price controls gradually and also to minimize the subsidies to these parastatals. The marketing of yellow maize, red sorghum and millet was already partially decontrolled in April, 1990, and the producers are now free to sell directly to livestock producers (yellow maize), and industrial brewers (red sorghum) without going through the GMB (Grain Marketing Board). Moreover, movement of maize within a communal area is already free.

(d) Labor market regulations

Trade liberalization and progressive withdrawal of control on private investment are expected to bring vigorous activity to the Zimbabwe ecomony. However, it should be accompanied by a relaxation of the existing strict regulation of the labor market.

The government amended The Labor Regulations Act to permit hiring and firing of individual employees in accordance with rules developed through the process of collective bargaining. Wages are to be established by collective bargaining also, and the statutory minimum wages were abolished because they did not reflect the prevailing rates.

(e) Local government regulations

The zoning regulations and the system of licensing by local government for small business, shops, hawkers and vendors are inhibiting the growth of informal employment. A commission is to be established to review these regulations taking into consideration the public health standards and balanced development of towns and cities by April, 1991.

(f) Transport regulations

It is recognized that requiring permits for operating road transport services has discouraged single owner trucking operations which are considered to be an effective means of improving rural transport. Currently, permission is not required only during the harvest seasons for single owner-operation with a truck of 15 tons or less, and abolition of the permit system itself is under consideration except for an operating license to ensure road worthiness of vehicles. As for urban transport, ZUPCO (Zimbabwe Urban Passenger Company) is the only company to operate in 4 cities. It is considered that their servicies are inadequate despite the reasonable fares which are currently controlled by the government, due to the absence of competition. Before the current franchise agreement lapses in June, 1994, the government is to allow more than one operator to provide urban services.

3–5–4 Financing Requirements from Abroad

The deficit on the external balance of payments in 1989 amounted to US$89 million (1.5% of GDP) and is estimated to reach US$117 million (2.8% of GDP) in 1990. The increase in 1990 is largely accounted for by the higher prices of petroleum products caused by the Gulf War. The balance of payments (historical for 1985–1988, estimated for 1989–1990, projected for 1991-1995) are shown in Table 3–19.

Table 3–19 Balance of Payments in US Dollars

(US$ Million at current prices)

	Historical				Estimated		Projected				
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Trade Balance	202	312	382	512	361	355	218	236	299	378	478
Merchandise Imports	922	1013	1073	1157	1319	1333	1606	1746	1860	1986	2115
Consumption	125	120	114	120	150	128	145	160	178	194	211
Investment	274	394	395	450	505	575	552	665	712	764	819
Intermediate Goods	326	378	434	481	522	508	600	664	703	745	790
Petroleum	197	121	130	106	142	222	310	257	267	283	295
Merchandise Exports	1124	1325	1455	1669	1680	1688	1825	1982	2159	2363	2593
Agriculture	337	398	405	436	419	436	458	482	510	541	576
Mining	257	386	409	487	416	395	417	443	475	515	559
Manufacturing	298	290	333	401	463	468	518	576	641	713	795
Other	232	251	308	345	382	390	432	480	534	594	663
Net Nonfactor Services	185	152	159	199	216	265	287	303	319	337	357
Payments	289	291	309	380	421	450	491	528	569	614	664
Receipts	105	139	151	181	205	185	204	225	250	277	307
Net Factor Payments	126	183	213	229	214	253	259	281	307	330	352
Payments	189	252	259	267	271	298	307	341	376	410	441
Interest	161	149	158	162	156	165	166	191	217	241	262
Profits & other	28	103	101	105	115	133	141	150	159	169	179
Receipts	63	69	46	38	57	45	48	60	69	79	88
Current Transfers	–45	–26	–11	–6	–20	–15	–20	–25	–31	–35	–37
Current Account Balance	–153	–49	0	78	–89	–177	–348	–373	–358	–325	–269
Overall Balance	107	8	63	36	–51	12	136	114	123	108	114
Grants	55	58	80	66	78	94	98	102	108	114	120
Foreign Investment	3	7	–24	4	–10	5	19	26	28	32	33
LT Portfolio Inflows	79	8	–11	–42	15	90	367	359	346	287	230
Short-term Capital	123	–17	18	–70	–45	0	0	0	0	0	0
Financing											
Change in Total NFA(–)	–107	–8	–63	–36	51	–12	–136	–114	–123	–108	–114
Long Term External Debt	..	..	..	..	2381	2477	2834	3175	3504	3774	3987
Exchange Rate [Zim$/US$]	1.612	1.665	1.661	1.802	2.113	2.470	..	..	..	..	..

To successfully complete this Economic Reform, Zimbabwe has to overcome these external balance of payment deficits, by bringing the debt service ratio below 20% and also by foreign assistance.

The total required amount of finance from abroad during the 5 years (1991-95) is estimated to be US$3.44 billion as shown in Table 3–20.

Table 3–20 External Financing Requirements

(US$ million)

	1991	1992	1993	1994	1995	1991–95
Requirements:						
Imports (GNFS)	2097	2274	2429	2600	2779	12179
Factor Payments	307	341	376	410	441	1875
(Interest)	167	191	217	241	262	1078
Amortization	235	259	242	265	313	1314
Change in Reserves	136	114	123	108	114	595
Total	2775	2987	3170	3383	3647	15963
Sources:						
Exports (GNFS)	2028	2207	2409	2640	2900	12184
Factor receipts	48	60	69	79	88	344
Current Transfers	–20	–25	–31	–35	–37	–148
Foreign investment	19	26	28	32	33	138
Total Primary Sources	2076	2267	2475	2717	2984	12518
Total Financing Required	700	720	696	666	663	3444
Disbursement on Existing Commitments	360	380	167	79	77	1063
IBRD	29	31	35	36	36	168
Other Multilateral	95	86	66	40	39	326
Bilateral	83	90	66	2	2	244
Commercial Banks (incl. IFC)	152	173	0	0	0	325
Additional financing Required	340	340	528	587	586	2382

3–5–5 Implementation of the Program

An inter-ministerial coordination committee is to be established, which is to periodically report to the government about the progress of implementation, and propose, if necessary, the fine-tuning of this adjustment program. Especially, the first two years of the program are most important, and the committee is to monitor the implementation very closely and carefully. The government is also to carry out a comprehensive review of the program at the end of 1933.

Table 3–21 shows the key macroeconomic indicators for Zimbabwe during 1985–1995 (historical for 1985–90 and projected for 1991–95).

Table 3–21 Zimbabwe: Key Macroeconomic Indicators

Key Indicators	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
GDP Growth Rate	..	2.6	–1.5	5.8	5.6	4.2	4.3	4.4	4.6	4.8	5.0
GDP Per Capita Growth Rate	..	..	..	2.7	2.6	1.4	1.6	1.7	1.9	2.2	2.4
Consumption per capita growth rate	..	..	..	–3.4	5.9	2.8	2.1	0.8	1.1	2.1	1.8
Total DOD (in US$)	2464.7	2708.1	2913.8	2670.6	2633.6	2706.4	3056.3	3398.0	3726.6	3996.3	4209.6
DOD/GDP	56.6	54.4	54.2	45.2	44.7	44.4	51.4	57.9	62.9	64.0	63.2
Debt Service (in US$)	..	..	..	..	466.3	461.2	402.4	449.9	459.3	506.1	574.5
Debt Service/XGS	..	..	..	..	24.0	24.0	19.4	19.9	18.5	18.6	19.2
Debt Service/GDP	..	..	..	..	7.9	7.6	6.8	7.7	7.7	8.1	8.6
Gross Investment/GDP	21.1	19.4	19.1	19.7	20.7	21.0	23.0	24.3	25.2	25.1	25.3
Private Investment/GDP	12.4	11.1	8.0	7.7	9.8	10.5	13.0	14.7	16.0	16.2	16.4
Public Investment/GDP	8.7	8.3	11.2	11.9	11.0	10.5	10.0	9.6	9.2	8.9	8.9
Budgetary Investment/GDP	3.2	3.3	5.5	6.2	5.3	5.2	5.0	4.8	4.6	4.5	4.5
Public Enterprise Investment/GDP	5.5	5.0	5.7	5.8	5.6	5.3	5.0	4.8	4.6	4.4	4.4
Capital goods imports/Investment	29.9	40.7	38.4	38.8	41.3	7.2	40.4	46.6	47.7	48.8	48.6
Domestic Savings/GDP	21.1	19.4	19.1	19.7	20.7	21.0	23.0	24.3	25.2	25.1	25.3
National Savings/GDP	17.6	18.5	19.1	21.0	19.2	18.0	17.1	17.9	19.2	19.9	21.3
Private Savings/GDP	20.5	22.3	20.5	20.5	18.2	16.7	15.4	15.8	16.8	17.0	18.0
Public Savings/GDP	–2.9	–3.8	–1.3	0.5	1.1	1.3	1.7	2.2	2.4	2.9	3.3
Foreign Savings/GDP	3.5	1.0	0.0	–1.3	1.5	2.9	5.9	6.4	6.0	5.2	4.0
Total Public Sector Revenue/GDP	34.3	34.3	39.4	39.5	40.3	39.8	40.4	40.9	40.8	40.6	40.2
Total Public Sector Exp./GDP	45.4	45.5	50.9	51.1	50.8	49.2	48.6	48.1	47.3	46.1	45.3
Total PS Def.(+) or Sur.(–)/GDP	11.2	11.2	11.5	11.6	10.5	9.4	8.2	7.2	6.5	5.6	5.1
Cent. Govt Revenues/GDP	34.4	34.2	38.5	38.4	39.2	39.0	39.3	39.6	39.2	38.9	38.3
Cent. Govt Expenditures/GDP	44.4	44.6	49.3	48.0	48.3	47.6	46.9	45.7	44.0	42.6	41.5
Cent. Govt Savings/GDP	–4.9	–5.8	–4.1	–1.5	–1.0	–1.1	–1.0	0.0	0.9	1.5	1.8
CG Primary Def.(+) or Sur.(–)/GDP	4.4	4.7	4.3	3.0	2.2	2.2	0.6	–1.0	–2.1	–3.0	–2.9
CG Def.(+) or Surplus (–)/GDP	10.0	10.5	10.7	9.6	9.1	8.6	7.6	6.1	4.8	3.7	3.2
CG Def.(Excluding grants)/GDP	11.2	11.6	12.2	10.8	10.4	10.2	9.3	7.8	6.6	5.5	5.0
Inflation (% Change GDP Deflator)	..	15.2	9.2	12.6	10.8	16.0	16.0	14.0	12.0	10.0	10.0
Exchange Rate (ZIM$/US$)	1.612	1.665	1.661	1.802	2.113	2.470	..	..	..	..	..
[Real Index (1987 = 1)]	..	..	1.00	1.05	0.95	0.91	..	..	..	..	..
Terms of Trade (1987 = 1)	1.19	1.15	1.00	1.15	1.12	1.06	0.97	1.05	1.05	1.05	1.05
Real Export Growth Rate	..	..	..	..	..	..	4.8	5.2	5.6	5.7	5.8
Real Import Growth Rate	..	..	..	..	..	..	8.5	7.1	3.7	3.7	3.7
Exports/GDP	28.2	29.4	29.9	31.3	32.0	30.7	34.1	37.6	40.6	42.3	43.5
Imports/GDP	27.8	26.2	25.7	26.0	29.5	28.7	33.7	36.9	38.7	39.2	39.1
Net Factor Payments/GDP	2.9	3.7	4.0	3.9	3.6	4.1	4.4	4.8	5.2	5.3	5.3
Current Account Deficit/GDP	3.5	1.0	0.0	–1.3	1.5	2.9	5.9	6.4	6.0	5.2	4.0
Current Account Deficit (in US$)	152.9	48.7	0.1	–78.0	89.2	176.9	348.3	373.1	358.0	325.2	268.7
Net Reserves (in US$)	..	..	..	..	148.1	159.9	295.6	409.2	532.4	640.2	754.6
Net Reserves (in months of imports)	..	..	..	..	0.9	1.2	1.8	2.2	2.5	2.8	3.0

(1) Implementation of public enterprise reforms

The government subsidies to the major public enterprises for the past 5 years (1985–90) are shown in Table 3–22.

Table 3–22 Historical Trends in Government Subsidies and Advances to Major Public Enterprises 1986/87–1990/91

(Z$ million)

	1986/87	1987/88	1988/89	1989/90	1990/91
Agricultural Marketing Boards	166.0	210.0	156.1	160.2	.....
Grain Marketing Board (GMB)	48.1	123.9	80.0	48.9	.....
Dairy Marketing Board (DMB)	65.0	43.3	40.0	56.1	.....
Cold Storage Commission (CSC)	49.5	31.2	11.1	37.5	.....
Cotton Marketing Board (CMB)	––	11.7	25.0	17.7	.....
Agric. Marketing Authority	3.4	––	––	––	.....
National Railways of Zimbabwe (NRZ)	80.0	100.0	120.0	100.0	255.0
Air Zimbabwe Corporation (AZ)	45.0	39.9	10.0	15.0	9.0
Affretair	15.0	3.0	––	––	.....
Zimbabwe Steel Corporation (ZISCO)	82.0	100.0	167.0	100.0	100.0
Agricultural Finance Corporation	18.4	4.5	15.0	12.5	.....
National Oil Company of Zimbabwe	––	––	––	––	.....
Total	406.4	457.4	468.1	387.7	628.6

Now, the government has decided to reduce these subsidies according to the schedule shown in Table 3-23.

Table 3-23 Planned Reductions in Government Subsidies and Advances to Major Public Enterprises up to 1994/95

(Z$ million)

	1990/91	1991/92	1992/93	1993/94	1994/95
Reduction of operating losses of budgeted Parastatals:	309.0	160.0	--	--	--
Marketing Boards	166.7	83.4	50.0	33.3	--
of which GMB	(59.2)	(29.6)	(17.8)	(11.8)	(--)
DMB	(59.8)	(29.9)	(17.9)	(12.0)	(--)
CSC	(32.5)	(16.3)	(9.8)	(6.5)	(--)
CMB	(15.2)	(7.6)	(4.6)	(3.0)	(--)
NRZ	70.0	35.0	21.0	14.0	--
AZ	4.5	2.3	1.4	0.9	--
ZISCO	100.0	80.0	60.0	40.0	40.0
Total	650.2	360.7	132.5	88.2	40.0

(2) Implementation of monetary policy and financial sector reforms

The annual average rate of inflation increased from 12% at the end of 1989 to 16% in July 1990, and is expected to increase further during the next 2 years owing to price decontrol.

To cope with this heavy burden of inflation, reforms of monetary policy and the financial sector should be undertaken very carefully and properly as they have a key roll in the The Structural Adjustment Program. Financial liberalization should be advanced prudently and in step with the reduction of the fiscal deficit.

(a) First phase 1991–93

The reform of the interest rate policy is to start with the setting up of a principal interest rate in accordance with market conditions. The current BLR (Base Lending Rate) system was established in 1989. Basic lending interest rates are to be announced on a sector by sector basis such as for the production industry sector or service sector reflecting market conditions, and the bank margin will be added to determine the actual lending interest rates.

The BLR is to be based more closely on the relevant foreign interest rates such as LIBOR (London Inter-Bank Offered Rate).

The prevailing BLR system encouraged people to save by setting the minimum deposit interest rate. However, since these interest rates are to be determined almost in accordance with market conditions, the BLR system will be abolished by the end of 1993, as it is considered that its initial duty has been discharged. The differences between lending and deposit interest rates are to be fixed within the normal bank profit margins.

Throughout this first phase, the treasury bill and government bond rates are to be kept at the present level until the fiscal deficit reaches the target level.

(b) Second phase 1994–95

Since the fiscal deficit is to be reduced substantially during this second phase, almost all financial deregulations are to be completed including the entry of new banks.

The act which regulated the minimum holding of government papers by the insurance companies and the pensions funds are also to be relaxed. During this period, private enterprises are to be permitted to issue their own papers-short, medium and long term bonds, as the non-bank resources for their financial requirements.

(3) Assessing and addressing the social dimensions of adjustment

The basic purpose of this structural adjustment is to banish poverty and to promote the growth of social welfare.

The government is convinced that this reform will bring increased employment opportunities and decrease the inflation rate by the end of the program. However, there might be unavoidable problems in the initial stages which will have severe consequences especially for the low-income groups, i.e., temporary retrenchment in the public sector as a result of the process of rationalizing the government as well as enterprises, temporary high rates of inflation and rationalization of the fiscal budget including social welfare.

The government should adopt some compensatory measures.

(a) Employment and unemployment

Currently, the industry of Zimbabwe is operating at between 40 to 70 percent of its existing capacity, and this is expected to expand to between 85 to 90 percent during this Adjustment Program. In addition to this, increased investment is projected which might be expected to generate further employment growth.

On the other hand, however, it cannot be denied that unemployment will increase in some areas, i.e., the formal business sector (to the extent that some industry is inefficient and cannot adjust to the increased competition), the public sector (to the extent that civil service retrenchment is considered necessary), and parastatal sector (to the extent that restructuring will involve worker layoffs), at the initial stages. Retraining systems for these displaced individuals will be very necessary throughout these periods.

At present, there are seven national technical colleges located in urban areas and two vocational training centers in Msasa and Westgate. The capacity of these institutes can be expanded by adopting a double shift system or by providing evening courses.

For the retraining of civil servants, in particular, the government decided to set aside a substantial budget totaling Z$14 million in FY1991/92, Z$21 million in FY1992/93, Z$24 million in FY1993/94 and Z$10 million in FY1994/95.

To assist layed off workers who intend to establish their own small-scale businesses, the government is to arrange for the commercial banks to provide 5% of their total lending to the informal and small-scale sectors, and also to arrange that they can use the CGC (Credit Guarantee Company) more widely so as to strengthen their creditworthiness.

(b) Social welfare budget

The government is to reserve an amount equivalent to 30% of the fiscal savings resulting the reduction in the Grain Marketing Board subsidy which is to be used to cover the costs of social welfare (Z$9 million in FY1991/92, Z$14 million in FY1992/93, and Z$18 million in each of FY1993/94 and FY1994/95).

As for health services, people who are earning less than Z$150 per month are receiving their health care without paying any charges under the present regulations, and the government is intending to increase these health services partly by getting the support of the World Bank and several donor countries.

(c) Education fees

Education for people who cannot afford to pay is a very serious problem, so the government is making every effort to study a comprehensive cost recovery system for this problem. As a part of this scheme, the government is proposing to set up a scholarship fund.

3–6 Conclusion

The Second Five-Year National Development Plan (1991–95) announced in the middle of 1991 is based on the philosophy of "A Framework for Economic Reform (1991–95)". This chapter has described the main parts of the economic policy derived from the Framework.

It is widely appreciated that the Zimbabwe government accurately sized up the present economic situation of the country and analyzed it impartially so as to implement the "Economic Structural Adjustment" with a number of sound schemes. It seems to have led to obtaining the credit commitment from the donor countries at the Paris Conference held at the end of March, 1991 for the full amount of its requirements.

In July, 1991, economic sanctions were lifted from the neighboring country, the Republic of South Africa. Along with Zimbabwe's policy for the liberalization of trade and investment, it is expected that investment and technology transfer from the Republic of South Africa will be accelerated. The "Beira-Corridore" line, a prime transportation route which is currently interrupted by guerilla warfare, will be utilized more frequently, since South Africa will no longer support the resistance group RENOMO. If so, this will be very helpful for the Zimbabwe economy.

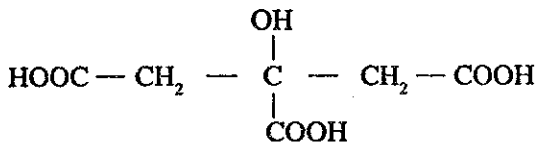
If political differences between the Republic of South Africa and neighbouring countries, including Zimbabwe, are resolved, the economic blocks in Southern Africa will be restructured, as is happening in other parts of the world today. In that case, ecomonic and trade developments in the region will be accelerated, thus benefiting the economy of Zimbabwe.

Chapter 4 Citric Acid and Its Production Technology

Chapter 4 Citric Acid and Its Production Technology

4–1 Introduction

Citric acid is a hydroxy tribasic acid with the following structural formula, and is widely used in the fields of food, beverages and pharmaceuticals.



It is found most abundantly in citrus fruits, particularly in lemons and limes. In the past, citric acid was extracted from lemon and lime juice. Today, it is most commonly produced by the fermentation of carbohydrates.

Commercial production of citric acid began in 1893 when certain filamentous molds produced citric acid, when grown on sugar solutions. Fermentation technology for commercial production of citric acid was vigorously developed in USA, Germany and other countries. The microbial production of citric acid on a commercial scale was begun by Pfizer Inc. at New York in 1923, based primarily on the first surface fermentation process in the world. In Japan too, production of citric acid based on the surface fermentation process was started in 1937. In 1951 Miles Laboratories Inc. of USA began production of citric acid by the submerged fermentation process. In the mean time solid culture technology was developed in Japan for the production of citric acid using potato wastes, which aimed at effective utilization of sweet potato starch residues. Commercial production using the solid culture method began in 1953. With the development of such fermentation technologies, commercial production of citric acid has been successful in many other countries, including Belgium, UK, Germany and Soviet Union. Today, world production of citric acid amounts to over 500,000 tons per year; the submerged culture process accounts for a substantial portion of the world's citric acid production.

Technology for producing citric acid with yeast, from a medium containing paraffin has also been developed, but this has not been commercialized.

4–2 Citric Acid Uses

Citric acid is extensively used in the field of beverages, food, pharmaceuticals and so forth for its safety (low toxicity), pleasant acid taste, high water solubility, chelating properties, and price dominancy. Other applications have been developed for liquid detergents, metal cleaning, plasticizers, photography, etc.

4–2–1 Food and Beverages

The food acidulants in common use include:

- Citric acid
- Malic acid
- Phosphoric acid
- Tartaric acid
- Lactic acid
- Fumaric acid
- Adipic acid

In selecting an acidulant several factors have to be considered. First among these is the effect that it will have upon the overall flavor of the product. Normally cost-in-use is a secondary consideration because the amount of citric acid added is very low in the final consumable products. The various food acids have slightly different tastes, which can affect the final end-use. The dominant acid is citric acid. It is widely used because it has the ability to blend well with almost all flavors and produce a clean acid taste. Citric acid has an important secondary property, that is, as a powerful chelating agent. The chelating properties of citric acid mean that it is an acidulant that is unequaled among food acids in its ability to stabilize color and flavor. It can stabilize color and flavor in three different ways:

- by inhibiting the development of oxidation colors,
- by preventing the formation of colored metal complexes, and
- by preventing change of taste and smell.

The principal applications of acidulants are in:

- Beverages
- Baked Goods
- Jams, Jellies and Preserves
- Confectionery Products

– Fruit and Vegetables

– Meat and Seafoods

– Fats and Oils

(1) Beverages

While citric acid is the most common acidulant used, some other acids have found use only in certain limited flavors. An example is phosphoric acid which is used mainly in cola drinks, another is tartaric acid which is associated with grape-flavored drinks. In some uses absolute solubility of the acid is extremely important. High solubility is required at some intermediate stage in the processing, this situation occurs in the manufacture of carbonated drinks where the syrup process requires good acid solubility even though the acid concentration in the finished product is relatively low.

Another area of acidulant use in the beverage sector is in wine-making. In wine production, control of the acidity of the must is essential for optimum fermentation by the yeasts. In some years, this is too low and an acid has to be added. While tartaric acid may be preferred as it is itself made in the vinification process, citric is frequently used as it is less expensive and the supply is not limited.

(2) Foods application

In the market sectors where acidulants in general and citric acid in particular play a role, the second major consumer of citric acid is confectionery, jams and preserves. Citric acid is used in jams and preserves to bring out the fruit flavor and to obtain proper gelation. Good gels are obtained only within a rather narrow pH range.

Citric acid is also used for the following purposes due to its chelating and anti-oxidant properties:

(a) Fruit and vegetables may well be peeled by treatment with alkaline solutions. Citric acid may be used to neutralize the residual alkali and to prevent discoloration of the exposed vegetable flesh.

(b) In the preparation of shellfish, citric acid may be used to prevent the development of off-flavors and also the development of blue and black copper complexes.

(C) In fats and fat-rich foods, citric acid may be used to prevent rancidity that is caused by oxidation.

(d) In the production of processed cheese and cheese spreads, citric acid is used as an emulsifying salt.

4–2–2 Pharmaceuticals

In pharmaceuticals citric acid is employed in vitamin C tablets, antacid preparations and analgesics. In certain cases, citric acid also adds a palatable flavor. This property is also used in medicinal preparations which would otherwise be rather bitter. Citric acid also increases product shelf life by complexing trace metals that might otherwise lead to product degradation. As anhydrous citric acid is less hygroscopic than the monohydrate form, pharmaceutical applications commonly require anhydrous material.

Sodium citrate is used in a number of pharmaceutical preparations as a buffer to maintain optimum pH for maximum stability of the ingredients. The anticoagulant property of sodium citrate is employed in sodium citrate solutions for plasma and blood fractionation. Ferric ammonium citrates are used as iron sources for treatment of anemia. Cupric citrates are used in ointment for trachoma and conjunctivitis.

4–2–3 Chemical and Industrial Use

In recent years there has been interest in the use of citrates as a replacement for sodium tripolyphosphate (STPP) employed in heavy duty laundry detergents as a builder. In comparison with STPP, citrates are rather poor sequestrants but they have been accepted by the major detergent producers in USA and also Europe because citrates do not cause eutrophication in lakes and marshes.

Citric acid is used in certain proprietary formulations in water treatment and oil field applications. Citric acid esters are sometimes used as plasticizers for PVC and other plastics, and have been promoted as replacements for certain phthalates. Citric acid has also been promoted for flue gas desulphurisation.

Since the 1960s considerable effort has been applied to the marketing of citric acid in industrial metal cleaning and finishing products. A leading proponent of this application was Pfizer which introduced its proprietary Citrosolv process some twenty years ago. This process was developed to remove boiler deposits (scale) with a single solution, normally this is an ammoniated citric acid formulation. A similar formulation may be employed to remove rust from new and fabricated steel. Although these techniques are attractive from the standpoint of worker safety, they have failed to gain a substantial market position compared with the mineral acids (inorganic acids such as sulfuric acid and hydrochloric acid) as the cost of using them is not particularly competitive.

4–3 Properties of Citric Acid

4–3–1 Physical/Chemical Properties

Citric acid is a hydroxy tribasic acid and there are two forms, i.e. anhydrous citric acid and citric acid monohydrate which contains one molecule of water of crystallization. The anhydrous form is obtained through crystallization of hot aqueous solutions, whereas the monohydrate form is made by crystallization of cold aqueous solutions. The transition temperature between the anhydrous and monohydrate forms is 36.6 degrees centigrade. Anhydrous citric acid has monoclinic crystals which have a melting point of 153 degrees centigrade. Citric acid monohydrate has prismatic crystals and is also deliquescent. Citric acid monohydrate loses water of crystallization in dry air or by heating at 40 or 50 degrees centigrade. Citric acid is highly soluble in water (145 grams are soluble in 100 milliliters of water at 20 degrees centigrade), menthanol and ethanol, but insoluble in other organic solvents. The pH of a 0.1 mol. solution of citric acid is about 2.1.

4–3–2 Biochemical Properties

In biochemistry, citric acid is an important intermediate product in the citric acid cycle. Decomposition and synthetic reactions are made repeatedly by microorganisms like Aspergillus niger through oxidative dissimilation. The conceptual scheme of the citric acid cycle is shown in Figure 4–1.

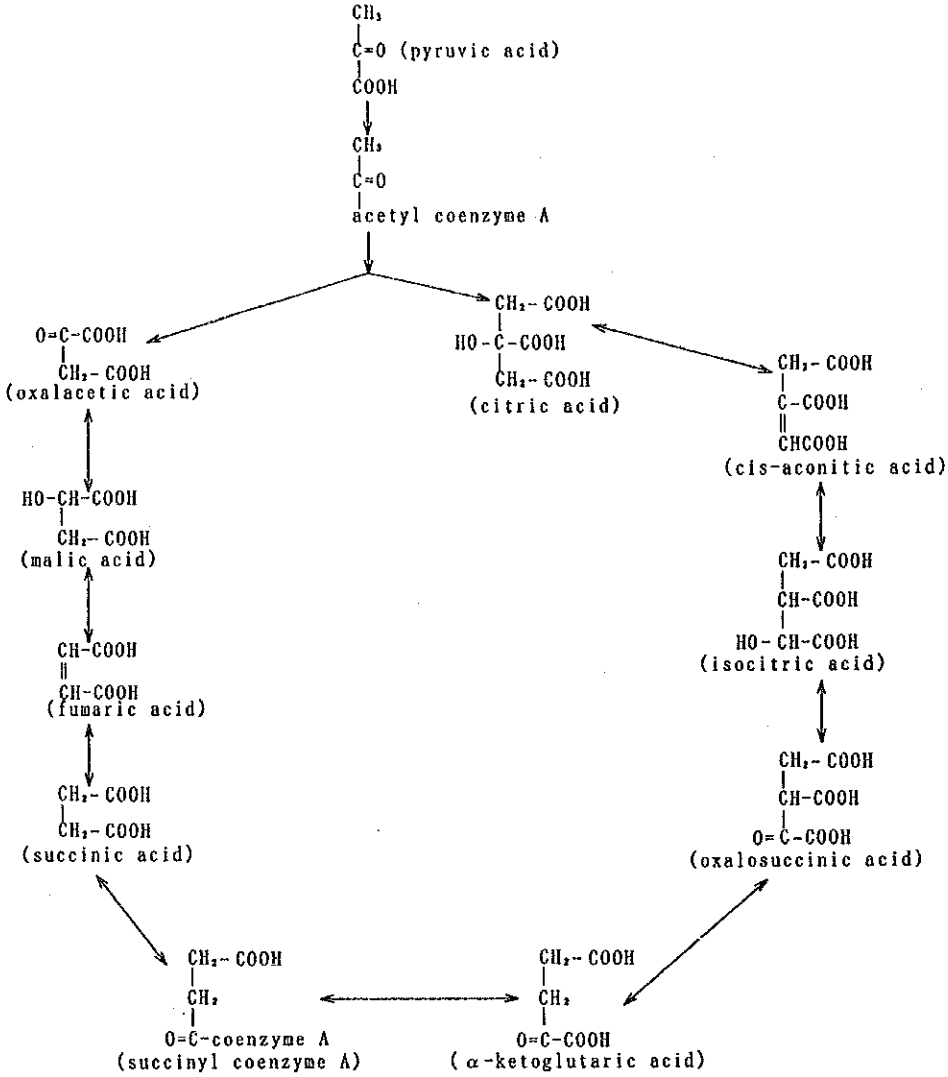


Figure 4–1 Citric Acid Cycle

4–4 Specifications and Standards for Citric Acid

Standards for citric acid differ in each country depending on the applications. In the world competitive markets today, consumers require stringent quality control of the physical characteristics such as particle size distribution. Specifications adopted in UK, USA and Japan are shown in Table 4–1, Table 4–2 and Table 4–3 respectively.

Table 4–1 Specification for Citric Acid in United Kingdom (British Pharmacopoeia)

Description	Anhydride	Monohydrate
Clarity & Color of Solution	within the limit	within the limit
Barium	within the limit	within the limit
Calcium	200 ppm or less	200 ppm or less
Heavy Metals (as Pb)	10 ppm or less	10 ppm or less
Iron	50 ppm or less	50 ppm or less
Chloride	50 ppm or less	50 ppm or less
Oxalate	350 ppm or less	350 ppm or less
Sulphate	150 ppm or less	150 ppm or less
Readily Carbonizable Substance	within the limit	within the limit
Sulphated Ash	0.1% or less	0.1% or less
Water	1.0% or less	7.5 ~ 9.0%
Content	99.5 ~ 101.0%	99.5 ~ 101.0%

Table 4–2 Specification for Citric Acid in USA

Description	Food Application (FCC)	Pharmaceutical Use (USP)
Content	99.5% or more (anhydrous basis)	99.5 ~ 100.5%
Arsenic (as As)	3 ppm or less	3 ppm or less
Heavy Metals (as Pb)	10 ppm or less	0.001% or less
Oxalate	within the limit	within the limit
Readily Carbonizable Substances	within the limit	within the limit
Residue on Ignition	0.05% or less	0.05% or less
Tridodecylamine	0.1 ppm or less	
Ultra Violet Absorbance	within the limit	
Water		
– Anhydrous	0.5% or less	0.5% or less
– Monohydrate	8.8% or less	8.8% or less
Sulphate		within the limit

Table 4–3 Specification for Citric Acid in Japan

	Application				
	Industry	Reagent	Food Additive	Pharmacopoeia	Cosmetics
Clarity & Color of Solution		within the limit			
Clarity & Color of Alcoholic Solution		within the limit			
Chloride		0.0005% or less			
Phosphate (as PO_4)		0.001 % or less			
Sulphate (as SO_4)	0.15% or less	0.005 % or less	0.48% or less	0.048% or less	0.048% or less
Oxalate	within the limit	0.01 % or less	within the limit	within the limit	within the limit
Tartrate		0.01 % or less			
Calcium		0.002 % or less	within the limit	within the limit	
Copper		0.0001% or less			
Zinc		0.0001% or less			
Heavy Metals (as Pb)	0.001% or less	0.0002% or less	10 ppm or less	10 ppm or less	10 ppm or less
Iron		0.0003% or less			
Arsenic (as As_2O_3)			4 ppm or less	1 ppm or less	1 ppm or less
Readily Carbonizable Substances	within the limit		within the limit	within the limit	within the limit
Polynuclear Aromatic Compounds			within the limit	0.05% or less	
Sulphated Ash	0.2% or less	less than 0.1%	0.1% or less	0.1% or less	
Iso-citric Acid			within the limit	within the limit	
Water					
– Monohydrate			8.8%		
– Anhydrous			0.5%		
Content	99.0% or more	99.5 ~ 100.5%	99.5% or more	99.5% or more	99.5% or more

Specifications for citric acid have different standard items and values, all depending on the application. The health requirements for the end users determine the standards for various applications. Also specifications for the constituents of citric acid are decided based on the different kinds of raw materials, subsidiary-materials and production methods utilized. For example:

(1) Oxalate is an organic acid which is easily produced as a side-reaction of the fermentation process.

(2) Specifications for sulfate, calcium and ash are to limit the contamination due to lime and sulfuric acid used in the separation process.

(3) As arsenic and heavy metals are toxic in large concentration, standard values for them are specified for citric acid used in food and pharmaceutical applications.

4–5 Manufacturing and Processing of Citric Acid

4–5–1 Introduction

Citric acid is manufactured in two ways; extraction of natural citric acid from the juice of certain citrus fruits and production of synthetic citric acid through fermentation from carbohydrate materials. Before commercial production based on fermentation technology was established, citric acid was extracted from natural fruits. Today, production by fermentation substantially accounts for all citric acid consumed in the world. In principle fermentation technology is classified into surface culture, submerged culture and solid culture processes, of which submerged culture is the major production method at present. Solid and semi-solid culture processes were exclusively developed in Japan and have been employed by several companies in Japan and South East Asian countries. The surface culture process has been utilized for a long time but only for small scale production. A variety of carbohydrate (starch and sugar) may be employed as raw materials for the fermentation but, in practice, cheap and easily obtainable materials, including beet molasses, cane molasses, starch syrup, cornstarch, potato starch residues, etc., are utilized. The recent trend has been to replace molasses with cornstarch because molasses require a large investment in water treatment facilities for pollution control. Table 4–4 indicates the fermentation processes adopted in commercial plants.

Table 4–4 Fermentation Process and Raw Material

Raw Material	Surface Culture	Submerged Culture	Solid Culture	Remarks
<< Starch >>				
Sweet Potato/Cassava		○	○	
Sweet Potato/Cassava Residues			○	
Cornstarch		○		
<< Sugar >>				
Cane Molasses	△	○		
Beet Molasses	△	○		
Pineapple Juice			△	Pilot Plant Only
Sugar		○		

Note ○ : Used at a large scale commercial plant

△ : Used at a smal scale commercial plant and/or pilot plant

4–5–2 Natural Citric Acid

The juice of unripe lemons contains about 5 percent of natural citric acid. Normally citrus fruits, which have less commercial value, are collected and their juice is squeezed. Calcium citrate is separated by adding a slurry of lime into the juice. The recovered calcium citrate is converted to citric acid and calcium sulfate (gypsum) by adding sulfuric acid, and the calcium sulfate is removed by filtration. Finally the citric acid is crystallized by concentrating the solution. This method has been superceded today by the process of making citric acid using fermentation techniques. Production of citric acid from citrus fruits is no longer significant.

4–5–3 Citric Acid by Fermentation Processes

Citric acid production by fermentation processes is accomplished by a microorganism which is grown on the substrate base of starch or sugar solution where citric acid is accumulated. As the final form of microbial metabolism of a carbohydrate consists of carbon dioxide and water, citric acid formation can be described as an abnormal metabolism which is a result of the shortage of nutrition in the culture medium.

(1) Mechanism of citric acid formation

Conversion of glucose to citric acid is considered to be as shown in Figure 4–2.

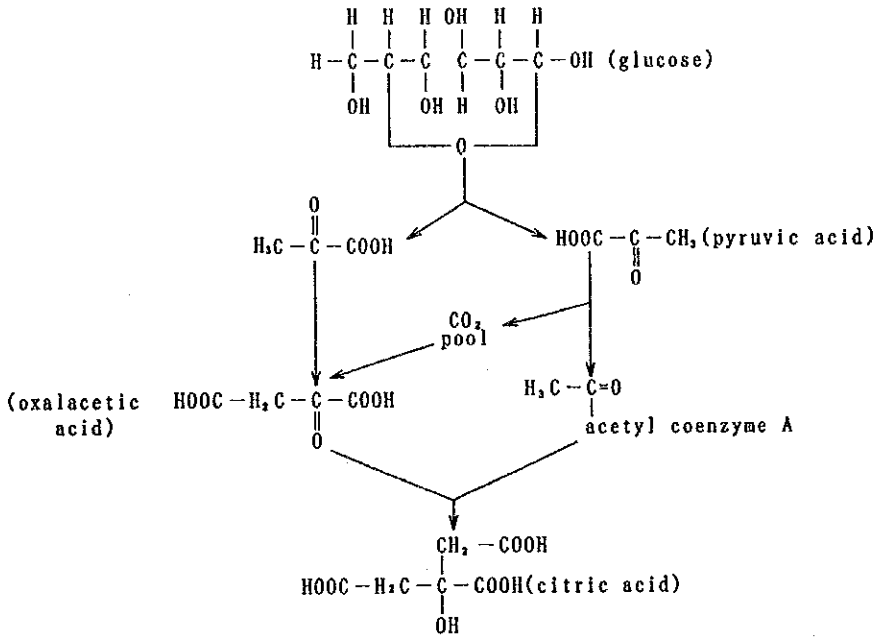


Figure 4–2 Conversion of Glucose to Citric Acid

Glucose is decomposed to pyruvic acid. The pyruvic acid combines with the carbon dioxide, which is discharged during the formation of activated acetic acid, and oxalacetic acid is formed. Then citric acid is produced when the oxalacetic acid and activated acetic acid are condensed.

The reaction formula for citric acid fermentation is as follows:

$$C_6H_{12}O_6 + 1.5\ O_2 \rightarrow C_6H_8O_7 + 2H_2O$$

Theoretical yield to glucose is 106.7 percent.

(2) Fungi for citric acid formation

Many yeasts, molds and bacteria have been found for citric acid synthesis since Wehmer reported certain molds in the Penicillium genus produced citric acid. Among others, major fungi for the commercial production of citric acid are Aspergillus niger, Aspergillus awamori and Aspergillus wentii in the Aspergillus genus and Penicillium luteum and Penicillium citrium in the Penicillium genus.

In the fermentation process, retention of the citric acid yield of the fungi is the prime concern. For that purpose, citric acid producers are inclined to develop methods of preserving the strain so as not to cause degeneration of the fungi and also methods of separating superior strains. The fermentation yield largely depends on the type of fungi being suitable for the process used and the properties of the raw materials. Thus research and development of strains are prerequisites for the producers.

Fermentation processes require aeration because every strain is of the aerobic type. Also sterilization of the culture solution is essential to prevent contamination by other miscellaneous molds. Temperature control and nutrient control are improtant too, depending on the properties of the mold.

4–5–4 Fermentation Technology for Citric Acid Production

Currently, commercial production of citric acid depends on fermentation technologies such as surface culture, submerged culture and solid/seme-solid culture which have the following basic processes:

– Adjustment of the culture medium (solution concentration, pH and nutrient controls)
– Sterilization
– Implantation of fungi
– Fermentation (temperature and defoaming controls)
– Separation of the fermented solution

Three such fermentation processes are described below:

(1) Surface culture process

In this surface process certain fungi are inoculated into the cluture solution, which has been pre-treated in various ways including sterilization, and the culture solution is fermented at a temperature between 30 and 35 degrees centigrade in shallow pans. These fermentation pans are maintained in a stable state, during which they are aerated through the surface of the solution to promote the growth of the mold. The depth of the solution is usually between 10 to 15 centimeters. Required fermentation time is normally 4 to 14 days, depending on such conditions as raw materials, concentration of solution and solution depth. Because citric acid itself tends to diminish when more than 90 percent of the sucrose in the solution is consumed, termination of the fermentation should be appropriately determined.

This process has the advantages of cheaper power cost, easier maintainability for the fermentation process and the ability to reuse the fungi. The surface culture process, however, requires a large labor force, large floor space for fermentation, and longer fermentation time per batch. Thus it is not suitable for mass production. Today this process is of minor importance.

(2) Submerged culture process

In the submerged process the culture solution is agitated and aerated by sterilized air in the fermentation vessel which contains aeration pipes, a mechanical agitator, baffleplates, etc. The molds are cultivated by respiration of air and form citric acid as a metabolized substance. The submerged process requires advanced techniques for improving the citric acid yield by control of the fermentation temperature (30 to 35 degrees centigrade), aeration and so forth. Usually fermentation takes 4 to 7 days; it depends mainly on raw material properties and solution concentration.

This process consumes much electric power for agitation and aeration during fermentation which help promote acid production. The plant area required for this process is smaller and for mass production the submerged process is more suitable than the surface or solid culture processes. The submerged process is the most competitive methodology in cost terms and has become the major method of producing citric acid in the world.

(3) Solid/semi-solid culture process

The solid culture process is used by several companies in Japan and South-East Asian countries. In Japan sweet potato starch residues are utilized as the principal raw material and rice bran as a nutrient for this process, whereas in South-East Asian countries cassava residues are used as the raw material. The solid culture medium is adjusted to contain about 70 percent of water. About 10 to 20 kilograms of the solid culture medium is filled into open tray pots and the tray pots are placed on shelves in a fermentation building for approximately 7 days. This process requires much manpower for moving the tray pots in and out of the fermentation building. The production yield of this process often tends to fall due to contamination by miscellaneous molds in the atmosphere even if the culture medium, tray pots and fermentation building are kept sterilized. As the recovery of citric acid from one tray pot is usually from 1 to 2 kilograms, this process is not desirable for mass production. Appropriate water retension and permeability of the raw materials are very important for this process because they affect the control of the oxygen supply through the surface of the culture medium, fermentation temperature and other fermentation conditions.

The advantages of the solid/semi-solid culture process are cheaper facility costs and the effective utilization of very cheap potato starch residues, and agricultural waste products. Hence this methodology is quite applicable to an area which can provide the agricultural waste and a cheap labor force.

The semi-solid culture process uses sugar materials and is based on solid culture fermentation. Also it utilizes bagasse, rice chaff and the like as a carrier to maintain the water retention and permeability of the culture medium. This process was developed to make effective use of the juice squeezed from the waste products of pineapple processing (pineapple cores and skin). Although a pilot plant was constructed, commercial production has not been successful due to changes in the circumstances of the supply of the raw materials.

4–5–5 Separation Process of Citric Acid

Citric acid production consists of the fermentation processes discribed above and the subsequent separation process. This section explains the steps in the separation process.

(1) Separation of solid impurities

Fermented solutions of the surface culture and submerged culture processes contain unconsumed materials and mycelium as well as cultured citric acid. The solid impurities are separated by filtration.

The fermented medium of the solid/semi-solid culture process is washed with water; citric acid is dissolved into the water; and residual insolubles are separated by the filtration.

(2) Recovery of calcium citrates

After the separation of solid impurities, citric acid is recovered from the fermented broth as calcium citrate which has a low solubility in water. This process precipitates the calcium citrate by adding a lime slurry under the control of pH and temperature. The precipitated calcium citrate is recovered by the filtration.

(3) Preparation of citric acid solution

The calcium citrate is treated with sulfuric acid. This reaction converts the calcium citrate to calcium sulfate and citric acid. Calcium sulfate is filtered and washed free of citric acid solution.

(4) Recovery of crude citric acid

Citric acid solution is concentrated and filtered to obtain crystals of crude citric acid.

(5) Refining of crude citric acid

Crude citric acid is dissolved in water and decolorized with activated carbon. After the treatment the activated carbon is removed by filteration.

(6) Final product

The crystals of citric acid are obtained by evaporating water from the refined citric acid solution. The crystals are filtered, dried and packaged to form the final product.

The above are the basic processes of citric acid separation, which do not vary significantly for the various types of raw materials and fermentation processes.