THE FIRST PROGRESS REPORT FOR THE STUDY RELATED TO THE REGIONAL DEVELOPMENT PLAN OF THE GREAT CARAJAS PROGRAM OF THE FEDERATIVE REPUBLIC OF BRAZIL

Vol. 3

AGRICULTURAL PRODUCTS PART II

NOVEMBER 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

THE FIRST PROGRESS REPORT
FOR
THE STUDY RELATED TO
THE REGIONAL DEVELOPMENT PLAN
OF THE GREAT CARAJAS PROGRAM
OF
THE FEDERATIVE REPUBLIC OF BRAZIL

Vol. 3
AGRICULTURAL PRODUCTS PART II

NOVEMBER 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

OVERALL CONTENTS

CONTENTS OF VOL. 3

[AGRICULTURAL PRODUCTS — Part II]

[3] ETHYL ALCOHOL

[3] ETHYL ALCOHOL

CONTENTS

[3] ETHYL ALCOHOL

A. GENERAL DESCRIPTION

I. Historical Background of Ethyl Alcohol Production

Ethyl alcohol has many useful properties, such as intoxicating, dissolving, reacting, germicidal and combustible properties. And these properties have been made use of since early days for application in alcoholic beverages, medicinals, industrial uses and as fuel. Ethyl alcohol has been produced in various countries of the world, since it can be made comparatively easily from agricultural products. The latest United Nations statistics list 43 alcohol producing countries.

While ethyl alcohol is such a popular substance, it has been treated as an object of government involvement in most countries, as a source of tax revenue when used in alcoholic beverages and as an energy source to secure handy liquid fuel which is domestically producible.

Production of ethyl alcohol was commenced with the fermentation process using farm products or saccharine and starchy substances, which are by-products of farming, as raw materials. Alcohol production has greatly been boosted between 1920 and around 1940 in various countries of the world for industrial and fuel uses from the need for national defense or for promotion of agriculture. As a result, outputs of ethyl alcohol rapidly expanded.

However, ethyl alcohol as fuel has practically been ignored after 1945, when international oil supplies became plentiful and oil prices remained low.

With regard to alcohol for industrial application, it began to be produced largely in the developed countries, when the synthesis of alcohol using ethylene as raw material was industrialized between 1930 and 1948. And on account of the raw material supply situation and agricultural policies followed in the respective countries, the use of both the synthesis and fermentation processes has continued to this day.

The 1973 oil crisis took place amid such a situation, and ethyl alcohol production under the fermentation method was limelighted again, and alcohol again began to attract attention for industrial application and as fuel.

Ethyl alcohol production technology have also been spotlighted at every encounter with oil crisis in recent years, and as production of alcohol for industrial use and for fuel increased, ethyl alcohol production technology also achieved progress. Further technological development efforts are also being made.

II. Properties of Ethyl Alcohol

More important physical and chemical properties of ethyl alcohol are shown in Table A-1 in comparison to those of methyl alcohol, gasoline, diesel oil and fuel oil. Data in this table are quoted from those by the American Petroleum Institute (API). For more detailed physical, chemical and pharmacological properties refer to Appendix Table 1.

III. Uses of Ethyl Alcohol

As stated above, ethyl alcohol has many highly useful properties, which make it usable for a large variety of purposes. As details of use will be presented in subsection C-I later, the historical development of uses will be briefly introduced here.

It is said that man has already known how to brew alcoholic drinks by the time he learned to leave records in writing. Ethyl alcohol, as a consequence, was first used for drinking purposes. And after distilled alcoholic beverages made from the drinking liquer became available, alcohol came to be valued as a substance for medicinal use. With further progress made in the distillation technology, dehydrated ethyl alcohol became available, and this reportedly began to be used as fuel and solvent for perfume refining. Meanwhile, use of ethyl alcohol in food and beverage and for hygienic purposes also expanded. And with rise of the chemical industry, use of alcohol as solvent, auxiliary agent and raw material commenced. Around 1910, 20,000 to 100,000 kl of ethyl alcohol was being used for industrial purposes in the leading countries of Europe and America.

After World War I, since 1920 in particular, the demand for fuel and industrial use ethyl alcohol expanded. From 1950 towards the first half of the 1960s, ethyl alcohol-based chemical industry using

Table A-1 Main Physical/Chemical Properties of Alcohol and Hydrocarbon Fuels

Property	Ethyl Alcohol	Methyl Alcohol	Gasoline	Diesel	Fuel Oil
Formula	CH_3CH_2OH	CH_3OH	C_4 to C_{12} Hydrocarbons	C_{14} to C_{19} Hydrocarbons	C_{20+} Hydrocarbons
Molecular weight	46.1	32.0	100-105 avg.	240 avg.	-
Composition (weight %)					
Carbon	52.2	12.5	85-88	85-88	85-87
Hydrocarbon	13.1	12.5	12-15	12-15	10-11
Oxygen	34.7	50.0	Neg.	Neg.	Neg.
Specific gravity	0.79	0.79	0.72-0.78	0.83-0.88	0.88-0.98
Boiling temperature, °C	78	65	27-225	240-360	360+
Flash point, °C	13	-	-43	38	66
Autoignition temperature, °C	423	878 F	257	-	-
Flammability limits (volume %)					
Lower	4.3	-	1.4	-	-
Higher	19.0	-	7.6	-	-
Octane Number (Research)	106-111	106-115	79-98	-	N.A.
(Motor)	89-100	82-92	71-90	-	N.A.
Cetane Number	0-5	N.A.	5-10	45-55	N.A.
Solubility in water	Infinite	Infinite	0	0	0

Note : N.A. - Not Applicable
Source: American Petroleum Institute (API)

ethyl alcohol as raw material began to develop mainly in Brazil and India, and commercial production of ethylene, polyethylene and ethylbenzene commenced.

In parallel with the above development, manufacture of synthetic chemical products based on petrochemical processes commenced in the United States from the 1940s. And in 1948, production of synthetic ethyl alcohol under direct hydration of ethylene commenced, and by the latter half of the 1960s the ethyl alcohol-based chemical industry using fermented ethyl alcohol as raw material has lost competitiveness in the international market.

In the fuel ethyl alcohol sector, on the other hand, use of ethyl alcohol as fuel almost ceased since 1945 as low-cost stable oil supplies became available.

The oil crisis in 1973 amid such a situation and the repeated price hikes in the subsequent years forced the countries of the world to reassess their energy policies, and since ethyl alcohol made under the fermentation process uses biomass as raw material, it has lately been attracting attention not only as an energy source but also as raw material for chemical products.

As described in the foregoing, uses of ethyl alcohol can be broadly classified into three main categories, namely, for beverage, as industrial material and for fuel. However, use of alcohol as beverage has been excluded from this report because of the aims of this Study. Uses of ethyl alcohol for industrial purposes and as fuel only have been taken up.

B. PRODUCTION

I. Product Specification

1. Purity of Product

In the specification applicable to ethyl alcohol, the specification for product purity is applicable both to industrial and fuel ethyl alcohol. For instance, the two types of ethyl alcohol include the hydrous ethyl alcohol with alcohol content of 94 to 95% by volume and the anhydrous ethyl alcohol with alcohol content of 99.4 to 99.6% by volume. However, some countries do not produce anhydrous alcohol.

2. Other Items of Specification

The industrial ethyl alcohol specifications of developed countries include, as other items specified, specific gravity, evaporation residue, free acid (as acetic acid) content, methyl alcohol content and the fusel oil content.

For reference, the industrial ethyl alcohol standard in selected countries are given in Appendix Table 2.

Meanwhile, specifications for fuel alcohol have not yet been established except for product purity and organic acid content. As ethyl alcohol for fuel is normally produced with top priority given to cost reduction, use of fuel ethyl alcohol for industrial purposes like making cosmetics may require further refining to a certain extent.

II. Raw Materials

1. Raw Material Production and Regional Distribution

There are two manufacturing processes of ethyl alcohol. One is fermentation process and the other is synthesis process, each using raw material widely different from the other.

The fermentation process consists of obtaining alcohol from fermentable sugars through fermentation. And as the starchy and fibrous substances are fermented after saccharification, the raw materials for the fermentation process may be classified as hereunder.

- Saccharine raw materials: Molasses, sugar cane, etc.
- Starchy raw materials: Grains, potato, sweet potato, etc.
- Cellulosic raw materials: Lumber, etc.

The synthesis process consists of producing alcohol by causing chemical reactions between ethylene from the petrochemical plant and water.

- Synthesis process materials: Ethylene (from petroleum or natural gas).

While raw materials cited in the foregoing are used extensively for making industrial ethyl alcohol, the production of fuel ethyl alcohol is naturally limited to the fermentation process, and the raw materials used in Brazil largely consist of molasses, sugar cane and cassava. On the other hand, corn is the principal material used in the United States.

In the following the production of principal raw materials and the regional distribution of such materials will be outlined.

1.1 Saccharine Raw Materials

1.1.1 Molasses

When sugar is manufactured using sugar canes and sugar beets as raw materials, molasses is obtained as a by product. As it contains 50 to 60% of sugar and is low priced, it is used for a variety of purposes; it is also used as raw materials for making both industrial and fuel-use ethyl alcohol. Molasses production and their regional distribution are given in Table B-1.

Table B-1 Molasses Production of the World

(1,000 MT)

July-June	1976/1977	1977/1978	1978/1979	1979/1980
EC	(3,565)	(3,276)	(3,033)	(2,995)
Western Europe	5,077	4,638	4,380	4,174
Eastern Europe	4,371	5,227	5,226	4,557
North & Central America	6,743	6,971	7,153	6,393
South America	5,452	7,106	7,195	7,390
Africa	2,087	2,099	2,102	2,197
Asia	6,698	6,931	6,676	5,332
Oceania	728	746	683	750
World Total	31,156	33,718	33,415	30,803

Note : 1) Refined molasses included.
2) Figures for EC given in ( ) are part of total for Western Europe.

Source: *The third estimate by Licht*

1.1.2 Sugar cane

Sugar cane has originally been used as a raw material for making sugar, but they began to attract attention as raw material for ethyl alcohol, when ethyl alcohol began to be used in large quantities as fuel. *In Brazil sugar cane is already used as a raw* material for fuel ethyl alcohol. Sugar cane production and regional distribution are shown in Table B-2.

In addition to sugar cane, saccharine raw materials include fruit juice and sweet sorgham.

1.2 *Starchy Raw Materials*

Any substances with high starch content may serve as raw material, but raw materials for making ethyl alcohol become limited when the yield, ease of production and economic efficiency are taken into consideration. Typical materials include corn and potato, and in Brazil cassava is also used for making fuel ethyl alcohol.

Table B-2 Sugar Cane Production of the World

	AREA HARV 1000 HA				YIELD KG/HA				PRODUCTION 1000 MT			
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
WORLD	10747	13584	13249	13819	52833	55547	54328	56102	567817	754536	719800	775285
AFRICA	698	864	887	930	67394	70744	64568	69582	47036	61095	57293	64687
ANGOLA	15	15F	15F	15F	51602	28000	20000	27333	776	420F	300F	410F
CAMEROON	11	20F	22F	17F	20394	36000	35909	34118	224	720F	790F	580F
CAPE VERDE	1	1F	1F	1F	18378	15000	15000	15000	11	15F	15F	15F
CHAD		3F	3F	3F	55918	86000	88000	66667	22	215F	220F	220F
CONGO	20	5F	7F	8F	33899	24600	29000	28125	672	123F	203F	225F
EGYPT	77	104	105*	109F	92300	84203	84060	83575	7096	8791	8791*	9076F
ETHIOPIA	7	9	9F	9F	148197	165412	160976	150000	1092	1406	1320F	1380F
GABON	1	2	3	3F	22928	53884	51339	51852	13	94*	134*	140F
GHANA	6	9*	9*	9F	28712	21111	21333	21111	179	190*	192*	190F
GUINEA		3F	3F	3F		81481	81481	81481		220F	220F	220F
GUIN BISSAU		2F	2F	2F	56250	13333	12500	12500	5	20F	25F	25F
IVORY COAST		10	21	26		80317	75551	76453		770F	1550F	2000F
KENYA	26	34*	40*	41*	62878	108492	112767	112683	1645	3678F	4517F	4620F
LIBERIA	5	10F	10F	10F	10000	14737	15000	15500	45	140F	150F	155F
MADAGASCAR	21	35	34	34F	55791	41049	41047	41176	1153	1432	1388	1400F
MALAWI	4	11F	15F	17F	74967	100000	100000	100000	296	1130F	1480F	1700F
MALI	1	3*	3F	3F	56739	77077	78571	77586	56	213*	220F	225F
MAURITIUS	80	80	79	80F	67552	79178	57674	68750	5400	6313	4564	5500F
MOROCCO		4	4	4F		73729	93277	74419		293	375	320F
MOZAMBIQUE	52	50F	50F	55F	53716	44000	40000	35455	2767	2200F	2000F	1950F
NIGER	1	4	4F	4F	27432	53414	52778	50000	39	189	190F	190F
NIGERIA	12	16F	16F	18F	46306	52581	54375	55556	556	815F	870F	1000F
REUNION	40	36F	34F	36F	50659	66800	66176	65556	2026	2405	2250F	2360*
RWANDA		1F	1F	1F	20608	51667	49231	47143	5	31F	32F	33F
SENEGAL		4	5*	6F		84445	103140	100000		367*	473*	600F
SEYCHELLES												
SOMALIA	3	3	7	7F	126738	87067	63561	58571	436	261	420	410F
SOUTH AFRICA	188	222*	215*	217F	77495	82833	65182	77086	14561	18412	14014	16720*
SUDAN	13	26	26F	30F	65458	66341	58594	80000	825	1700F	1500F	2400F
SWAZILAND	14	22	26	30F	110367	104014	107722	108333	1548	2280	2782	3250F
TANZANIA	39	42F	42F	42F	29598	30476	31881	30643	1141	1280F	1339F	1287F
UGANDA	31	30F	29F	30F	54055	17667	18966	18333	1667	530F	550F	550F
UPPER VOLTA		4F	4F	4F		90000	87500	87500		360F	350F	350F
ZAIRE	11	14F	14F	15F	58997	49265	43662	45426	619	670F	620F	658F
ZAMBIA	3	10	10	12F	102160	88752	91972	83333	303	888	920	1000
ZIMBABWE	18	25	25	30*	104338	104209	103121	119206	1861	2555	2528	3529*
N C AMERICA	2698	2920	2983	3036	57088	61236	54788	56535	154022	178785	163440	171625
ANTIGUA	2				31033				59			
BAHAMAS	7	7F	7F	8F	32857	30833	30270	29737	230	222F	224F	226F
BARBADOS	20	16	16	16*	66121	66247	76071	54430	1325	1052	1208	860F
BELIZE	12	25	25	25	51685	40053	41012	38804	622	989	1013	970
COSTA RICA	36	45*	49*	51*	55891	58521	51686	49448	2008	2615	2516	2522
CUBA	1273	1313	1361	1400F	47493	58890	45843	47857	60467	77311	62374	67000F
DOMINICA					21615	20000	20000	20000	4	4F	4F	4F
DOMINICAN RP	147	173*	180*	185*	60990	57823	50309	62703	8986	10304	9056	11600*
EL SALVADOR	31	37	34	28	53224	86816	64794	68501	1662	3214	2201	1916
GRENADA					39290	33330	33750	37785	14	14	14F	9
GUADELOUPE	28	21	21	23F	63982	55380	47509	36457	1785	1163	1007*	839*
GUATEMALA	38	74*	79*	83*	71713	69153	68811	68611	2692	5100F	5409*	5680*
HAITI	75	75F	80F	80F	36186	38667	37500	37500	2702	2900F	3000F	3000F
HONDURAS	49	75F	85F	90F	27821	34667	33176	33333	1368	2600F	2820F	3000F
JAMAICA	58	47*	49*	45*	70655	63082	58000	55124	4098	2965	2816	2453*
MARTINIQUE	8	5	5	5	65352	57983	52083	48636	499	291	250	243
MEXICO	518	538	546	545	64261	64288	66869	65076	33271	34587	36480	35461
NICARAGUA	32	42	32*	37*	58143	65029	76838	76072	1866	2699	2431*	2800*
PANAMA	18	44	48	48F	68609	59408	49868	53250	1242	2624	2386	2556F
PUERTO RICO	68	39	34	32F	72373	53897	59350	59375	4952	2076	2028	1900F
ST KITTS ETC	4	4	3F	3F	70291	100392	101515	96875	285	384	335*	310*
SAINT LUCIA												
ST VINCENT												
TRINIDAD TOB	35	39*	34*	28*	70854	40858	41154	42857	2481	1600*	1400*	1200F
USA	238	297	297	305	89769	81173	82497	88802	21406	24069	24460	27076
US VIRGIN IS												
SOUTH AMERIC	2477	3530	3616	3831	51735	58028	59704	57230	128123	204853	215912	219249
ARGENTINA	200	306	314	323	51195	46204	54760	47201	10213	14120	17200	15260
BOLIVIA	36	67	66	65*	37293	46349	46978	50039	1327	3120	3080	3259*
BRAZIL	1708	2537	2605	2803	45926	54750	56069	54888	78460	138899	146065	153858
COLOMBIA	241	282	290F	300F	54709	87589	90000	86333	13167	24700F	26100F	25900F
ECUADOR	84	103	108	108F	77689	64019	61389	61574	6500	6599	6615	6650F
FR GUIANA					50056	32000	34000	34500	5	6	7F	7F
GUYANA	50	57*	57*	58F	81563	73684	66316	68966	4081	4200*	3780*	4000F
PARAGUAY	35	35	37	41*	35137	36940	37511	37805	1215	1287	1373	1550*
PERU	56	54	49	40*	141926	130507	113928	104680	7915	7034	5598	4160
SURINAME	3	2	2	3F	77632	80343	82121	64000	213	164	146	160F
URUGUAY	4	10	9	10*	38960	31355	49008	44500	145	323	448	445*
VENEZUELA	62	77*	80*	80*	79025	57143	68750	50000	4883	4400	5500	4000*
ASIA	4599	5935	5402	5633	47389	47886	47295	51548	217931	284207	255463	290357
AFGHANISTAN	3	4F	4F	4F	22000	16763	16250	16250	55	64	65F	65F
BANGLADESH	165	155	151	149	45847	44787	44155	44355	7551	6937	6676	6599
BURMA	43	50	42F	43F	33907	36346	35474	35835	1458	1812	1477	1523F
CHINA	474	622	652F	700F	41306	49720	49019	47143	19581	30944	31978	33000F
INDIA	2632	3088	2610	2648	48899	49114	49358	56844	128689	151655	128833	150522
INDONESIA	69	166	170	177*	148941	96355	100500	99208	10322	15995F	17085F	17560F
IRAN	4	18*	15F	14F	125745	83333	100000	100000	556	1500*	1500F	1400F
IRAQ	2	5F	6F	6F	39197	46667	47273	47273	78	210F	260F	260F

Table B-2 (cont'd.)

	AREA HARV			1000 HA	YIELD			KG/HA	PRODUCTION			1000 MT
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
JAPAN	39	35	34	37	62313	65653	61982	66216	2407	2311	2095	2450
KAMPUCHEA DM	6	2F	3F	3F	70833	52273	46429	48462	397	115F	130F	126F
LAO	1	1F	1	1	7756	8182	8534	27369	8	9F	9	30
LEBANON					21750	22000				1F		
MALAYSIA	4	20	18	19*	30623	46269	33889	44737	122	930F	610F	850F
NEPAL	14	20F	21F	21F	17185	18497	18750	17868	237	370	384	379
OMAN					30303	27027	25641	24390	1	1F	1F	1F
PAKISTAN	599	753	719	825	39799	36313	38271	39238	23836	27326	27498	32359
PHILIPPINES	384	424*	425	420F	42421	47209	46738	48690	16271	20007F	19846F	20450F
SINGAPORE					11702	6000	6233	6333	1	2	2	2F
SRI LANKA	4	7F	5F	5F	42433	50000	50000	52132	168	325F	265F	276F
SYRIA					53947	45000	50000		1			
THAILAND	144	480*	416*	480*	40683	42175	29952	38750	5856	20244	12460	18600*
VIET NAM	12	84	110	80F	27799	40828	39854	48750	333	3446	4388	3900F
YEMEN AR	2	2F	2F	2F	2941	2941	2941	2941	5	5F	5F	5F
EUROPE	7	6	6	6	72132	63910	66250	64000	486	374	371	384
PORTUGAL	1	1	1F	1F	38058	18906	26923	26154	49	24	35F	34F
SPAIN	5	5	4	5*	80198	76616	78140	74468	437	350	336	350*
OCEANIA	269	329	355	384	75065	76570	76907	75437	20220	25222	27321	28983
AUSTRALIA	222	267	288	310*	79185	79159	83141	81161	17607	21151	23948	25160
FIJI	47	62	67	74F	55554	65452	50149	51486	2603	4058	3360	3810F
FR POLYNESIA					74227	80645	81250	81818	2	3F	3F	3F
PAPUA N GUIN					60714	60606	60000	61176	9	10F	10F	10F
SAMOA					14000	15000	15000	15000				
DEV.PED M E	694	827	839	875	81356	80186	77346	82064	56465	66317	64889	71790
N AMERICA	238	297	297	305	89769	81173	82497	88802	21404	24069	24460	27076
W EUROPE	7	6	6	6	72132	63910	66250	64000	486	374	371	384
OCEANIA	222	267	288	310	79185	79159	83141	81161	17607	21151	23948	25160
OTH DEV.PED	227	257	249	254	74906	80485	64747	75502	16968	20723	16109	19170
DEV.PING M E	9562	12048	11645	12162	51355	54260	53106	54800	491042	653714	618416	666470
AFRICA	421	511	542	574	58387	62961	60846	63555	24555	32193	32988	36491
LAT AMERICA	4936	6153	6303	6562	52824	58435	56305	55442	260740	359568	354892	363798
NEAR EAST	100	158	155	164	86041	77622	77352	80610	8616	12271	12022	13207
FAR EAST	4058	5163	4577	4788	47936	47573	47003	52038	194518	245611	215141	249150
OTH DV.PING	47	62	67	74	55577	65446	50188	51522	2613	4071	3373	3823
CENTR PLANND	492	709	765	783	41314	48669	47691	47312	20310	34505	36495	37026
ASIAN CPE	492	709	765	783	41314	48669	47691	47312	20310	34505	36495	37026
DEV.PED ALL	694	827	839	875	81356	80186	77346	82064	56465	66317	64889	71790
DEV.PING ALL	10053	12757	12410	12944	50864	53950	52772	54347	511352	688219	654911	703496

* Unofficial figures
F: Estimates by FAO

Source: FAO, Production Yearbook, 1981

1.2.1 Corn

Large quantities of corn in the United States as raw material for fuel ethyl alcohol is well known. Corn production and regional distribution are shown in Table B-3.

1.2.2 Potato

Potato is cultivated widely in various parts of the world. In northern Europe, potato is an especially important root crop and raw material for making ethyl alcohol. Potato production and regional distribution are shown in Table B-4.

1.2.3 Cassava

Cassava is used principally as a raw material for starch, but lately it is attracting attention as raw material for alcohol. Cassava production and regional distribution are given in Table B-5.

1.2.4 Sweet potato

It has been used principally in Japan as one of the raw materials for ethyl alcohol, but only in small quantities lately. The production and regional distribution are given in Table B-6.

1.3 Cellulosic Raw Materials

A total of some 30 billion tons of cellulosic are estimated to be produced annually in the world. It is the largest reproducible resource on the earth. Today alcohol is produced by acid saccharification in some countries, but with regard to production of alcohol by bio-saccharification method, research work on the preparatory saccharification and fermentation processes with a view to improving the efficiency thereof is being undertaken.

1.4 Raw Materials for Synthesis Process

Raw materials used for obtaining ethyl alcohol by synthesis process include natural gas, naphtha and ethylene produced from associated gas of oil fields. Ethylene is a basic raw material for the petrochemical industry, since ethyl alcohol and various other petrochemical products are manufactured from it. Ethylene production and regional distribution are shown in Table B-7.

Table B-3 Corn Production of the World

	AREA HARV 1000 HA				YIELD KG/HA				PRODUCTION 1000 MT			
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
WORLD	114485	125796	128764	134024	2472	3326	3060	3370	283031	418357	394056	451704
AFRICA	18549	20019	21373	22583	1170	1203	1271	1455	21710	24074	27173	32860
ALGERIA	6	1	2	1F	953	1117	966	1000	6	1	1	1F
ANGOLA	540	600*	600*	600F	864	500	533	417	467	300F	320F	250*
BENIN	359	424	427*	427F	559	724	817	817	201	307	349*	349F
BOTSWANA	34	21	47	50*	309	107	249	300	11	2	12	15*
BURUNDI	112	125F	130F	130*	1071	1120	1000	1077	120	140F	130*	140*
CAMEROON	309	545	540F	540F	1151	748	907	926	355	408	490F	500F
CAPE VERDE	4	10F	15F	10F	431	100	467	300	2	1	7*	3*
CENT AFR REP	62	103	108	100F	711	328	379	400	44	34	41	40F
CHAD	6	10F	10F	10F	1943	1500	1400	1500	12	15F	14F	15F
COMOROS	3	5	5F	5F	1061	1000	1000	1000	4	5	5F	5F
CONGO	8	26	26F	27F	667	654	423	556	5	17	11*	15F
EGYPT	634	791	800	714*	3741	3714	4038	3782	2370	2938	3231	2700*
ETHIOPIA	849	1001*	1106*	1100F	1071	1066	1034	1000	909	1067*	1144*	1100F
GABON	3	5F	6F	6F	1319	1481	1500	1667	4	8F	9F	10F
GAMBIA	7	10F	12*	12*	566	1000	1000	1075	4	10	12*	13*
GHANA	387	358	340*	350F	1078	1061	1147	1200	417	380	390*	420*
GUINEA	59	41	50F	55F	1153	1150	1140	1145	68	47	57F	63F
GUIN BISSAU	3	5F	5F	5F	628	800	400	800	2	4F	2F	4F
IVORY COAST	333	584	600	615F	773	471	467	488	257	275	280	300F
KENYA	1383	1400F	1120	1200	1489	1286	1579	1875	2060	1800	1768	2250
LESOTHO	143	112	110	110*	651	1112	957	1182	93	125	106	130*
LIBYA	1	1	1	1F	1234	1054	950	949	1	1	1	1F
MADAGASCAR	121	116	128	126*	1004	1004	994	1000	122	116	127	126*
MALAWI	1039	1000F	1100F	1100*	1025	1200	1000	1455	1066	1200*	1100F	1600*
MALI	78	90F	90F	90F	866	944	367	889	67	85	33*	80F
MAURITANIA	7	9F	9F	10F	580	556	571	600	4	5F	5F	6F
MAURITIUS				1F	1984	2502	2245	2500		1	1	2F
MOROCCO	474	416	411	360*	801	750	809	250	380	312	333	90*
MOZAMBIQUE	363	620	600F	550F	1003	483	417	364	364	300F	250F	200F
NAMIBIA	63	110F	110F	100F	368	318	364	300	23	35F	40F	30F
NIGER	3	12	12F	12F	600	779	750	750	2	9	9F	9F
NIGERIA	1398	1665F	1710F	1746F	869	901	906	905	1215	1500F	1550F	1580F
REUNION	3	3F	3F	3F	3564	5400	5385	5000	9	14F	14F	15F
RWANDA	50	78	77F	80F	1084	1072	1039	1063	54	83	80F	85F
SAO TOME PRN					1526	1535	1523	1556		1F	1F	1F
SENEGAL	52	68	70*	49*	814	684	760	1122	42	46	53*	55*
SIERRA LEONE	10	13F	13F	13F	984	923	962	1077	10	12*	13*	14F
SOMALIA	139	106F	114F	150F	793	984	974	800	110	104	111	120F
SOUTH AFRICA	5290	5000F	6000F	7000F	1265	1648	1798	2093	6691	8240	10790	14650
SUDAN	39	60F	61F	65F	780	750	738	769	31	45*	45F	50F
SWAZILAND	89	55F	71	65*	846	1000	1360	1462	75	55*	97	95*
TANZANIA	1005	1300F	1300F	1300F	813	692	577	577	817	900F	750*	750*
TOGO	144	115F	120F	120F	1109	1383	1283	1143	160	159	154	137
UGANDA	343	500F	258	260	1221	906	1109	1315	419	453	286	342
UPPER VOLTA	92	98	100F	100F	659	1066	983	1000	60	104	98	100F
ZAIRE	595	706F	710F	715F	713	721	727	727	424	509*	516*	520F
ZAMBIA	992	900F	1100F	1150F	792	778	727	870	786	700F	800F	1000F
ZIMBABWE	914	800	1146	1350	1495	1500	1343	2133	1366	1200	1539	2880
N C AMERICA	33570	37536	39441	41424	4062	5787	4798	5599	136352	217230	189227	231937
ANTIGUA					2296	2000	2045	2083				
BAHAMAS	1	1F	1	1F	985	1063	1141	1138	1	1F	1	1F
BARBADOS	1	1F	1F	1F	2391	2614	2500	2500	2	2F	2F	2F
BELIZE	9	11	11	11	1437	1437	1690	1686	13	15	19	19
CANADA	490	893	958	1058	5078	5583	5671	5874	2487	4983	5434	6214
COSTA RICA	50	50*	50*	47	1123	1458	1492	1876	56	73	75	88
CUBA	100	76F	77F	77F	853	1250	1234	1234	85	95F	95F	95F
DOMINICA					1235	1419	1438	1438				
DOMINICAN RP	27	19*	24*	24*	1712	2012	2042	2083	46	38	49	50*
EL SALVADOR	203	276	292	259*	1670	1896	1806	1882	340	523	527	487*
GRENADA		1	1F		856	908	1100	976		1	1F	
GUADELOUPE					1778	1200	1200	1200	1			
GUATEMALA	671	622*	664*	680	1118	1512	1568	1547	751	941	1041*	1052
HAITI	231	234	245*	250F	1058	784	714	720	245	183	175F	180F
HONDURAS	283	341	340*	340*	1198	1037	992	994	339	354	337*	338*
JAMAICA	4	4F	3F	4F	1270	1741	1327	1795	4	6	4	7*
MEXICO	7412	5502	6955	8150	1218	1477	1780	1812	9025	8124	12383	14766
MONTSERRAT					1000	1000	1000	1000				
NICARAGUA	260	140*	197*	250*	912	1196	1164	1000	238	168*	229*	250*
PANAMA	77	66	66*	70*	859	959	955	971	66	63	63*	68*
PUERTO RICO	2				1043	920	920	920	2			
SAINT LUCIA					828	700	700	727				
ST VINCENT					3207	3333	3313	3235		1F	1F	1F
TRINIDAD TOB	1	1F	1F	1F	4153	4167	4167	4167	2	5*	5*	5F
USA	23749	29300	29555	30200	5164	6883	5711	6898	122649	201655	168787	208314
SOUTH AMERIC	16525	16690	16383	17361	1553	1741	1857	2212	25668	29056	30430	38406
ARGENTINA	3880	2800	2490	3500	2247	3107	2570	3857	8717	8700	6400	13500
BOLIVIA	223	278	293	190*	1306	1360	1306	1316	291	378	383	250*
BRAZIL	10021	11319	11438	11491	1365	1441	1781	1835	13680	16306	20374	21098
CHILE	70	130	116	126	3111	3752	3487	4128	217	489	405	518
COLOMBIA	684	616	614	629	1251	1414	1323	1399	856	870	813	880
ECUADOR	312	219	226	225*	767	996	1070	1094	239	218	242	246*
FR GUIANA					4420	4000	4000	4000		1	1F	1F
GUYANA	1	2F	3F	3F	1632	1158	1200	1000	2	2	3F	3F
PARAGUAY	162	353	377	400F	1245	1560	1553	1500	201	550	585	600F
PERU	373	361	258	316	1621	1721	1717	1986	605	621	443	628*
SURINAME					1906	1671	1585	1611				
URUGUAY	194	94	132	146	832	758	904	1338	161	71	119	196

Table B-3 (cont'd.)

	AREA HARV			1000 HA	YIELD			KG/HA	PRODUCTION			1000 MT
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
VENEZUELA	606	519	436	335*	1152	1634	1519	1451	698	848	662	486*
ASIA	30656	36653	36926	37510	1644	2250	2308	2308	50413	82460	85243	86570
AFGHANISTAN	453	460*	460F	470F	1560	1652	1733	1698	707	760	797	798*
BANGLADESH	3	2	2	2F	870	727	715	700	3	1	1	1F
BHUTAN	9	11F	11F	11F	1108	1110	1111	1109	9	12F	12F	12F
BURMA	112	83	80	80F	619	1219	1250	1250	69	102	100	100F
CHINA	15965	20167	20035*	20537F	2028	2983	3030	2999	32376	60149	61109	61601F
EAST TIMOR	16				918				15			
INDIA	5794	5721	5983	5800F	1051	979	1137	1207	6087	5603	6804	7000F
INDONESIA	2667	2594	2771	2735	965	1390	1448	1459	2575	3606	4012	3991
IRAN	25	42*	42F	42F	1400	1357	1429	1190	35	57*	60F	50F
IRAQ	6	35F	35F	35F	1495	2857	2571	2511	9	100F	90F	90F
ISRAEL	1	3	3	3F	4806	4038	4893	5000	5	11	14	15F
JAPAN	12	2	2	1*	2674	2591	1989	3000	33	5	4	3*
JORDAN	1				290	4041	7650	1000				
KAMPUCHEA DM	94	75	99	95	1332	933	1010	1032	125	70F	100F	98F
KOREA DPR	302	370F	380F	380F	4950	5210	5789	5789	1493	1950F	2200F	2200F
KOREA REP	44	32	35	33	1450	4587	4362	4383	63	149	154	145
KUWAIT						3000	3000	3000				
LAO	15	28	28	31	1711	1123	1000	1062	26	32	28	33
LEBANON	1	2F	2F	2F	904	1333	1333	1333	1	2*	2*	2*
MALAYSIA	8	7	7	7	1942	1143	1143	1143	15	8	8	8
MALDIVES					4500	3333	3667	3667				
NEPAL	439	450F	450F	450F	1812	1231	1651	1600	796	554	743	720F
PAKISTAN	640	701	745	727	1088	1248	1271	1381	697	875	947	1004
PHILIPPINES	2356	3327	3281	3319	813	952	950	957	1915	3167	3117	3176
SAUDI ARABIA	1	3F	3F	3F	5070	1600	1600	1600	4	4F	4F	4F
SRI LANKA	19	19	19	23F	775	1139	1166	1087	15	22	23	25F
SYRIA	6	18	22	36	1403	1835	2093	2512	8	34	47	89
THAILAND	771	1509	1562	1716*	2567	2187	2017	2156	1979	3300	3150	3700*
TURKEY	646	585	583	580*	1637	2308	2127	1897	1058	1350	1240	1100
VIET NAM	239	371	246	350F	1136	1281	1701	1543	272	475	418	540F
YEMEN AR	8	31*	31*	34*	1975	1548	1548	1441	16	48*	48*	49*
YEMEN DEM	2	6F	10F	10F	2528	2419	1500	1500	5	15F	15F	15F
EUROPE	11478	12154	11586	11520	3366	4674	4507	4655	38635	56808	52214	53627
ALBANIA	111	85F	85F	85F	1988	2941	2941	2941	220	250*	250F	250F
AUSTRIA	122	188	193	189	5547	7110	6700	7270	677	1347	1293	1374
BELGIUM-LUX	2	6	6	4*	5510	6130	6270	6250	11	37	39*	25*
BULGARIA	623	666	585	571	3913	4840	3859	4337	2436	3223	2256	2477
CZECHOSLOVAK	127	190	159	190F	4021	5008	4685	4211	511	949	745	800*
FRANCE	1436	1995	1757	1570	5148	5220	5326	5796	7394	10413	9358	9100
GERMAN DR	3	1	1	1*	2631	4692	4490	2000	9	6	4	2F
GERMANY FR	99	115	119	129	5052	6423	5653	6455	590	741	672	832
GREECE	162	123	170	159	3073	5804	6812	7862	498	711	1158	1250
HUNGARY	1272	1367	1253	1350F	3570	5411	5324	4815	4542	7396	6673	6500*
ITALY	986	937	937	991	4664	6617	6936	7318	4691	6197	6403	7250
NETHERLANDS	1	1	1		4630	3333	3922	4500	5	2*	2*	2F
POLAND	5	46	16	20	2449	3900	3544	3965	17	181	58	79
PORTUGAL	432	394	394	388	1385	1284	1355	1035	599	506	534	417
ROMANIA	3170	3311	3288	3150*	2320	3752	3392	3556	7354	12425	11153	11200F
SPAIN	526	460	448	430	3432	4793	4931	5002	1804	2205	2208	2151
SWITZERLAND	10	18	14	17	6168	7542	6472	6882	61	134	91	117*
UK	1	1*	1F	1F	4666	895	785	1000	2	1	1	1F
YUGOSLAVIA	2391	2251	2161F	2275F	3095	4480	4312	4308	7399	10084	9317	9800*
OCEANIA	89	77	78	82	2911	4619	4032	3724	260	356	316	304
AUSTRALIA	77	50	54	56	2387	3380	2791	2122	184	169	151	118
FIJI	2	2F	2F	2F	2438	2000	2000	2000	4	4F	4*	4F
GUAM					1130	1590	1500	1500				
NEWCALEDONIA			1	1F	2222	2046	2925	3000	1	1	2	2F
NEW ZEALAND	9	22	19	21*	7753	8031	8076	8429	70	179	156	177*
PACIFIC IS					1125	1171	1195	1195				
PAPUA N GUIN		1F	1F	1F	888	2030	2000	2000		2F	2F	2F
VANUATU	1	1F	1F	1F	509	500	520	520		1F	1F	1F
USSR	3617	2667	2977	3545	2763	3139	3176	2257	9993	8373	9454	8000F
DEV.PED M E	35196	41757	42790	44491	4349	5930	5057	5885	155622	247620	216410	261810
N AMERICA	24238	30192	30513	31257	5163	6844	5710	6863	125137	206638	174221	214528
W EUROPE	6168	6488	6200	6153	3818	4991	5012	5253	23552	32378	31075	32319
OCEANIA	86	72	73	77	2951	4814	4185	3851	255	348	307	295
OTH DEV.PED	5303	5005	6005	7004	1269	1450	1800	2094	6728	8256	10807	14668
DEV.PING M E	53162	54723	56850	59259	1279	1376	1464	1622	68016	75291	83230	96148
AFRICA	12586	14167	14511	14803	1003	907	903	1044	12618	12850	13107	15459
LAT AMERICA	25857	24034	25311	27521	1426	1650	1795	2028	36883	39648	45436	55816
NEAR EAST	1824	2034	2050	1991	2328	2633	2723	2486	4246	5354	5580	4948
FAR EAST	12892	14484	14974	14934	1106	1203	1275	1334	14263	17430	19099	19916
OTH DV.PING	3	5	5	5	1790	1612	1710	1737	6	8	8	9
CENTR PLANND	25527	29316	29124	30274	2325	3256	3242	3097	59343	95447	94416	93746
ASIAN CPE	16600	20983	20763	21362	2064	2985	3074	3017	34261	62644	63823	64439
E EUR+USSR	8927	8333	8364	8912	2809	3916	3659	3289	25076	32803	30592	29307
DEV.PED ALL	44723	50090	51154	53403	4041	5598	4829	5451	180748	280423	247003	291117
DEV.PING ALL	69761	75706	77610	80621	1466	1822	1895	1992	102284	137936	147053	160586

* Unofficial figures

F: Estimates by FAO

Source: FAO, Production Yearbook, 1981

Table B-4 Potato Production of the World

	AREA HARV			1000 HA	YIELD			KG/HA	PRODUCTION			1000 MT
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
WORLD	20014	18515	17978	17861	13855	15571	12800	14387	277286	288294	230122	256978
AFRICA	367	568	582	585	7976	8591	8870	8764	2931	4881	5161	5127
ALGERIA	43	77	76	80F	5906	6493	7770	7771	253	501	591	616F
ANGOLA	5	6F	6F	6F	6296	7273	7273	7273	34	40F	40F	40F
BURUNDI	14	11	12F	12F	5435	1774	1833	1833	77	19	22F	22F
CAMEROON	20	25F	25F	25F	2672	968	2000	2400	54	24	50F	60F
CAPE VERDE					10250	16667	16667	16667	1	2F	2F	2F
CENT AFR REP					1968	2000	2048	2091				
CHAD	3	3F	3F	3F	4747	5200	5200	5200	12	13F	13F	13F
CONGO					7083	4815	5667	6000	2	1F	2*	2F
EGYPT	30	60	70*	63*	16570	17061	17279	17886	496	1019	1214*	1120*
ETHIOPIA	30	38F	39F	39F	5303	6184	6182	6154	161	235F	238F	240F
IVORY COAST		1F	1F	2F		10000	10714	11111		10F	15F	20F
KENYA	29	48F	48F	48F	7145	7500	7292	7604	206	360F	350F	365F
LIBYA	2	16F	17F	17F	6450	5647	6050	6053	15	90	103	103F
MADAGASCAR	16	30	29	40F	6428	6070	5462	6441	106	183	159	258*
MALAWI	25	30F	32F	34F	3387	3667	3594	3493	85	110F	115F	117F
MAURITANIA					20670	16000	16000	16000	2	4F	4F	4F
MAURITIUS		1	1	1F	15027	15539	16564	16216	7	8	12	12F
MOROCCO	28	40*	38*	28*	10119	14200	14300	14000	283	568*	543*	396*
MOZAMBIQUE	6	5	6F	6F	6917	10853	10909	10333	40	57	60F	62F
NIGER						15000	13333	13333				
NIGERIA	2	3F	3F	3F	12514	14000	14000	14000	25	35F	35F	35F
REUNION					11121	20000	19048	19048	1	4F	4F	4F
RWANDA	19	31F	32F	33F	7153	6859	6891	6921	134	213F	221F	228F
SENEGAL	1	1F	1F	1F	6543	5854	5714	5581	4	5F	5F	5F
SOUTH AFRICA	44	50F	50F	50F	13374	13920	13720	14000	583	696	686	700F
SUDAN	1	1F	1F	1F	17446	19231	19231	19231	25	25F	25F	25F
SWAZILAND	2	3F	3F	3F	2960	2000	2000	2000	5	6F	6F	6F
TANZANIA	13	25F	25F	25F	3873	5600	5600	5600	50	140F	140F	140F
TUNISIA	9	10	11	11F	7656	12500	11215	11367	69	125	120	124F
UGANDA	17	45F	45F	47F	8800	7333	7333	7447	147	330F	330F	350F
ZAIRE	5	6F	6*	6F	5377	4921	4921	4906	29	31F	31*	31F
ZAMBIA					8823	8667	9000	9000	3	3F	3F	3F
ZIMBABWE	2	2F	2F	2F	11167	10000	10000	10000	22	22*	23F	23F
N C AMERICA	762	717	675	705	22954	26996	25918	26851	17482	19354	17501	18938
BERMUDA					15565	13446	6397	6410	1	1		1F
CANADA	121	113	107	108	19113	24400	23417	23624	2312	2760	2509	2555
COSTA RICA	3	3F	3F	3	9557	10299	10024	9333	27	27	27	28
CUBA	9	11	13	13F	9359	18301	18828	18850	83	201	239	239F
DOMINICA					4764	5548	5500	5688	1	1F	1F	1F
DOMINICAN RP	2	1F	1F	2F	12703	10886	11385	12857	23	11	15	27*
EL SALVADOR					7367	14140	19954	19677	3	4	6	6F
GUADELOUPE					7000							
GUATEMALA	7	14F	8*	9F	4209	3614	4750	4353	28	51	38*	37F
HAITI		1F	1F	1F	15217	15000	15000	15000	7	9F	9F	9F
HONDURAS	1	1F	1F	1F	6808	5412	5618	5667	4	5F	5F	5F
JAMAICA	1	1F	1F	1F	9826	9443	9131	8889	10	11	7	12F
MEXICO	46	56	71*	67	10631	12982	12500	12945	489	727	892*	868
MONTSERRAT					2500	2500	2529	2553				
NICARAGUA					4000	4250	4250	4250	1	2F	2F	2F
PANAMA	1	2*	2*	2F	10057	6667	8000	8667	9	10*	12*	13F
ST KITTS ETC					7133	8667	8333	8333				
USA	571	514	467	498	25386	30220	29405	30368	14483	15535	13737	15135
SOUTH AMERIC	1037	980	906	947	8392	9829	9940	11116	8706	9633	9001	10531
ARGENTINA	190	110	105	117	11617	15470	14874	19255	2212	1694	1568	2247
BOLIVIA	95	130	131	150F	6968	5616	6009	6333	660	730	787	950*
BRAZIL	214	204	181	171	7260	10554	10745	11175	1557	2154	1948	1911
CHILE	76	81	89	90	9312	9520	10175	11202	707	770	903	1007
COLOMBIA	84	148	142	160	10407	13284	12160	13169	871	1966	1727	2100
ECUADOR	47	27	30	31*	11818	9463	10639	11271	560	255	323	349*
PARAGUAY	1	1	1	1F	5451	8828	8900	9000	6	9	9	9F
PERU	293	242	194	189	6413	7005	7106	8596	1877	1695	1380	1627*
URUGUAY	22	21	13	20*	6040	6493	8662	6500	135	135	110	130*
VENEZUELA	15	17	19	19*	8258	13366	13000	10526	121	225	247	200*
ASIA	2603	3308	3150	3227	10241	11619	11674	11755	26657	38441	36778	37929
AFGHANISTAN	16	21F	21F	21F	10510	12619	12619	12789	172	265	265F	272F
BAHRAIN						25000	25000	25000				
BANGLADESH	85	97	96	102	9863	9406	9506	9781	842	909	917	999
BHUTAN	1	2F	2F	2F	6604	6667	6667	6750	8	13*	13F	14F
BURMA	9	11	12	14	4576	4851	4703	4702	40	54	57F	65F
CHINA	1336F	1556F	1504F	1505F	9254	9986	9996	9996	12362F	15536F	15036F	15039F
CYPRUS	10	8*	9*	9*	18641	23256	23043	24888	183	190*	208*	216*
EAST TIMOR					9519				1			
GAZA STRIP						15000	16667	16667		5	5F	5F
INDIA	501	807	685	732	8950	12555	12152	13113	4482	10133	8327	9599
INDONESIA	16	22	23F	25F	6111	9456	9395	9368	99	204	219F	234F
IRAN	46	81F	81F	81F	9072	8494	8519	8702	417	688F	690F	705F
IRAQ	1	7F	7F	7F	14256	15000	15000	14568	16	105F	105F	108F
ISRAEL	5	6	5	6	25869	35533	36170	35455	131	211	175	195
JAPAN	164	125	123	126*	21258	27031	27723	25896	3490	3381	3421	3250*
JORDAN			1	1F	5717	14877	17293	17297	1	7	13	13F
KOREA DPR	90	120F	125F	130F	10627	12500	12400	12308	960	1500F	1550F	1600F
KOREA REP	54	34	37	41	11100	10577	11931	13512	598	356	446	554
KUWAIT						15000	15000	15000				
LAO	3	4F	4F	4F	6667	7750	7907	7955	17	31F	34F	35F
LEBANON	9	7F	7	7F	10694	16471	20714	20431	96	112*	145	147F

Table B-4 (cont'd.)

	AREA HARV			1000 HA	YIELD			KG/HA	PRODUCTION			1000 MT
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
MONGOLIA	3	7	7	8F	6056	9918	5270	7143	18	72	39	55F
NEPAL	49	50F	51F	49F	5425	5576	5459	5616	265	279	278	275
PAKISTAN	19	38	43	38	10955	10408	10430	10353	213	392	449	396
PHILIPPINES	3	4	4	4F	7006	7234	8911	7500	22	29	37	30F
QATAR					9000	10000	10000	10000				
SAUDI ARABIA					8527	11750	11750	11750	1	5F	5F	5F
SRI LANKA	3	4	5	5F	9545	9244	11268	11111	30	38	51	50F
SYRIA	5	14	19	18	11402	16406	15503	15232	62	235	292	272
THAILAND	1	1F	1F	1F	7650	11404	11404	11290	9	7F	7F	7F
TURKEY	160	169	183	180*	12377	16982	16393	16111	1984	2870	3000	2900
U A EMIRATES						74844	15031	14286		3	1	1F
VIET NAM	7	103	82	100F	15449	6673	10485	7500	103	684	862	750F
YEMEN AR	5	11*	11*	12*	7242	11981	12018	12000	35	127*	131*	138*
YEMEN DEM					4752	4064	4000	4000	1	1F	1F	1F
EUROPE	7172	5928	5684	5500	17665	20911	16453	20232	126701	123963	93515	111270
ALBANIA	19	18F	18F	18F	5747	7697	7667	7735	109	137F	138F	140F
AUSTRIA	109	58	53	50	25506	25732	24043	26386	2787	1494	1264	1310
BELGIUM-LUX	46	38	39	43*	35363	38848	36924	33176	1631	1460	1450	1426*
BULGARIA	30	39	35	36	12781	10876	8598	11145	378	424	301	407
CZECHOSLOVAK	331	213	195	195F	14683	17508	13804	17930	4864	3725	2695	3500
DENMARK	34	32	34	37	24788	26618	25034	24595	845	844	842	910
FAEROE IS					14611	13684	13684	13684	1	1F	1F	1F
FINLAND	56	43	41	37	16171	15787	18000	12949	906	674	736	478
FRANCE	376	275	230	215	22783	25955	28773	30140	8569	7148	6618	6480
GERMAN DR	643	549	513	513F	16225	22293	17959	20464	10432	12243	9214	10500*
GERMANY FR	580	325	307	277	27250	31419	25928	29000	15804	10205	7970	8045
GREECE	55	63	65	53	12727	15365	15846	18097	700	968	1030	953
HUNGARY	169	105	93	100F	11097	14427	14998	16000	1874	1512	1392	1600F
ICELAND	1	1F	1F	1F	8060	7611	15341	9884	7	6	15	9F
IRELAND	55	41	40	34*	26581	28138	27827	32353	1450	1141	1125*	1100*
ITALY	277	169	161	145	13133	17875	18600	19728	3632	3020	2994	2863
LIECHTENSTEN	1	1F	1F	1F	18466	18772	18793	18644	9	11F	11F	11F
MALTA	3	2	2F	2F	7553	9164	9167	9250	20	22	22F	22F
NETHERLANDS	153	166	172	165	35169	37772	36413	39071	5367	6277	6267	6445
NORWAY	32	20	21	22*	24919	20300	24976	24091	807	406	527*	530*
POLAND	2707	2441	2344	2258	16630	20311	11260	18869	45013	49572	26391	42600
PORTUGAL	117	117	118*	115F	10446	9473	9788	8139	1222	1110	1155	936
ROMANIA	310	294	286	286F	8627	15536	14435	15712	2671	4562	4135	4500F
SPAIN	389	355	356	337	12011	15879	16139	16531	4985	5637	5737	5571
SWEDEN	52	42	41	43	23511	30738	26604	29939	1221	1284	1084	1278
SWITZERLAND	31	24	25	25	32951	36300	34601	42602	1016	871	853	1048
UK	270	204	206	192	27223	31867	34476	31862	7359	6485	7109	6108
YUGOSLAVIA	328	296	287	300*	9198	9203	8502	8333	3020	2724	2440	2500*
OCEANIA	52	43	45	43	20392	24707	25252	27319	1069	1066	1143	1182
AUSTRALIA	43	35	37	35	18384	22937	23387	25842	782	795	857	896
FIJI					5569	5926	5926	5926	1	2F	2F	2F
FR POLYNESIA					10000	10000	10000	9714	1	4F	4F	3F
NEWCALEDONIA					7683	4143	8571	8571	1	1	3	3F
NEW ZEALAND	9	8	8	8F	30022	35235	36402	36526	284	264*	278*	278F
PAPUA N GUIN					6600	4167	4167	4167				
USSR	8019	6970	6936	6854	11689	13050	9663	10505	93739	90956	67023	72000
DEV.PED M E	3921	3121	2996	2922	21278	24172	23667	24306	83425	75431	70913	71032
N AMERICA	692	627	574	607	24289	29170	26288	29166	16796	18296	16247	17690
W EUROPE	2964	2270	2200	2093	20699	22812	22391	22949	61360	51788	49250	48023
OCEANIA	52	42	44	42	20498	25126	25628	27763	1066	1059	1135	1174
OTH DEV.PED	213	181	178	181	19754	23689	24023	22901	4204	4289	4282	4145
DEV.PING M E	2430	2981	2843	2936	8782	10716	10705	11328	21337	31940	30433	33255
AFRICA	290	441	443	454	6245	6916	7068	7002	1813	3051	3133	3180
LAT AMERICA	1108	1070	1006	1046	8480	9994	10189	11260	9392	10691	10255	11779
NEAR EAST	287	396	428	418	12211	14498	14489	14441	3502	5746	6203	6031
FAR EAST	745	1072	964	1017	8898	11604	11239	12055	6626	12444	10834	12257
OTH DV.PING		1	1	1	8413	7084	8159	8066	4	7	9	9
CENTR PLANND	13663	12413	12139	12003	12627	14575	10608	12721	172523	180924	128775	152691
ASIAN CPE	1436	1786	1719	1742	9362	9964	10174	10013	13443	17792	17487	17444
E EUR+USSR	12227	10628	10420	10261	13010	15349	10680	13181	159080	163131	111288	135247
DEV.PED ALL	16148	13748	13417	13183	15018	17352	13580	15647	242506	238562	182702	206279
DEV.PING ALL	3866	4766	4562	4678	8997	10434	10505	10838	34780	49732	47920	50699

* Unofficial figures

F: Estimates by FAO

Source: FAO, Production Yearbook, 1981

Table B-5 Cassava production of the World

	AREA HARV			1000 HA	YIELD			KG/HA	PRODUCTION			1000 MT
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
WORLD	10889	13680	13777	14054	8880	8601	8674	9055	96695	117651	119506	127261
AFRICA	5794	7179	7334	7433	6617	6266	6346	6433	38339	44979	46539	47816
ANGOLA	121	130F	130F	130F	13196	13846	14231	14615	1597	1800F	1850F	1900F
BENIN	88	113	125F	125F	6084	6492	7768	7800	533	735	971*	975F
BURUNDI	80	77F	77F	77F	10542	14935	15584	15584	843	1150F	1200F	1200F
CAMEROON	161	230F	233F	236F	3965	4348	4292	4283	637	1000*	1000F	1011F
CAPE VERDE					11301	24000	24000	24000	2	6F	6F	6F
CENT AFR REP	262	320F	327F	334F	2930	3031	2999	3061	767	970F	980F	1021F
CHAD	44	50F	50F	51F	3162	3600	3700	3723	140	180F	185F	188F
COMOROS	23	28F	28F	29F	3088	3080	3071	3084	70	85F	86F	88F
CONGO	99	80F	80F	80F	4660	6575	6500	6625	461	526F	520*	530F
EQ GUINEA	16	22F	22F	23F	2745	2364	2353	2310	43	52F	53F	54F
GABON	44	40F	41F	42F	3504	2625	2439	2381	155	105F	100F	100F
GAMBIA	2	2F	2F	2F	3820	3500	3500	3500	8	7F	7F	7F
GHANA	207	219	230F	230F	7419	8032	7826	8043	1533	1759	1800F	1850F
GUINEA	70	68	78F	85F	6848	6998	7051	7059	482	475	550F	600F
IVORY COAST	166	212	219	220F	3300	3443	3425	3545	546	730F	750F	780F
KENYA	64	80F	81F	81F	7969	7875	7888	7901	510	630F	635F	640F
LIBERIA	79	82F	85F	87F	3356	3659	3529	3621	264	300*	300F	315F
MADAGASCAR	188	267	278	297*	6514	5885	6096	5873	1227	1570	1692	1745*
MALAWI	15	13F	15F	15F	5921	6154	6000	6000	90	80F	90F	90F
MALI	5	7F	7F	7F	7213	8523	8585	8646	36	55F	56F	56F
MAURITIUS					16467	20222	17200	16667				
MOZAMBIQUE	450	602	600F	600F	5669	4485	4667	4750	2549	2700F	2800F	2850F
NIGER	25	28	28F	28F	7155	8005	8036	7923	182	224	225F	225F
NIGERIA	894	1150F	1200F	1200F	10592	9130	9167	9167	9473	10500F	11000F	11000F
REUNION					6333	10000	10000	10000	3	4F	4F	4F
RWANDA	29	43F	44F	45F	11358	10490	10754	11007	333	450F	472F	494F
SAO TOME PRN					10515	11111	11111	11111	2	3F	3F	3F
SENEGAL	36	8	8F	7F	4365	3166	3500	3571	159	25	28F	25F
SEYCHELLES					6062	5000	5000	5000				
SIERRA LEONE	16	18F	22F	22F	4676	4722	4318	4316	75	85F	95F	95F
SOMALIA	2	3F	3F	3F	10573	11071	11034	11000	25	31F	32F	33F
SUDAN	39	50	45	45F	3402	2541	2689	2687	133	127	122	122F
TANZANIA	695	930F	940F	950F	4854	4892	4894	4895	3373	4550F	4600F	4650F
TOGO	31	28F	28F	28F	17926	15821	16071	16786	562	443	450F	470F
UGANDA	277	400F	410F	420F	3825	3375	3415	3381	1058	1350F	1400F	1420F
UPPER VOLTA	5	6F	6F	6F	6000	6774	6774	6774	30	42F	42F	42F
ZAIRE	1493	1800F	1818*	1853F	6851	6667	6711	7017	10232	12000*	12200*	13000F
ZAMBIA	52	55F	55F	57F	3084	3182	3182	3123	159	175F	175F	178F
ZIMBABWE	15	18F	19F	18F	3033	3000	3243	2778	46	54*	60F	50F
N C AMERICA	125	147	148	157	6284	5995	5855	6091	783	880	865	954
ANTIGUA					3625	2353	2353	2353				
BARBADOS					26355	25000	25128	25000	1	1F	1F	1F
CAYMAN IS					3600	4500	4500	4500				
COSTA RICA	3	2F	3F	3F	3782	6600	6696	6667	12	15	18	18F
CUBA	33	46F	47F	48F	6566	6957	6915	6899	217	320*	325*	328F
DOMINICA					9958	10000	10000	10000	1	1F	1F	1F
DOMINICAN RP	15	11F	11F	18F	11490	10845	10482	10000	173	119	115	180*
EL SALVADOR	1	2	2	2	9102	11829	11843	11840	12	20	20	25
GRENADA					4969	5367	4571	4000				
GUADELOUPE					11250	8000	9000	9000	5	1	1	1F
GUATEMALA	2	3F	3F	3F	3000	2600	2567	2567	6	8F	8F	8
HAITI	51	63	63F	63F	4020	4038	3968	4048	205	254	250F	255F
HONDURAS	4	3	2	2F	6984	2871	3281	3273	28	9	7	7F
JAMAICA	2	2F	2F	2F	8241	10892	9326	10833	16	24	20	26F
MARTINIQUE					14057	2700	5000	5000	3		1	1
MEXICO	2	2	2	2F	20000	13390	9961	10000	43	33	20	22F
NICARAGUA	4	6F	7F	7F	4111	4000	4000	4077	17	24F	26F	27F
PANAMA	4	5F	5F	5F	8547	8473	8333	8212	32	40	40F	43F
PUERTO RICO	1				3474	8228	8252	7678	4	4	3	3F
SAINT LUCIA					4007	3462	3500	3500	1	1F	1F	1F
ST VINCENT					13516	12000	12000	12000	3	3F	3F	3F
TRINIDAD TOB					8966	12500	12500	12500	3	5*	5F	5F
SOUTH AMERIC	2483	2591	2489	2577	13873	11613	11663	11905	34444	30089	29034	30677
ARGENTINA	26	21	23	23F	11555	8551	9639	10000	296	183	222	230F
BOLIVIA	18	16	18	19F	12671	12737	12150	12432	223	201	219	230F
BRAZIL	2042	2111	2006	2093	14655	11825	11669	11968	29922	24962	23411	25050
COLOMBIA	185	222	208	207	7476	8610	10353	10386	1380	1909	2150	2150
ECUADOR	35	20	25	26*	10753	9115	9109	9100	382	183	229	236*
FR GUIANA	1	1	1F	1F	7564	10000	10000	9877	5	8	8F	8F
PARAGUAY	100	126	136	135F	14365	14936	14967	14815	1442	1888	2031	2000F
PERU	37	35	35*	36*	12716	11487	11429	11389	477	403	400*	410*
SURINAME					6846	6995	6897	7073	2	3	3F	3F
VENEZUELA	39	38	37	37F	8080	9117	9663	9730	317	350	361	360F
ASIA	2470	3743	3786	3866	9289	11083	11316	12307	22943	41484	42843	47584
BRUNEI					7107	8571	7778	7838	2	3	3F	3F
BURMA	1	3	3	5	10378	9146	8997	9283	10	23	28F	48
CHINA	161F	215F	243F	251F	12062	12693	13107	13061	1938F	2726F	3185F	3276F
EAST TIMOR	7				2816				20			
INDIA	352	362	352	346	14176	16736	16611	16803	4993	6050	5845	5817
INDONESIA	1424	1434	1414	1412	7512	9587	9571	9718	10695	13751	13532	13726
KAMPUCHEA DM	2	22F	25*	25F	10244	6500	6000	5800	24	143F	150F	145F
LAO	1	4F	5F	5F	13636	15000	15111	15217	15	60F	68F	70F
MALAYSIA	30	40F	35F	35F	9096	10000	10000	10286	271	400F	350F	360F
PHILIPPINES	82	192	204	200F	5297	11692	11145	11500	436	2269	2276	2300F
SINGAPORE					10744	10370	10000	10000	4	1F	1F	1F

Table B-5 (cont'd.)

	AREA HARV			1000 HA	YIELD			KG/HA	PRODUCTION			1000 MT
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
SRI LANKA	65	54	51	62F	5755	9974	9788	8703	376	535	499	537F
THAILAND	211	950F	1015*	1050*	15205	12737	13414	17048	3208	12100F	13615F	17900*
VIET NAM	133	468	439	475F	7153	7367	7496	7158	950	3444	3290	3400F
OCEANIA	17	20	20	21	10972	10894	11035	11124	187	219	225	229
AMER SAMOA					26800	14167	13462	12857	4	4F	4F	4F
COOK ISLANDS					27445	32258	32258	32258	85	93F	94F	95F
FIJI	7	8F	8F	8F	12305	12000	12000	12141	6	7F	7F	7F
FR POLYNESIA					17877	18611	18630	18356	4	3F	3F	3F
NEWCALEDONIA					22699	26000	28000	30000				
NIUE					5200	3846	3846	3846	6	9F	9F	10F
PACIFIC IS	1	1F	1F	1F	9032	9000	9300	9600	72	92F	94F	96F
PAPUA N GUIN	7	9F	9F	9F	10188	10698	10682	10667				
SAMOA					18750	10667	10667	10667	10	11F	13*	14F
TONGA	2	2F	2F	2F	5742	5238	6413	6667				
DEV.PING M E	10593	12975	13070	13303	8853	8581	8636	9054	93784	111339	112881	120441
AFRICA	5755	7129	7288	7388	6639	6292	6369	6456	38206	44852	46417	47696
LAT AMERICA	2607	2738	2637	2733	13510	11312	11338	11572	35227	30970	29900	31631
NEAR EAST	39	50	45	45	3402	2541	2689	2687	133	127	122	122
FAR EAST	2174	3039	3079	3116	9213	11574	11762	13083	20031	35172	36218	40763
OTH DV.PING	17	20	20	21	10972	10894	11035	11124	187	219	225	229
CENTR PLANND	296	704	707	751	9844	8964	9372	9085	2912	6313	6625	6821
ASIAN CPE	296	704	707	751	9844	8964	9372	9085	2912	6313	6625	6821
DEV.PING ALL	10889	13680	13777	14054	8880	8601	8674	9055	96695	117651	119506	127261

* Unofficial figures

F: Estimates by FAO

Source: FAO, Production Yearbook, 1981

Table B-6 Sweet Potato Production of the World

	AREA HARV			1000 HA	YIELD			KG/HA	PRODUCTION			1000 MT
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
WORLD	12268	12202	12026	11771	11586	12153	12061	12384	142140	148293	145045	145765
AFRICA	677	775	785	794	5917	6444	6455	6487	4004	4993	5065	5151
ANGOLA	18	19F	19F	19F	8339	9474	9474	9474	147	180F	180F	180F
BENIN	17	4	4F	4F	3878	3390	3500	3500	66	14	14F	14F
BURUNDI	101	92F	93F	93F	8231	9457	9892	9982	831	870F	920F	928F
CAMEROON	42	38F	38F	39F	3212	3421	3421	3512	134	130*	130F	135F
CAPE VERDE	1	1F	1F	1F	1864	5000	5000	5000	3	5F	5F	5F
CHAD	5	6F	6F	7F	5135	5645	5625	5615	25	35F	36F	37F
COMOROS	1	2F	2F	2F	10159	8222	8389	8158	11	15F	15F	16F
CONGO	4	4F	4F	4F	6000	6099	6098	6220	24	25F	25F	26F
EGYPT	4	4	3*	3F	21309	23662	21726	21471	87	104	73*	73F
EQ GUINEA	7	11F	11F	12F	3727	3000	3009	2957	27	33F	34F	34F
GABON	2	1F	1F	1F	1500	1200	1300	1400	3	1F	1F	1F
GUINEA	10	10	10F	10F	8200	7500	7400	7500	82	73	74F	75F
IVORY COAST	11	16F	16F	16F	1927	1806	1875	1875	21	28F	30F	30F
KENYA	30	38F	38F	39F	7753	8947	8684	8846	230	340F	330F	345F
LIBERIA	1	2F	2F	2F	10002	10200	10267	10333	12	15F	15F	16F
MADAGASCAR	59	78	80F	80F	5864	5242	5125	5125	348	407	410F	410F
MALI	3	4F	4F	4F	12625	11707	11667	11628	35	48F	49F	50F
MAURITANIA	3	5F	5F	6F	629	400	377	357	2	2F	2F	2F
MAURITIUS					12667	13125	17000	10000				
MOZAMBIQUE	8	9F	9F	9F	4813	5294	5294	5294	40	45F	45F	45F
NIGER	1	5	5F	5F	6729	5932	5957	6064	9	28	28F	29F
NIGERIA	15	18F	19F	19F	9087	12778	12973	12973	139	230F	240F	240F
REUNION					18000	21923	22692	23462	5	6F	6F	6F
RWANDA	65	111F	116F	120F	5788	7874	7838	7805	379	874F	906F	938F
SENEGAL	3	1	2F	2F	4186	4736	4667	4688	11	7	7F	8F
SIERRA LEONE	7	5*	6F	6F	2856	2037	2105	2083	20	11*	12F	13F
SOMALIA					10000	10000	10000	10000	3	3F	3F	4F
SOUTH AFRICA	13	13F	13F	13F	2900	3545	3538	3692	39	46	46	48F
SUDAN	1	2F	2F	2F	26496	24118	24706	24000	21	41F	42F	46F
SWAZILAND	2	2F	2F	2F	4013	5882	5882	5882	8	10F	10F	10F
TANZANIA	39	53F	54F	53F	6053	6226	6206	6226	234	330F	332F	330F
TOGO	1	2F	2F	2F	2500	3000	3500	3500	3	6F	7F	7F
UGANDA	133	139F	139F	140F	5200	4820	4820	4857	693	670F	670F	680F
UPPER VOLTA	12	15F	15F	15F	2611	2800	2933	2933	31	42F	44F	44F
ZAIRE	53	63F	63*	64F	4977	4762	4810	4821	264	300F	303*	309F
ZAMBIA	2	3F	3F	3F	7041	7143	7143	7143	17	20F	20F	20F
N C AMERICA	200	208	204	211	6930	6528	6061	6369	1387	1356	1237	1347
ANTIGUA					4032	4000	4000	4000				
BAHAMAS					3247	3951	4024	4146				
BARBADOS	1		1F	1F	9620	6857	8278	8000	6	2	4	4F
BERMUDA					5538	6739	6600	6600				
CAYMAN IS					5000	5500	5500	5500				
CUBA	63	80F	80F	80F	3803	3950	4063	4070	238	316*	325*	327F
DOMINICA					10000	10000	10000	10000	1	1F	1F	1F
DOMINICAN RP	10	8	10F	13F	8850	7806	6810	6800	87	59	68	85*
EL SALVADOR					5058	5000	5000	5000				
GRENADA					5441	5456	4000	2659	1			
GUADELOUPE	1	1	1	1F	10000	9400	9700	10200	6	5	5	5F
HAITI	53	63	63F	64F	5283	4235	4127	4219	280	265	260F	270F
HONDURAS					2632	3548	3750	3750	1	1F	1F	1F
JAMAICA	2	2F	2F	2F	7903	11757	11662	12500	16	21	21	25F
MARTINIQUE	1	1F	1F	1	9995	9920	11000	10000	6	5	6F	5
MEXICO	14	4	2	2F	9843	13811	14313	14130	142	58	33	33F
MONTSERRAT					2333	2500	2500	2500				
PUERTO RICO	3	2F	2	2F	3496	4255	4358	4362	10	9	9	10
ST KITTS ETC					2886	5000	5000	5000				
SAINT LUCIA					2368	5385	3370	5357	1	1F	1F	2F
ST VINCENT	1	1F	1F	1F	3560	2044	2063	2133	4	1	2	2F
TRINIDAD TOB					3366	10370	10345	10345	2	3*	3F	3F
USA	51	46	41	44	11538	13121	12012	12944	586	606	497	573
SOUTH AMERIC	271	175	174	166	11117	8517	8365	8468	3008	1488	1455	1404
ARGENTINA	44	34	34	24	10410	9527	8988	10107	457	322	302	247
BOLIVIA	2	3	3	3F	7471	4888	5362	5000	12	14	15	15F
BRAZIL	183	92	90F	90F	11775	8948	8889	8889	2155	819	800F	800F
CHILE	1	1*	1*	1F	14000	7000	7000	7000	14	7*	7*	7F
ECUADOR	3	1	1	1F	3574	5004	4398	4615	10	4	3	3F
FR GUIANA					6570	5667	6000	5806	1	2	2F	2F
PARAGUAY	10	14	14	15F	10710	7541	7785	7667	110	106	112	115F
PERU	13	14	15*	15F	12502	10639	10000	9941	167	149	150*	151F
SURINAME					4679	5444	5238	5000				
URUGUAY	13	15*	15*	15*	5975	4000	4000	4000	78	60*	60*	60*
VENEZUELA	2	1F	1F	1F	2495	3573	3525	3583	4	4	4F	4F
ASIA	11012	10919	10738	10472	12088	12797	12716	13093	133113	139726	136543	137108
BAHRAIN					20000	10000	6667	6667				
BANGLADESH	72	73	72	73F	11557	10905	10936	10890	830	795	791	795F
BRUNEI					6490	14286	8571	8219		1	1F	1F
BURMA	3	4F	4F	4F	4951	4103	4154	4100	15	16F	16F	16F
CHINA	9636F	9474F	9262F	9050F	12507	13508	13526	13887	120511F	127975F	125280F	125680F
EAST TIMOR	3				5933				15			
HONG KONG					10510	24353	27867	24000	4			
INDIA	225	220	207	207F	10052	7381	6518	7246	2260	1623	1349	1500F
INDONESIA	361	287	287	276	6131	7649	7655	7530	2215	2194	2193	2079
ISRAEL					20455	40000	40000	40000		1F	1F	1F
JAPAN	134	64	65	65F	19356	21283	20324	20324	2590	1360	1317	1317F
KAMPUCHEA DM	2	2F	2F	2F	8731	7368	8333	7778	21	14F	15F	14F

Table B-6 (cont'd.)

	AREA HARV			1000 HA	YIELD			KG/HA	PRODUCTION			1000 MT
	1969-71	1979	1980	1981	1969-71	1979	1980	1981	1969-71	1979	1980	1981
KOREA DPR	21	27F	28F	29F	13226	13704	13393	13172	273	370F	375F	382F
KOREA REP	125	61	55	50	16489	22651	20049	22160	2053	1387	1103	1108
LAO	2	3F	3F	3F	8333	9615	9655	9667	15	25F	28F	29F
MALAYSIA	7	4F	4F	4F	4567	9474	9474	9610	30	36F	36F	37F
MALDIVES					6000	2500	2500	2500				
PAKISTAN	16	18F	18F	19F	8660	8901	8859	8865	141	162F	163F	164F
PHILIPPINES	134	238	236	235F	5069	4706	4444	4681	680	1120	1040	1100F
SINGAPORE					9380	12632	12632	12632	4	1F	1F	1F
SRI LANKA	17	16	14	17F	3937	9190	8904	8169	65	149	127	136F
THAILAND	32	36F	38F	39F	8660	9254	8995	8992	280	335F	340F	348F
VIET NAM	223	392	443	400F	4977	5522	5324	6000	1108	2162	2358	2400F
EUROPE	14	12	12	13	9807	10810	11234	10379	140	135	138	136
GREECE					12935	18095	18095	18095	2	4F	4F	4F
ITALY	2	1	1	1F	11870	20398	21502	21502	27	21	23	23F
PORTUGAL	9	9F	9F	9F	7782	7635	7941	7765	69	65	68F	66F
SPAIN	4	3	3	3F	11229	16526	17480	13030	42	46	44	43F
OCEANIA	95	113	114	115	5168	5256	5344	5392	489	595	608	620
AMER SAMOA					4500	5000	5250	5500				
AUSTRALIA					5719	10152	11772	11818	1	3	4	4F
COOK ISLANDS					19231	23333	23333	23333	2	1F	1F	1F
FIJI	1	1F	1F	1F	9776	10000	10000	10118	7	8F	8F	9F
FR POLYNESIA					4377	5433	5500	5333	1	2F	2F	2F
GUAM					3667	5882	6111	6000				
NEWCALEDONIA	1	1F	1F	1F	4250	4452	4459	4533	3	3F	3F	3F
NEW ZEALAND		1	2	2F	16453	8596	10667	10867	7	8	16	16F
NIUE					16333	25000	25000	25000				
PACIFIC IS			1F	1F	7237	7143	7200	7255	3	4F	4F	4F
PAPUA N GUIN	82	98F	98F	99F	4237	4449	4490	4543	346	436F	440F	450F
SOLOMON IS	5	5F	5F	5F	9518	9804	9804	9804	46	50F	50F	50F
TONGA	5	6F	6F	7F	13797	12391	12422	12369	73	79F	80F	80F
DEV.PED M E	213	137	133	137	15798	15776	15144	15291	3364	2160	2018	2094
N AMERICA	51	46	41	44	11538	13121	12012	12944	586	606	497	573
W EUROPE	14	12	12	13	9807	10810	11234	10379	140	135	138	136
OCEANIA	1	1	2	2	12618	8937	10863	11038	9	11	20	20
OTH DEV.PED	147	77	78	78	17665	18290	17525	17551	2629	1407	1364	1366
DEV.PING M E	2174	2170	2158	2153	7757	7195	6950	7057	16863	15613	14999	15195
AFRICA	658	756	767	776	5859	6355	6397	6426	3858	4802	4904	4985
LAT AMERICA	420	336	337	333	9070	6655	6520	6541	3809	2238	2194	2178
NEAR EAST	5	6	5	5	22145	23785	22718	22368	107	145	115	119
FAR EAST	997	960	938	926	8637	8170	7673	7899	8609	7844	7197	7314
OTH DV.PING	94	112	112	113	5113	5215	5254	5301	480	584	588	600
CENTR PLANND	9881	9895	9735	9481	12338	13191	13151	13551	121914	130521	128028	128476
ASIAN CPE	9881	9895	9735	9481	12338	13191	13151	13551	121914	130521	128028	128476
DEV.PED ALL	213	137	133	137	15798	15776	15144	15291	3364	2160	2018	2094
DEV.PING ALL	12055	12065	11893	11634	11512	12112	12026	12349	138777	146134	143027	143671

* Unofficial figures

F: Estimates by FAO

Source: FAO, Production Yearbook, 1981

Table B-7 Ethylene Production

(million MT)

	1960	1965	1970	1973	1974	1975	1976	1980	1985
EC	(0.68)	1.87	5.63	9.04	9.75	7.27	9.45		
Scandinavia	0.01	0.05	0.16	0.35	0.42	0.37	0.44	(12.0)	(15.3)
Other European OECD Member Countries	-	-	0.15	0.25	0.30	0.32	0.38		
USA	2.47	4.34	8.39	10.13	10.84	9.30	9.99		
Canada	-	0.27	0.41	0.49	0.43	0.43	0.51	(13.5)	(18.0)
Japan	0.08	0.78	3.10	4.17	4.18	3.55	3.87	(4.7)	(6.1)
Other OECD Member Countries	-	-	-	-	-	-	-	-	-
Subtotal	(3.3)	(7.3)	17.85	24.45	25.93	21.24	24.64	(30.2)	(39.4)
Others	-	-	-	-	-	(1.4)	-	(6.0)	(9.0)
Total	-	-	-	-	-	(22.6)	-	(36.2)	(48.4)

Note: 1) From the report by the Petrochemical Subcommittee of the Industrial Committee of OECD.
2) ( ): estimates

2. Prices of Raw Materials

2.1 Raw Materials for Fermentation Process

As stated before, raw materials generally used for making ethyl alcohol by the fermentation process consist principally of saccharine materials like molasses and sugar cane and the starchy materials like corn, potato, cassava and sweet potato. But the prices at which these materials are made available to the ethyl alcohol breweries are not disclosed for the most part. Moreover, the prices fluctuate widely from region to region and from year to year.

According to the survey of the Economic and Social Commission for Asia and the Pacific undertaken in 1982 with respect to the prices of molasses, sugar cane and cassava, considerable differences were seen in the raw material prices in various parts of the world, as shown in Table B-8.

Table B-8 Cost of Potential Ethyl Alcohol Feedstocks (1982)

(US$/MT)

	Molasses	Sugar Cane	Cassava
Australia	65	24	34 (est.)
India	7	17	27
Indonesia	120		27
Philippines	6,490	19	40
Sri Lanka	100 (est.)	30	
Thailand	76	31	33
Brazil		12	

These raw materials are all farm products or their by-products having a wide range of applications besides being used for ethyl alcohol production. Thus it seems that a big difference in raw material acquisition cost tends to be generated even within the same country depending on the location of each alcohol brewery because of the difference in such factors as:

- Mode of raw material procurement (captively operated farm or not)
- Competition with prices of the same material for other applications
- Agricultural productivity
- Mode of assembling
- National policy, etc.

In working out any concrete plant locating program, as a consequence, detailed investigations into the stable availability and prices of raw material supplies at each particular location would be necessary. Incidentally, changes in the prices of molasses, the most generally used saccharine raw material, between 1948 and 1978 are shown in Fig. B-1. Wide fluctuations are evident in the figure.

2.2 Raw Materials for the Synthesis Process

Ethylene is the raw material used for ethyl alcohol synthesis process. Ethylene, which is the basic raw material for the petrochemical industry, is produced in Japan and Europe largely from naphtha, a fraction of the crude oil. In the United States it is mostly produced from natural gas.

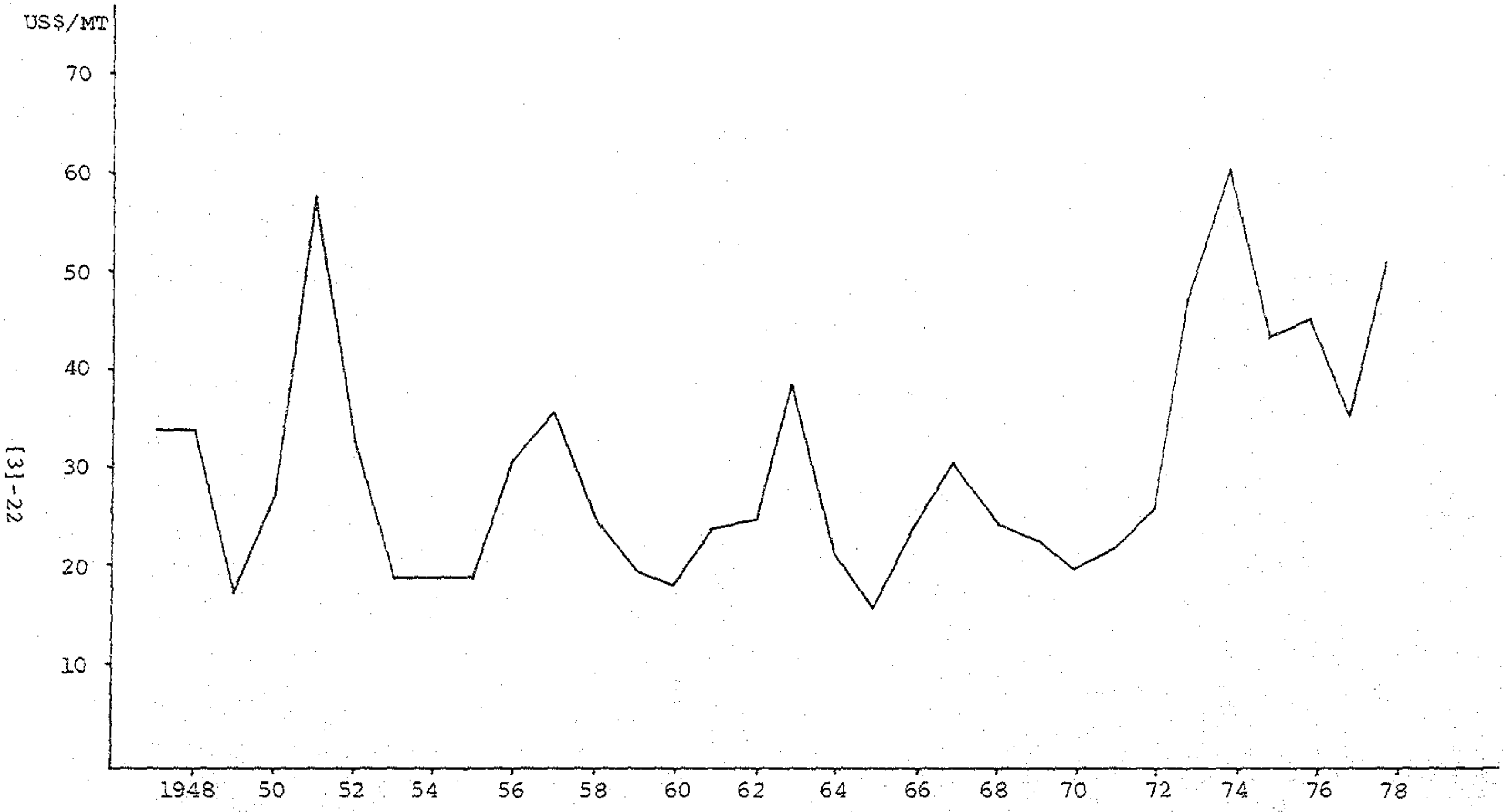
Fig. B-2 presents price fluctuations between 1973 and 1980. It is clear from the figure that the prices of ethylene have sharply been affected by the soaring in the crude oil price. It is also evident that the price of ethylene in the United States where natural gas is used as a raw material for the most part is lower than that in Japan and Europe.

III. Production Technology

1. Principal Production Processes

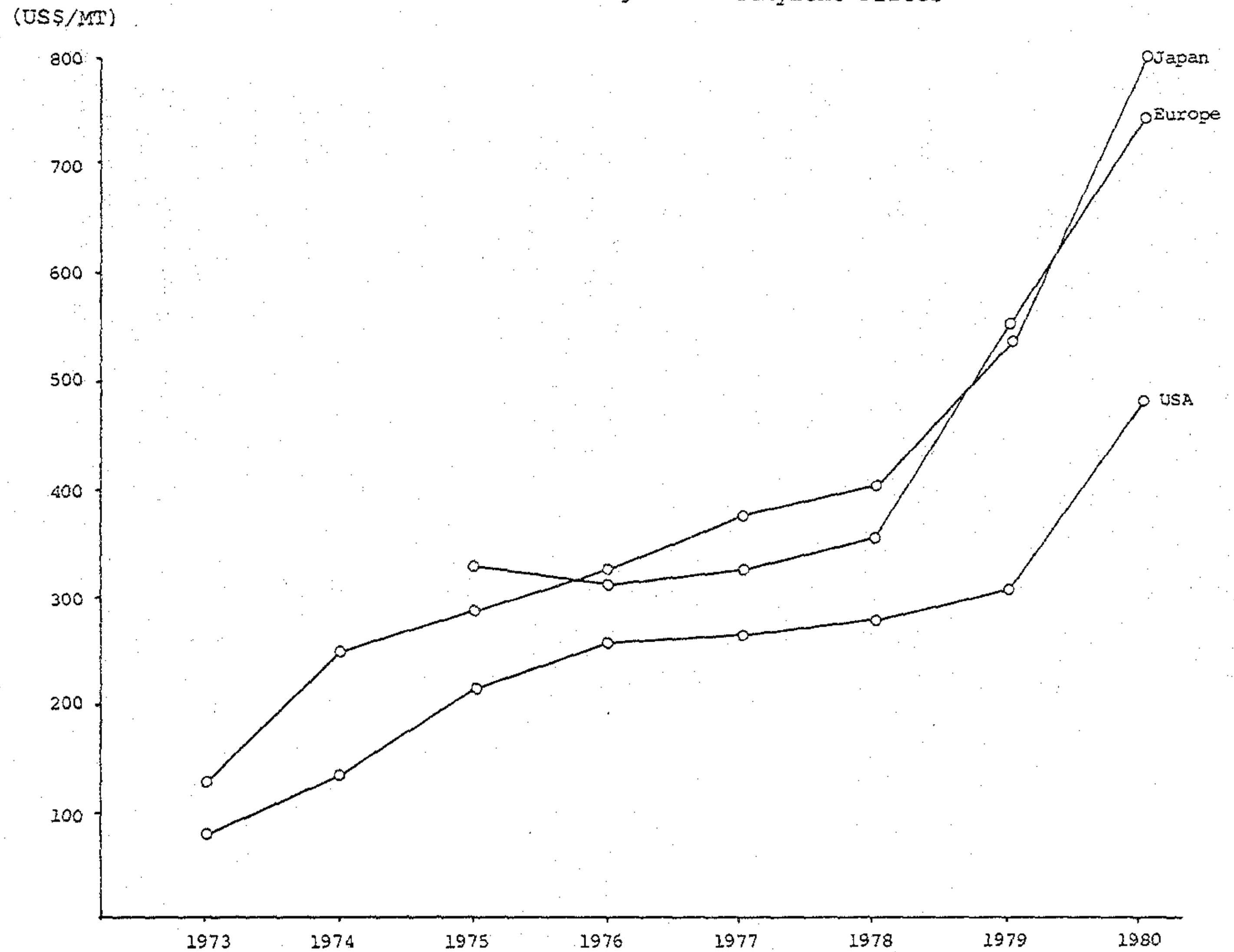
Ethyl alcohol production processes are divided into the fermentation and synthesis methods. The processes by the fermentation method differ when the types of a raw material differ. Also, the production processes by the fermentation method differ somewhat according to the end-uses of ethyl alcohol produced. This means the process for manufacturing industrial ethyl alcohol differs somewhat from that for manufacturing fuel alcohol. And as stated before, the ethyl alcohol purity is about on the same level for every product specifications, standardization of fuel ethyl alcohol specifications has not made much progress yet excepting the items

Fig. B-1 Sugar Cane Molasses Prices



Source: 1947-1969 ; New Orleans Market
1970-1978 ; Cuba-Azucar-Mincex Estimates

Fig. B-2 Ethylene Prices



Source: Japan; Chemistry & Economy, Aug. 1980, Aug. 1981
Europe; Europe Chemical News
USA; Chemical Marcketing Reporter

related to purity and organic acid content. For fuel ethyl alcohol, the general practice is to simplify the distillation process with a view to reduce the manufacturing cost as much as possible. Other processes, however, are followed in much the same way both for industrial and fuel ethyl alcohol manufacture.

While the leading processes will be outlined in the following, this section will be devoted to the generally practiced processes, leaving matters connected with new technologies in particular to subsection III-3 on technological innovations.

1.1 Fermentation Process - Using Molasses as Raw Material

As total sugar content of molasses used as raw material ranges from 50 to 60%, it is diluted with hot water in the pre-treatment unit.

Molasses is also diluted with hot water when it is used for cultivating the yeast. It is then sterilized to become a sterilized mash. To this is added some nutrient like ammonium sulfate, which nourishes the yeast. Then mixing the yeast into the mash, it is cultivated as the seed at about 33°C.

Cultivated yeast is added to the molasses, the raw material, to cause fermention. This fermented raw material is known as the mash, whose total sugar content has been diluted to about 23%. When the temperature is maintained for four days at 31 to 33°C for ripening, about 12.5% ethyl alcohol is formed by the work of the yeast. This is known as the broth.

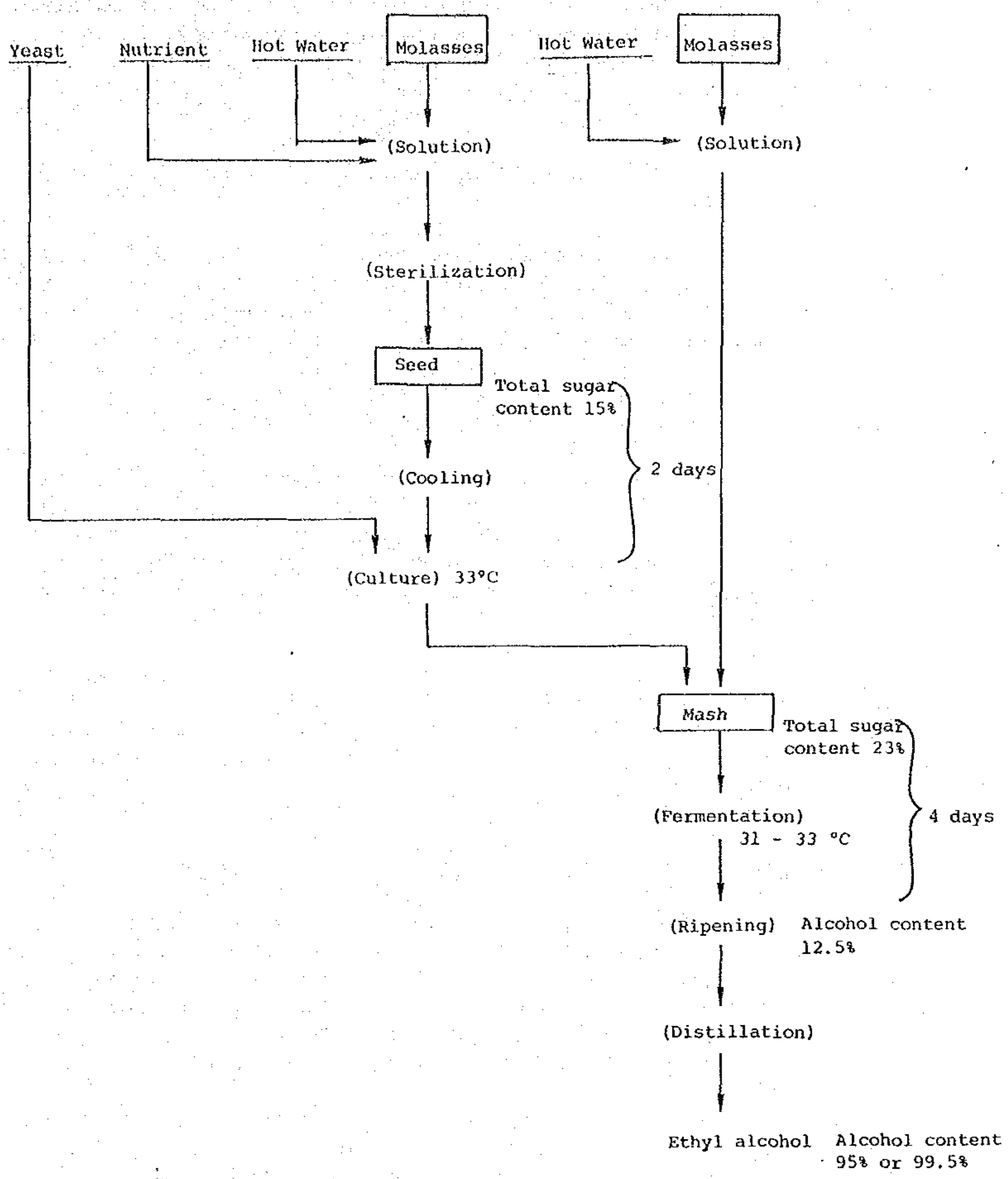
This broth is refined by the distillation process to obtain hydrous alcohol of 95% purity. To obtain anhydrous ethyl alcohol of 99.5% purity, dehydrating distillation process is executed using dehydrating agents like benzene and cyclohexane. Refer to Fig. B-3 for the process flow.

1.2 Fermentation Process - Using Sugar Cane as Raw Material

Sugar cane used as raw material is crashed to obtain juice. Milk of lime is added to the juice during the clarifying process. When it matures, it is divided into clarified juice and sludge.

To this processed clarified juice are added the nutrient and the yeast solution sterilized by means of acid, and the mixture is allowed to go through fermentation for 15 to 18 hours at a temperature of 34 to 37°C. The ethyl alcohol concentration of the fermented mash thus obtained is about 8.5 vol %. This mash is sent to the yeast separator where the yeast is recovered, and after it is treated with acid, it is used as the seed for the next fermentation process.

Fig. B-3 Ethyl Alcohol Production Process Using Molasses as Raw Material



Source: Alcohol Handbook

The mash from which the yeast has been separated is then refined by distillation and 95% hydrous ethyl alcohol is obtained. For obtaining anhydrous ethyl alcohol of 99.5% purity, further dehydration distilling using benzene and cyclohexane is executed. Refer to Fig. B-4 for the process flow.

1.3 Fermentation Process - Using Cassava and Sweet Potato as Raw Material

The raw material is washed and crushed. The crushed material is sent to the cooker in the slurry form. The slurry sent to the cooker is given liquefying enzyme as additive and is cooked while steam is applied. After this, it is cooled down and partly sent to the seed tank. Here saccharifying enzyme is added at 55°C and it is cooled down further. At 33°C yeast is added and the mixture is cultivated for 24 hours to obtain the seed.

The remainder is transferred to the fermentation tank, where it is saccharified by adding liquefying and saccharifying enzyme. After saccharification, it is cooled down to 33°C, and adding the seed to it, it is allowed to ferment. The treated mash with the alcohol content of 8.5 vol % is run through the screen filter to remove the sludge.

The treated mash is refined by means of distillation and 95% hydrous ethyl alcohol is obtained. Anhydrous ethyl alcohol is obtained by putting the hydrous ethyl alcohol through dehydration distillation using some dehydrating agent. See Fig. B-5 for the process flow.

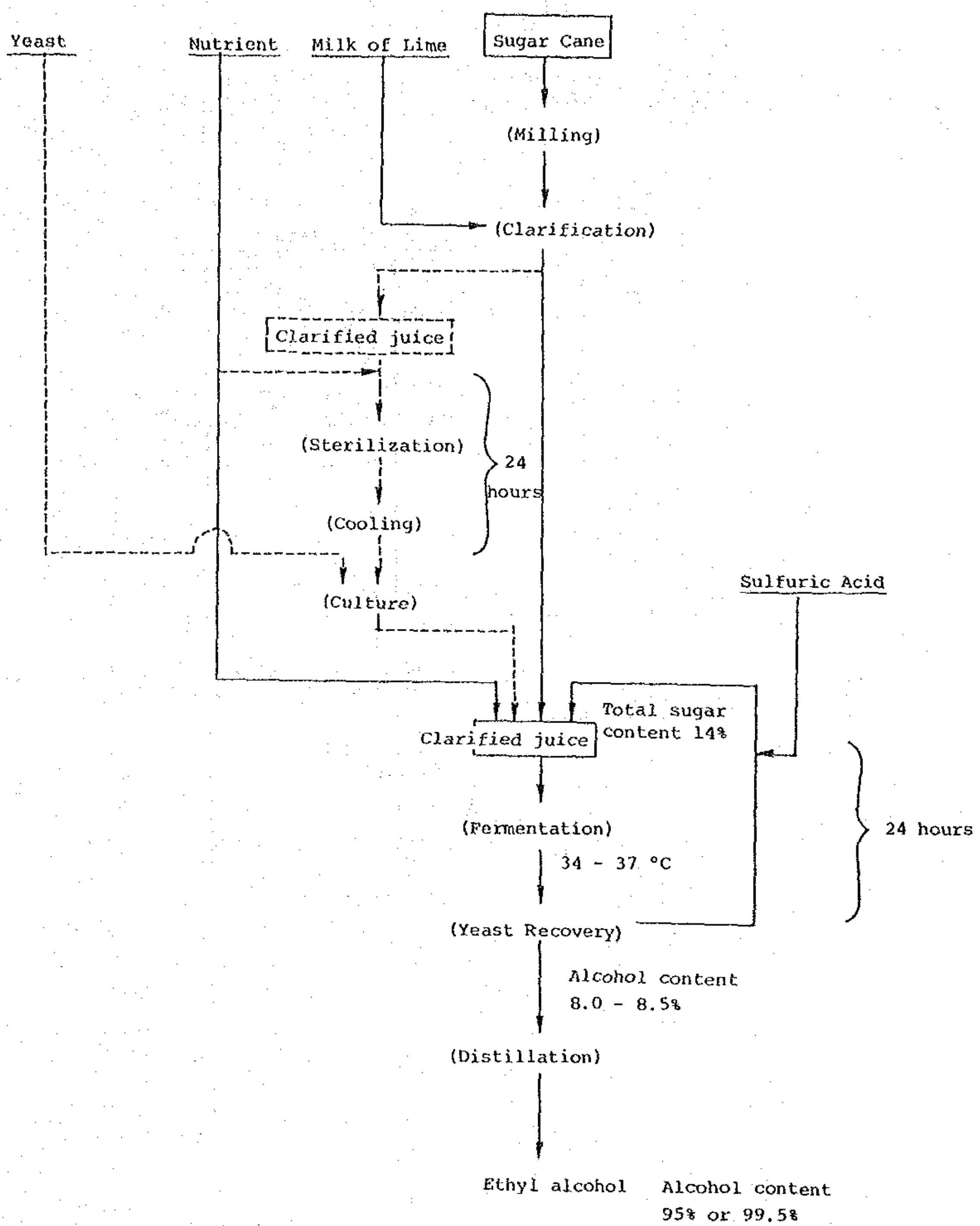
1.4 Synthesis Process Using Ethylene as Raw Material

The feed ethylene is compressed to 70 kg/cm^2G with a compressor and is heated and fed to the reaction column. Water is added in the reaction column, and the phosphoric acid catalyst is used to bring about the reaction. The product of reaction is isolated as gas, while ethylene that had failed to react is sent to the preliminary stage of the reaction column for recycling.

Crude ethyl alcohol obtained by the reaction process account from 20 to 25 wt %. This crude ethyl alcohol is fractionally distilled at the fractional distilling column and is sent to the reduction column after fractional distillation.

At the reduction column, the aldehyde content of the crude ethyl alcohol is reduced under high-pressure hydrogen using nickel catalyst to become ethyl alcohol, which is fed into the refining column. Finished alcohol of 95% purity is obtained from the top of the refining column. As in the case of the fermentation

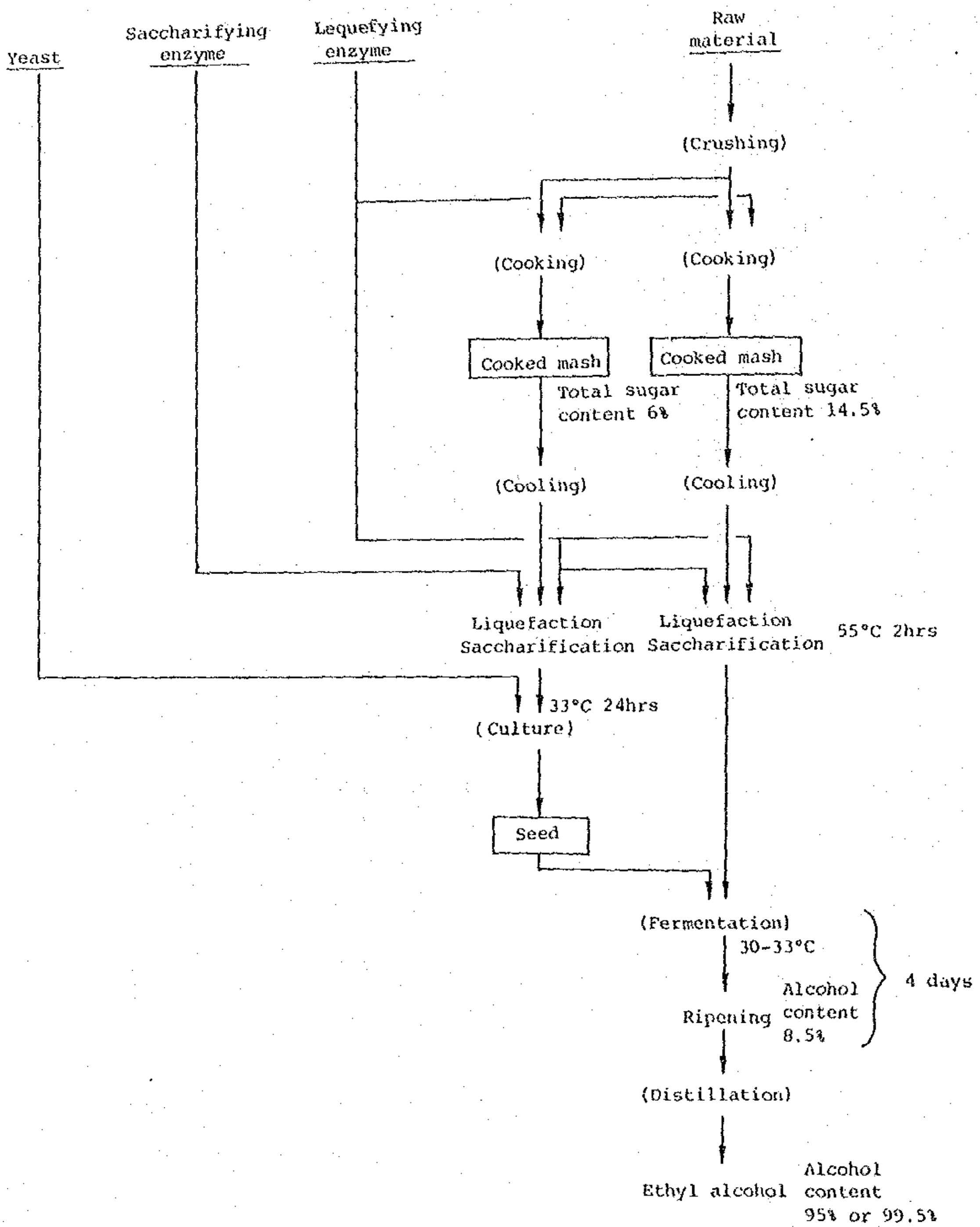
Fig. B-4 Ethyl Alcohol Production Process Using Sugar Cane as Raw Material



Source: Prepared by the Study Team

Fig. B-5 Ethyl Alcohol Production Process Using Starchy as Raw Material (Raw Sweet Potato and Cassava)

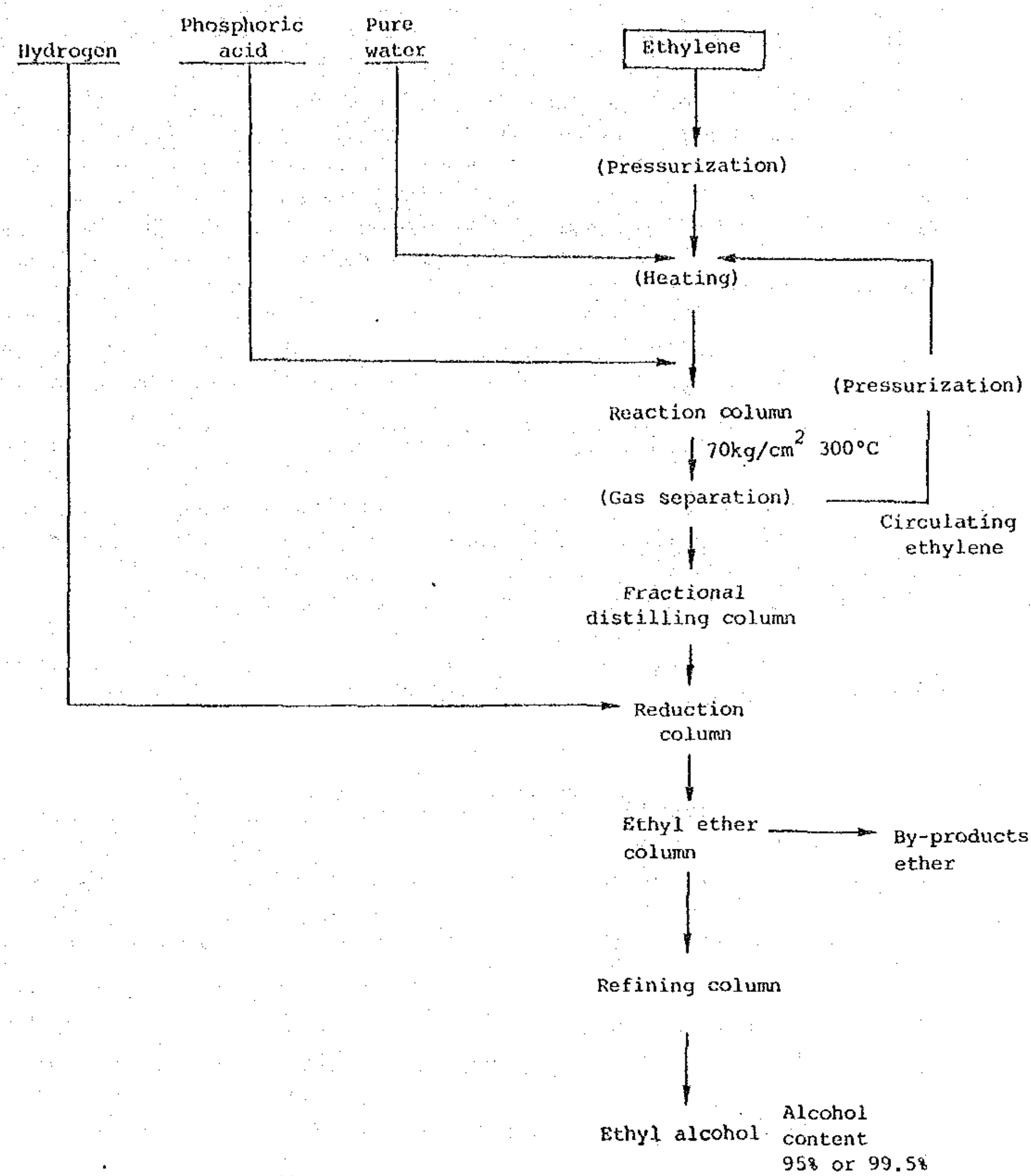
- Enzyme saccharification method -



Source: Alcohol Handbook

Fig. B-6 Ethyl Alcohol Production Process Using Ethylene as Raw Material

- Direct hydration method -



Source: Alcohol Handbook

process, 99.5% anhydrous alcohol is obatined by dehydration distillation using benzene and cyclohexane.

2. Energy Balance

Ever since ethyl alcohol began to be used as fuel, the balance of the output energy against the input energy (energy balance) has been attracting attention. The energy balance means the ratio between the energy expended in cultivating raw materials and manufacturing ethyl alcohol and the energy inherent in the ethyl alcohol produced. NER (net energy ratio) is generally used as the assessing index.

$$NER = \frac{\left(\begin{array}{l}\text{Calorie put into production}\\ \text{of 1 } \ell \text{ of ethyl alcohol}\end{array}\right) - \left(\begin{array}{l}\text{Calorie produced inciden-}\\ \text{tal to production of 1 } \ell\\ \text{of ethyl alcohol}\end{array}\right)}{\text{Low-level calorie production of 1 } \ell \text{ of ethyl alcohol}}$$

Large number of reports on energy balance involving various raw materials, such as those of Battele and da Silva (Brazil), have been made, but the results of calculations are not uniform because of differences in the premises, such as farm production, production technology and so forth, that constitute bases for calculations. An example of comparison between sugar cane and cassava as undertaken by the Study Team is given in Table B-9.

Table B-9 Energy Balance

(kcal/ℓ)

		Sugar Cane	Cassava
Input	Farm Production	(280)	(415)
	Alcohol Production Process	(15)*	(5,880)
	Total	295	6,295
Output	Alcohol	5,045	5,045
	NER	0.06	1.25

* In the case of sugar cane, input energy for alcohol production process is low as the bagasse derived from the stems is usable as fuel.

NER > 1 means minus energy balance, and NER closer to zero means acquisition of greater energy. In the table, cassava NER of 1.25, which is higher than 1, stems from the need for using outside heat source like burning wood in the production process.

As NER > 1 offers no more than a qualitative conversion to liquid fuel for ease of use as merit, research and development efforts related to energy-saving processes are specially brisk as the ethyl alcohol production process requires large energy consumption.

Also, in case large quantities of fertilizer, mechanized farming and long distance haul for assembling are required in the raw material production process, energy balance deteriorates. These reasons call for detailed study of the conditions of location at the time of drafting concrete plans.

3. Technical Innovations

The areas in which technological innovations are expected in connection with ethyl alcohol production consist of raw material cultivation and ethyl alcohol production techniques.

3.1 Raw Material Cultivation

Among farm products now used as raw material for ethyl alcohol, sugar cane as material for making sugar and corn as feed claim mass cultivation history. On the other hand, it was only in recent years that cassava began to attract attention, and there is room left for improving the methods of cultivating these crops.

Principal points needing development in the cultivation of these crops include.

- Development of high-yielding varieties
- Boosting of harvests through improved fertilizer administration
- Better protection from plant diseases and harmful insects

According to the report issued by the World Bank, the average yields of cassava and sweet potato are respectively 9 - 12 tons/ha and 15 tons/ha, but improvements in the above-cited points are expected to boost the yields.

3.2 Ethyl Alcohol Production Technology

As ethyl alcohol production technology, as stated before, two processes are available, one of which is the fermentation and the other is synthesis processes. Technological innovations expected in the synthesis process include development of a technology for producing ethyl alcohol direct from natural gas, development of new catalysts in the production of ethyl alcohol from ethylene, and development of some new ethyl alcohol separation technology.

The technology for producing ethyl alcohol directly from ethylene is now in the process of research and development; it is a technology of the future as yet. Development of new catalysts in the production of ethyl alcohol from ethylene has little prospects as no research work is undertaken as of now. As for the new ethyl alcohol separation technology common to both the synthesis and fermentation process, it will be discussed under the fermentation process.

Technological innovations expected in the ethyl alcohol production under the fermentation process consist mainly of the reduction in the ethyl alcohol conversion energy and in the cost of production. In the following some of the technological developments undertaken in Japan will be discussed with respect to different raw materials and processes.

3.2.1 Bio-saccarification ethyl alcohol production technology using cellurose as raw material

Cellurose used as raw material has to be saccharified before the fermentation process. As means of facilitating saccharification, physical and chemical pre-treatments are conceivable and in Japan, various combinations of electron beam application, pulverization, blasting, ozone treatment and alkali treatment are under study for commercialization.

3.2.2 Saccharification process of starchy materials

(1) Non-cooking saccharification process

In the case of a starchy raw material, about 30% of steam needed for production is consumed as energy for cooking. For this reason, any means of saccharification without cooking will save much energy. When fresh sweet potato is used as raw material, saccharification at 80°C has successfully been achieved on the industrial level. Under the existing state of things, however, enzyme requirement for the process is somewhat larger than for the cooking process. With some room for further technological development in this respect, this process has already reached the commercialization stage as a feasible energy conservation technique.

(2) Continuous saccharification with process immobilized enzymes

In manufacturing insomerized sugar by converting corn starch into fruit sugar (fructose), continuous saccharification by immobilized enzyme has already been commercialized. In manufacturing ethyl alcohol from uncooked sweet potato as the starting material, enzymes are still mixed into the cooked mash to bring about saccharification at present, and therefore it is possible to repeatedly use enzymes by immobilizing them. Depending on the raw material, however, clogging of fibrous substance may sometimes occur. Commercialization of continuous saccharification process by solving this problem is much awaited.

3.2.3 Saccharification process of cellulosic material

As the saccharinity of the saccharified mash of cellurosic material is low, technology for upgrading the saccharinity by combining the excess filter film and the reverse infiltration film, technology for recovering enzymes by fixation, development of new enzymes with higher saccharification potential and other technological developments are underway for commercializing ethyl alcohol production from cellulosic materials.

3.2.4 Fermentation unit

(1) Immobilized yeast process

Immobilization of yeast makes continuous fermentation process possible. And since this upgrades the capacity efficiency of the fermentation tank, cuts in the cost of fermentation tank installation as well as saving in energy can be expected. In Japan, two processes of either using calcium alginate gel or photo-curing resin film as support have been researched, with each has of them having undergone pilot operation for an extended period.

(2) Vacuum fermentation

Under normal fermentation the activity of yeast is impeded by the ethyl alcohol generated. In this process, vacuum fermentation process is promoted while removing the generated ethyl alcohol by reducing the pressure. By this process, the capacity efficiency of the fermentation tank can be improved and high-concentration feeding is made possible. As this process has further merits like energy saving in the distillation process, technological development in the pilot stage is now being pursued.

3.2.5 Distillation unit

(1) Pressurized distillation

Pressure is applied to one column to raise the temperature of the steam generated in that column so that it can be used as the heat source for other columns. This technology makes energy saving possible. In Japan this technology is in the pilot stage and is expected to be commercialized in near future.

(2) Membrane utilization

Unlike the ethyl alcohol separation process under conventional distillation, this is a technology for promoting ethyl alcohol concentration by the use of membrance. It is still under research now, and still more time is likely to be needed for commercial use.

4. Plant Investment Cost

Estimation of plant investment cost should properly be calculated on the basis of estimates collected after choosing the location and undertaking detail design. However, because of the aims of this Study, no such calculations have been undertaken, but the reports issued by the World Bank and data published in various literatures have been used as reference. Estimations of the Study Team have also been used as part of data, as shown in Table B-10.

Table B-10 Plant Investment Cost by Raw Material

(US$ million)

Fermentation Process	Molasses	Fuel	9.8
		Industrial	11.0
	Sugar Cane	Fuel	14.3
	Cassava	Fuel	11.5
Synthesis Process	Ethylene	Industrial	17.8

Notes: 1) Plant capacity of 120 kl per day.
2) 1982 as a base year.
3) Finished product will be anhydrous grade.

IV. Production Cost

Specific production costs of any operating plant have not been made public because of its nature. As production costs differ according to the raw material prices, plant investment cost and labor cost prevailing at each different location, detailed study should be made after picking specific location, collecting various estimates on facility investment cost and making concrete calculations. In this Study, however, trial calculations were undertaken on the following general and standard premises in order to grasp the trends in production cost for different raw materials.

1. Premises for Cost Estimation

1.1 Matters Examined

Molasses, sugar cane and cassava were examined as raw materials used in the fermentation process, while ethylene was assumed as material for synthesis. In view of the existing state of things, uses were divided into industrial and fuel uses with respect to molasses. Sugar cane and cassava were considered as material for making fuel ethyl alcohol only, while ethylene was considered as material for making industrial ethyl alcohol only. With regard to sugar cane, the case of Brazil was taken up as an example of a country where raw material cost was low.

Also for ethyl alcohol production facilities, a newly installed plant was assumed for all cases.

	Raw Material	Application
Case A	Molasses	Fuel
Case B	Molasses	Industrial
Case C	Sugar cane	Fuel
Case D	Sugar cane (Brazil)	Fuel
Case E	Cassava	Fuel
Case F	Ethylene	Industrial

1.2 Plant Capacity

The most commonly used 120 kl/day capacity is adopted.

1.3 Product Purity

The anhydrous grade of 99.5 vol % has been used both for industrial and fuel ethyl alcohol. With regard to the impurity content, specifications generally used in the developed countries were adopted for the industrial ethyl alcohol, but no provisions were made for the impurities in the fuel ehtyl alcohol, for which only product purity was considered.

1.4 Operating Days

While climatic conditions in the various parts of the world may lead to different operating days with respect to farm products used as raw materials under the fermentation process, plant operating days were set at 300 days a year, assuming that the materials would be available for 300 days. With respect to the synthesis process, 330 days a year were assumed according to Japan's case.

1.5 Annual Production Rate

The annual production rate is expressed by multiplying the per day production capacity of the plant by the number of days a year operated.

- Fermentation process: Annual production rate of 36,000 kl
- Synthesis process: Annual production rate of 39,600 kl

1.6 Raw Material Cost

Unit price of each raw material is as given in the costs of raw materials.

- Raw material for fermentation process:
  Average price in various parts of the world in 1982.
- Raw material cost for synthesis process:
  Average price in Japan, Europe and the United States in 1980.
- Premised on the above, the unit prices will be:

Molasses:	$74 per ton
Sugar cane:	$22 per ton
Sugar cane (Brazil):	$12 per ton
Cassava:	$32 per ton
Ethylene:	$680 per ton

The unit consumption rate required for producing 1 kl of ethyl alcohol from each of the raw materials was quoted from Chemical Engineering (No. 5, Vol. 45), but the cost of cassava was estimated by the Study Team.

1.7 Utility Cost, Chemical Cost

The unit cost and quantity for calculating the utility cost and the chemical cost for each raw material are quoted from Chemical Engineering (No. 5, Vol. 45).

1.8 Labor Cost

The unit cost of labor and required number of workers have been calculated on the basis of data the Study Team has compiled for the case of Southeast Asia. The unit cost has been set at $2,000 per man-year, and the required number of workers was set at 60 for the case of plant producing fuel ethyl alcohol and at 80 for the plant producing industrial ethyl alcohol.

1.9 Maintenance Cost

Annual maintenance cost is assumed to be 3% of the plant investment which is a normal rate for chemical plants. For the plant investment cost, values cited in the previous section III-4 have been adopted.

1.10 Taxes, Insurance

These have been estimated at 2% of the plant investment cost normally used for chemical plants.

1.11 Depreciation

Taking the residual value as 10%, the period of depreciation has been set at 12 years. As a consequence, the depreciation cost was calculated as plant investment cost x 0.9 x 1/12.

1.12 Profit

Estimated at plant investment cost x 0.1.

1.13 Management Cost

Labor cost x 80% has been estimated as cost needed for plant management.

2. Results of Tentative Production Cost Calculations

The results of tentative calculations of production cost on the premise cited in 1 are shown in Table B-11. Case D, production cost in Brazil, is shown in Table B-12. Details for other cases are given in Appendix Table 3.

Table B-11 Production Cost Estimate by Raw Materials

(US$/kl)

Method		Variable Costs		Fixed Cost	Production Cost
		Material Cost	Utility Cost, etc.		
Fermentation Process	Molasses - Fuel	259 (63)	73	77	402
	Molasses - Industrial	259 (62)	76	80	412
	Sugar cane - Fuel	330 (77)	4	95	429
	Sugar cane - (Brazil) - Fuel	184 (66)	4	95	279
	Cassava - Fuel	208 (48)	141	80	427
Systhesis Process	Ethylene - Industrial	326 (63)	85	107	518

Note: Figures in ( ) indicate the percentage share of raw material cost in the production cost.

As stated at the beginning of this section, the result of production cost estimations cited here are based on general premises. In undertaking concrete location planning, therefore, comparative study of each item of premises with actual conditions and modifications would be necessary. In particular, as the ratio of raw material cost to the total cost is very high, as is evident from the table, stable material procurement price at the chosen location becomes highly significant.

While a lagoon, for instance, has been assumed for waste water treatment in the premises for pollutant treatment facilities, the cost naturally becomes higher in a country like Japan where regulations on environmental pollution are stringent.

In any case, under the premises cited herein, the following points can be gleaned from the table as general trends:

Table B-12 Production Cost Estimate for Ethyl Alcohol by a Newly Installed Plant in Brazil

Ethyl Alcohol Production Cost

Plant capacity: 120 kl/day
Product purity: 99.5 vol %
Raw Material: Sugar cane
End-use: Fuel

	Production Cost Item	Unit Price	Quantity	US$/kl
Variable Costs	Raw material cost	$12/MT	15 MT/kl	180
	Utilities costs			
	Power	-	-	0
	Fuel	-	-	0
	Water	¢20/MT	10 MT/kl	2
	Chemical cost			2
	Subtotal			184
Fixed Costs	Labor cost	$2,000/y/man x 60 men	=	$120,000/y
	Maintenance cost	$14,300,000 x 0.03	=	$429,000/y
	Taxes and insurance	$14,300,000 x 0.02	=	$286,000/y
	Depreciation charges	$14,300,000 x 0.9 x 1/12	=	$1,073,000/y
	Profit	$14,300,000 x 0.1	=	$1,430,000/y
	Management cost	Labor cost x 0.8	=	$96,000/y
	Subtotal			95
	Total production cost			279

- Comparison of the fermentation and synthesis processes give the edge to the fermentation process in the aspect of production cost .
- Not much difference is observed in the costs of molasses, sugar cane and cassava used as raw materials for the fermentation process.
- In each case, the ratio of raw material cost to the total production cost is more than 50%, indicating that the total production cost is greatly affected by the raw material cost.

V. Production Policy

Policies related to ethyl alcohol production, especially to fuel ethyl alcohol production, have been lately made public by various countries as ideas or as measures for implementation. In this report policies under implementation in Brazil, the United States and the Philippines will be discussed.

1. Brazil

Findings of the interview survey conducted in march 1983 with respect to the preferential measures for promoting the "National Alcohol Program" are summarized below:

1.1 Low Interest Loans for Industrial and Agricultural Projects

a. Industrial project

(a) Loan ceiling
70 to 90%

(b) Interest rate
Middle and southern Brazil: Inflation rate x 0.8 + 5%
Northeastern Brazil: Inflation rate x 0.6 + 5%

(c) Repayment period
12 year repayment (4 year grace period)

b. Agricultural project

(a) Loan ceiling
50 to 100%

(b) Interest rate
Middle and southern Brazil: Inflation rate x 0.7 + 5%
Northeastern Brazil: Inflation rate x 0.55 + 5%

(c) Repayment period
12 year repayment (4 year grace period)

c. Incentive for ethyl alcohol production

Producers will be guaranteed a parity purchase price.

2. The United States

The "Alcohol Fuel Policy Study Program" which the Department of Energy announced in July 1978 and the "Alcohol Fuel Policy Review" announced by the same department in June 1979 indicate the production policy as follows:

- The Department of Agriculture will provide loan guarantee for pilot plants for ethyl alcohol.
- The Department of Energy will provide conditional loan guarantees for the ethyl alcohol production plants.
- When an ethyl alcohol production plant is newly established, the 20% investment tax under the "Energy Tax Law" will be exempted.

3. The Philippines

The revised Alcogas Program which the Philippine National Alcohol Commission (PNAC) announced in 1982 provides the following policies on production:

- Acceleration of the depreciation period of the equipment in the ethyl alcohol plant will be given special approval.
- Import duties on the imported equipment used in the ethyl alcohol plant will be exempted.

VI. Changes in World Production

Although several reports are available on world production of ethyl alcohol for certain years, it is only the United Nations' statistics that offers complete data on year-to-year changes in production. However, as the following problems are associated with the United Nations statistics, the Study Team modified some of the production figures.

- As the French production was under-reported, figures estimated by Japan's Ministry of International Trade and Industry was used instead.
- As production for certain years was not surveyed, production in each of these years was assumed to be equal to each of the nearest fiscal year surveyed. For the Brazilian production

over 1977 to 1980, the figures obtained from the Comissão Nacional do Álcool of Brazil were used.

- The production volumes reported by some countries may presumably include ethyl alcohol used as material for liquors, but as such quantities are unknown, no corrections have been made.
- The United Nations statistics do not make clear distinction between industrial use and fuel use, but Brazilian production of fuel ethyl alcohol is represented by figures obtained from the Instituto do Açúcar e do Álcool and they are recapitulated in a graph as the component of total production. Incidentally, while countries producing fuel ethyl alcohol as of 1983 are Brazil, the United States and the Philippines, Brazil is the only country that was producing fuel alcohol before 1980. Industrial ethyl alcohol production volumes are shown in Fig. B-7 and Table B-13.

The average annual growth rates in production between 1965 and 1980 was 0.9% for industrial ethyl alcohol and 16.5% for fuel ethyl alcohol (Brazil).

VII. Fuel Ethyl Alcohol Production Programs

With regard to fuel ethyl alcohol which is attracting attention lately, a number of countries have announced production programs or future directions of development. Situations in the leading countries are as given below.

1. Brazil

The national alcohol program of Brazil was adopted and put to implementation in 1975. The production plan of the "Proálcool" calls for the following annual production schedule:

1980:	4.0 million kl
1981:	4.9 million kl
1982:	6.0 million kl
1983:	7.3 million kl
1984:	8.9 million kl
1985:	10.7 million kl

The programs were implemented just about on schedule up to 1981, but according to information obtained from CENAL (the Comissão Nacional do Álcool of the Commerce and Industry Department) as of November 1982, the projected 1985 production has been revised to 8.3 million kl, so that the program is now somewhat behind schedule.

Fig. B-7 Changes in Ethyl Alcohol Production (including fuel ethyl alcohol)

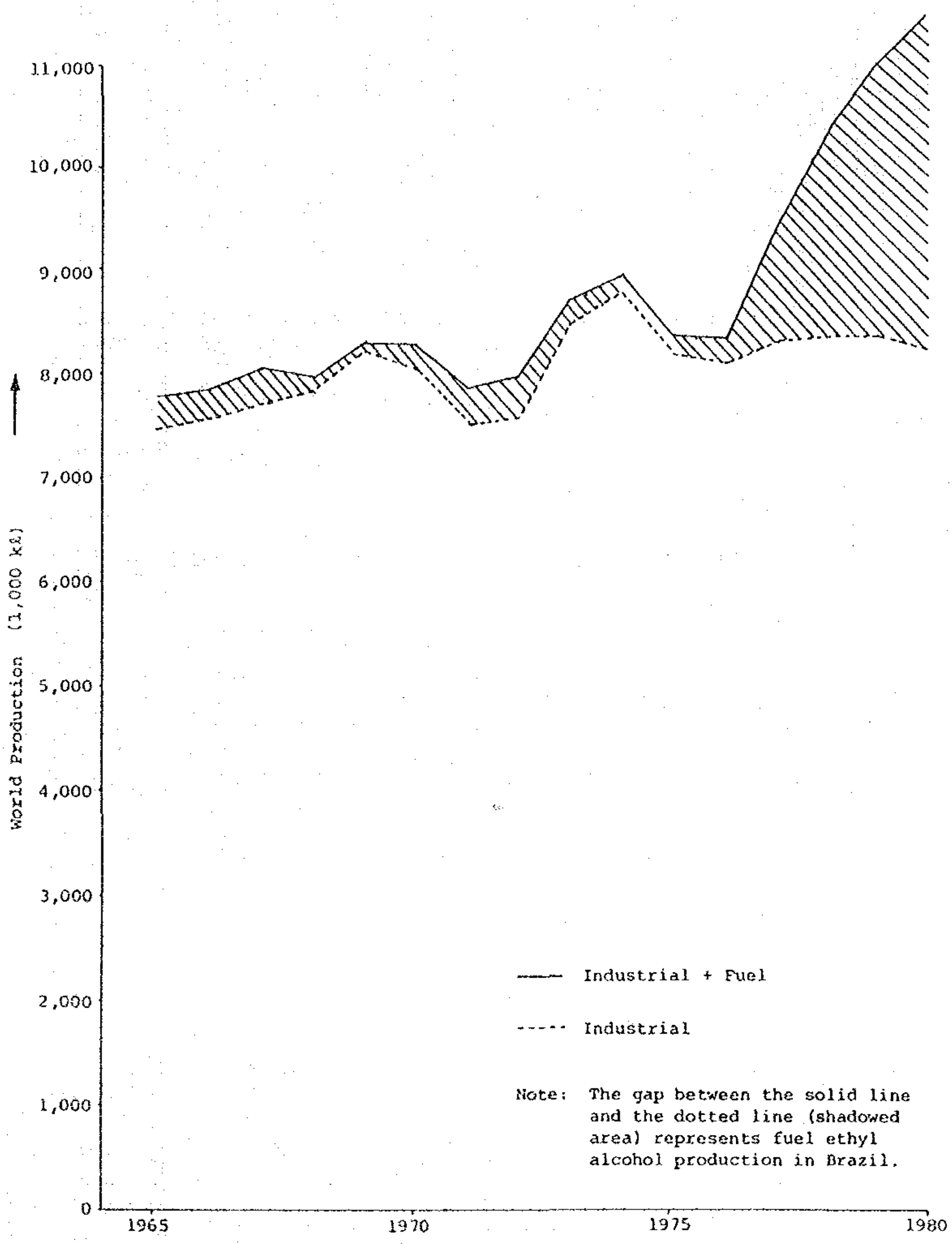


Table B-13 Changes in Production of Ethyl Alcohol (including Brazil's fuel ethyl alcohol)

(1,000 kl)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Developed Countries																
USA	2,632	2,602	2,571	2,590	2,818	2,619	2,158	2,154	2,573	2,451	2,199	1,891	1,886	(1,886)	(1,886)	(1,886)
[USA's fuel use]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[76]	[246]
Canada	19	20	25	29	30	28	40	47	27	26	23	23	24	(24)	(24)	(24)
France	(301)	(301)	(301)	(301)	(301)	(301)	(301)	(301)	301	270	214	241	297	(297)	(297)	(297)
Germany, FR	(195)	(195)	(195)	(195)	195	222	219	192	214	243	183	215	212	182	182	218
Italy	136	113	117	157	169	176	185	149	179	238	235	(235)	(235)	(235)	(235)	(235)
UK	177	155	143	145	165	175	167	156	186	295	198	249	272	297	280	(280)
5 EC Countries	(137)	137	131	153	164	164	170	173	192	206	196	209	216	203	(203)	(203)
Northern Europe	149	148	152	145	137	124	135	135	130	128	118	101	101	(101)	109	99
Other European Countries	122	158	123	147	194	102	75	164	135	162	170	(170)	(170)	(170)	310	328
Japan	193	197	230	228	199	207	229	229	240	237	208	222	222	228	218	211
Developing Countries																
Mexico	73	56	33	(33)	51	53	60	54	55	58	59	53	76	79	92	91
Other CA Countries	245	202	249	235	206	(206)	(206)	(206)	(206)	(206)	(206)	(206)	(206)	(206)	(206)	(206)
Brazil	572	691	684	461	450	625	625	684	653	615	580	642	(1,530)	(2,491)	(3,070)	(3,440)
[Brazil's fuel use]	[283]	[282]	[347]	[112]	[62]	[229]	[344]	[376]	[247]	[147]	[176]	[244]	[1,172]	[2,050]	[2,593]	[3,009]
Colombia	9	15	12	13	14	21	(21)	17	19	35	(35)	(35)	(35)	(35)	13	(13)
Other SA Countries	4	5	4	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Philippines	24	32	32	32	36	33	(33)	39	47	(47)	(47)	(47)	(47)	(47)	(47)	(47)
Korea, Rep. of	26	31	46	44	47	47	60	61	73	87	114	122	132	129	126	130
Middle East	1	1	2	(2)	(2)	(2)	3	3	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Africa	26	26	26	29	36	37	38	37	38	(38)	(38)	(38)	(38)	(38)	(38)	(38)
Planned Economy Countries																
USSR	2,360	2,430	2,626	2,670	2,732	2,796	2,731	2,740	2,935	3,143	3,128	3,168	3,255	(3,255)	3,118	3,056
China	30	18	21	24	20	18	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)
Poland	208	189	198	206	189	190	185	181	249	250	227	262	330	324	327	270
Others	154	150	163	151	163	170	265	273	288	243	262	284	260	259	(259)	259
Total for industrial & fuel ethyl alcohol	7,793	7,872	8,084	7,994	8,322	8,320	7,928	8,017	8,765	9,003	8,465	8,438	9,569	10,511	11,141	11,602
Total for industrial ethyl alcohol*	7,510	7,590	7,737	7,882	8,260	8,091	7,584	7,641	8,518	8,856	8,289	8,194	8,397	8,461	8,472	8,347

* Total for industrial ethyl alcohol excludes fuel ethyl alcohol produced by Brazil and the U.S.
( ): Study Team estimates
CA: Central America; SA: South America

Source: United Nations, Statistical Yearbook

2. The United States

In the United States, the Department of Energy announced the Alcohol Fuels Policy Study Program in July 1978, followed in June 1979 by the Department's Report of the Alcohol Fuels Policy Review, which together formed the basis for the country's full-fledged fuel ethyl alcohol production policy. The Report of the Alcohol Fuels Policy Review which envisages a rapid increase in production calls for the following fuel ethyl alcohol production program.

1979:	80 million gallons	304,000 kl
1980:	100 million gallons	379,000 kl
1982:	300 million gallons	1,136,000 kl
1985:	500 million ∿	1,893,000 ∿
	600 million gallons	2,271,000 kl

However, the 1981 production of 265,000 kl reported by SRI indicates some delay in the progress of the program.

3. The Philippines

The Philippine National Alcohol Commission (PNAC) was set up in February 1980 under the President's order. Alcogas has been positioned as non-conventional type energy in the five-year energy program or ten-year energy program annually announced by the Ministry of Energy. The Alcogas Program, in fact, made a flourishing start in 1980 as the most important item for development stipulated in the five-year program. However, the alcogas production target has been scaled down to about 1/50 in the five-year energy program drafted two years later in 1982. Comparison of the 1980 and 1982 five-year energy programs is presented in Table B-14.

Table B-14 Philippine Ethyl Alcohol Production Program

(1,000 barrels of oil equivalent)

	1980 Program	1982 Program
1981	96	--
1982	576	35
1983	1,408	47
1984	1,964	47
1985	2,415	47
1986	--	47
1987	--	47

Source: Philippine Five-Year Energy Program

According to information obtained from the Ministry of Energy in January 1983, the curtailment of the program was made for the following reasons:

- The crude oil supply and demand situation has changed from that of the time when the program was announced.
- The government subsidies (about US¢18/l at 9.2 pesos = US$1) have become a fiscal issue.

4. Various Asian Countries

4.1 Thailand

In March 1979, the Thai Government inaugurated Power Alcohol Commission (PAC) consisting of representatives of the various government departments and agencies.

The Government plans to develop technology for producing ethyl alcohol as a future energy from cassava which is now grown and exported as animal feeds. Since 1980, development efforts for ethyl alcohol production technology have been made with use of cassava and other plants at the Science and Technology Research Institute of Thailand as a joint research and development cooperation project with Japan.

4.2 Indonesia

The Indonesian Government has made it clear to vigorously implement a policy of linking ethyl alcohol production with dispersion of population to local areas with the Agency for Development and Application of Technology (BPPT) as the principal organization.

No specific production plan has been announced yet, although the State Alcohol Commission was established in June 1980.

To develop technology and provide education on ethyl alcohol production, two pilot plants were built in the southern part of Sumatra: 5,000 kl/year pilot plant constructed by indigenous technology and 8 kl/day pilot plant with technical cooperation from Japan. Both plants are scheduled to start operation one after another within 1983.

5. Various European Countries

Various countries in Europe are making plans to use either ethyl alcohol or methyl alcohol as fuel by taking advantage of their respective available resources.

Particularly, France announced the Caburol plan in January 1981 which calls for meeting 25 to 50% of total gasoline consumption with Caburol in 1990 as the target.

Federal Republic of Germany, Sweden and Italy have already been conducting road tests on automobiles with fuel that is produced by mixing ehtyl or methyl alcohol with either gasoline or gas oil.

C. CONSUMPTION

I. Use

Use of ethyl alcohol can broadly be divided into industrial and fuel use. For industrial use, explanation will be made about specific areas in which ethyl alcohol is used at present. Regarding fuel use, its suitability in each particular application will be discussed.

Before explanation is given on both industrial and fuel applications, denaturation, a special factor to ethyl alcohol, will be described.

1. Denaturation

Ethyl alcohol has special properties that it will become alcoholic drinks in addition to its industrial and fuel uses.

Since liquor taxes on alcoholic drinks provide an important source of revenue to various countries, measures are taken to make ethyl alcohol unfit for drinking purposes if it is intended for industrial uses. These measures are referred to as denaturation, and substances used for denaturation are known as denaturant.

1.1 Properties Required as Denaturant

Generally, following properties are required as a denaturant:

- It easily blends with ethyl alcohol, and its presence will not adversely affect its industrial applications at all.
- It can give ethyl alcohol sufficient obnoxious malodor that will effectively prevent its use for beverage purposes.
- It cannot easily be separated from ethyl alcohol by filtration, distillation or any other simple treatment.
- Its presence even in extremely small quantity can easily and positively be detected.
- It is low priced and readily available.

1.2 Denaturant

Specific products of denaturant will be described by taking examples in Japan.

1.2.1 General denaturation

General denaturation is a denaturation standard that is used for general purposes. Major denaturants include methyl alcohol, benzene, toluene, fragrances, etc.

1.2.2 Selective denaturation

This is a denaturation standard which allows use of denaturants other than those for general denaturation purposes when industrial ethyl alcohol is used in manufacture of acetylene derivatives, ether, ester, etc. As selective denaturants, industrial ethyl ether, kerosene, formalin, ethyl acetate, etc. are used.

1.2.3 Special denaturation

Use of special denaturants is mandatory for some of ether and ester products. Benzene, methyl ethyl ketone, etc. are used for this purpose.

1.2.4 Exceptional denaturation

In case denaturation standards described under 1.2.1 through 1.2.3 cannot be used, the reasons for it must be stated in an "application for use of exceptional denaturants" and submitted to the Minister of International Trade and Industry for approval. The approved method is referred to as exceptional denaturation.

2. Industrial Use

Many countries use ethyl alcohol in the chemical industry for solvents and other products, food industry for preservatives, and pharmaceutical industry for strilizing alcohol, etc. Some countries extensively use ethyl alcohol as basic raw materials in chemical industry for production of ethylene, acetaldehyde, etc. However, it is difficult to apply the same category to explain every country's industrial use of ethyl alcohol because classifications of application vary depending on each country. Applications also slightly differ from one country to another. For these reasons, examples in Japan will be introduced as regards applications in chemical industry, beverage and food industry, hygienic and pharmaceutical industry. Ethyl alcohol is not used in Japan as basic raw materials for chemical industry. For these applications, examples in other countries which use ethyl alcohol for such purposes will be cited. Ethylene can be produced by two processes. One is to produce from ethyl alcohol. The other generally practiced method is thermal cracking of naphtha or natural gas (known as petrochemical process). Production costs by these methods have been calculated and compared.

Use of either fermentation process or synthesis process for particular industrial application slightly differs according to countries. However, generally, ethyl alcohol produced by fermentation method is used for human intake purposes such as food and drink additives like preservatives, vinegar, perfumery, and part of medicines under government regulations. Some countries restrict use of synthetic ethyl alcohol even for cosmetics and other products which come in contact with human body under their agricultural policy to protect farmers who produce raw materials for fermentation ethyl alcohol.

2.1 Chemical Industry Use

Ethyl alcohol is mainly used for solvents in chemical industry. It is lower in toxic effect on human body than other solvents such as acetone and benzene. For this reason, it is almost exclusively used in the field of solvents that will come in contact with human body such as soap, kitchen and clothing detergents, cosmetics, and aerosol products.

Aside from use as solvents, ethyl alcohol is used for production of ethyl esters including ethyl acrylate, ethyl malonate, ethyl silicate, ethyl phthalate, and ethyl cyanoacetate for textile processing and high-class paints as well as for production of intermediates of agricultural chemicals, medicines and dyestuff.

2.2 Beverage and Food Use

Ethyl alcohol is used as raw material for alcoholic drinks and vinegar, as well as preservatives for soybean sauce, pickles, ice cream, fresh cake, etc.

2.3 Hygienic and Medical Supplies

Ethyl alcohol is used in manufacture of vitamins, medicines for external use, antibiotics, amino acid drugs, etc. It is also used as alcohol of Japanese Pharmacopoeia.

2.4 Basic Raw Material for Chemical Industry

Another different use of ethyl alcohol besides its use in chemical industry such as for solvents described under 2.1, there is a field that uses ethyl alcohol as basic raw material to produce a series of ethyl alcohol derivatives. For the present survey, this particular field will be referred to as basic raw material for chemical industry, to distinguish it from its use in chemical industry described in 2.1.

This field of applications is mainly found in Brazil and India because both countries are oil importers and abundantly produce agricultural products.

Production method for ethyl alcohol derivatives is usually divided into the following three types:

- To produce ethylene and its derivatives from ethyl alcohol
- To produce acetaldehyde and its derivatives from ethyl alcohol
- To produce derivatives directly from ethyl alcohol

Fig. C-1 to C-3 show a block flow chart for each of these production processes.

Fig. C-1 Production of Etylene and Its Derivatives from Ethyl Alcohol

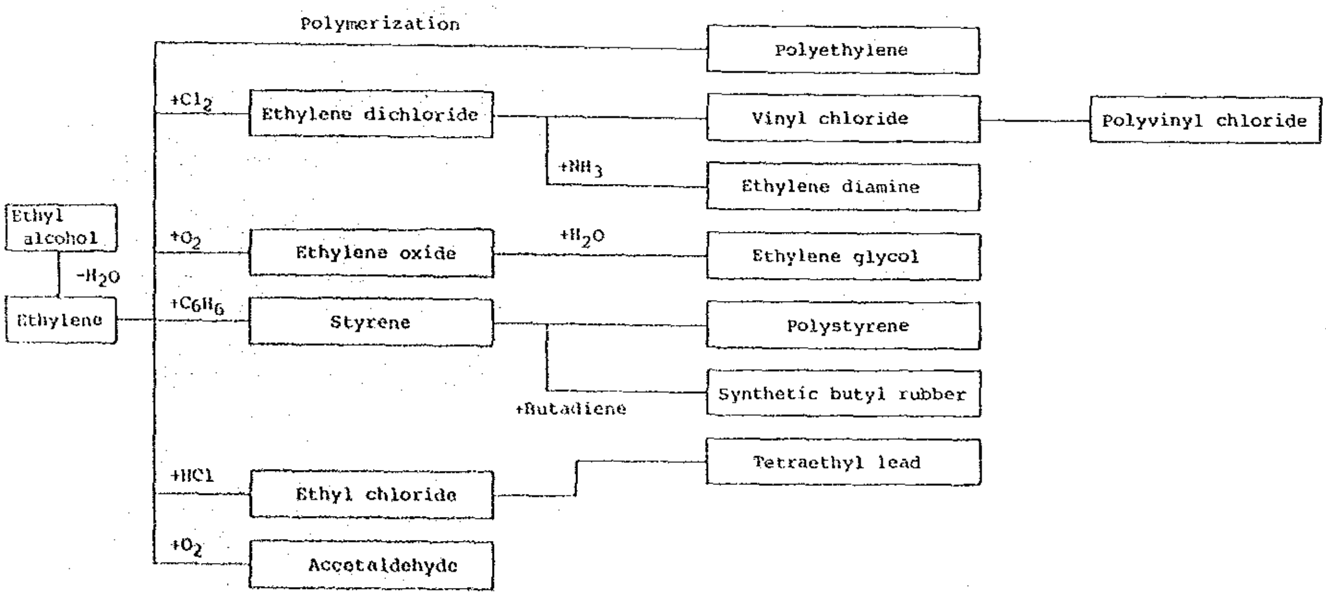


Fig. C-2 Production of Acetaldehyde and Its Derivatives from Ethyl Alcohol

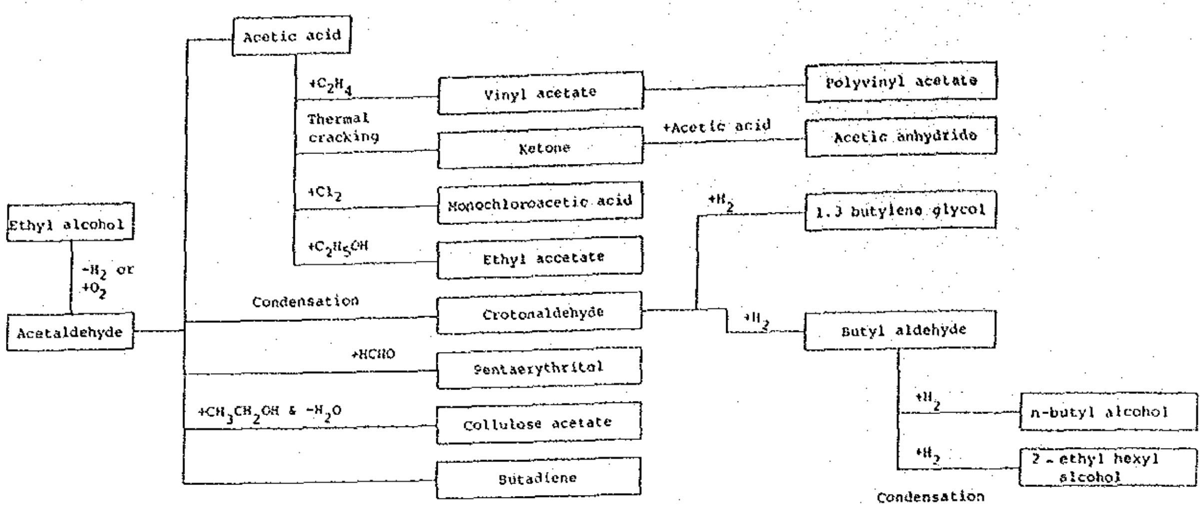
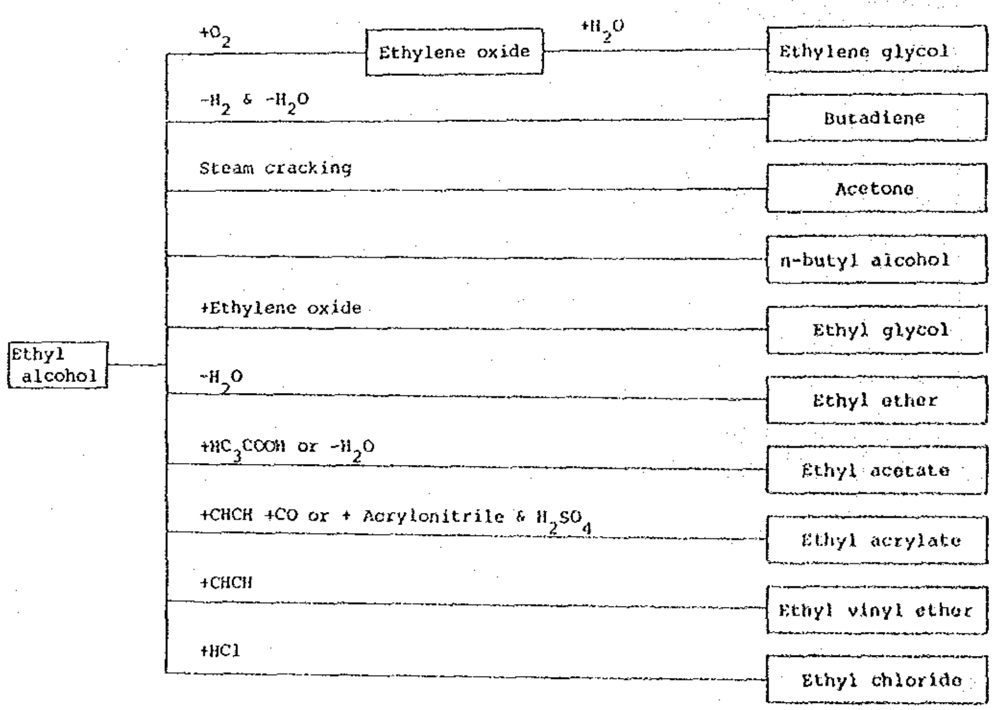


Fig. C-3 Production of Derivatives Directly from Ethyl Alcohol



2.4.1 Examples of actual applications as basic raw material for chemical industry

(1) Brazil

Brazil leads the world in this field. According to 1980 UNIDO data, with ethyl alcohol as raw material, Brazil produces ethylene, acetaldehyde, octyl alcohol, butyl alcohol, budadiene, butyl ether, ethylene glycol, diethylene glycol, etc.
For details including production capacity, refer to Appendix Table 4.

(2) India

According to 1980 UNIDO data, India produces acetic acid, acetic anhydride, butyl acetate, ethyl acetate, monochloro-acetic acid, pentaerythritol, DDT, styrene, polyethylene, acetone, butyl alcohol, butadiene, etc.
For details including production capacity, refer to Appendix Table 5.

(3) Peru

Peru also produces ethylene and polyvinyl chloride.

2.4.2 Comparison of ethylene production costs

As described above, ethylene can be produced from ethyl alcohol. However, it is usually produced from naphtha, a fraction of petroleum, or from natural gas.

Ethylene is one of basic raw materials for petrochemical industry and is being consumed in large quantities. Thus, if ethylene produced from ethyl alcohol is competitive with ethylene from petrochemical process, a huge market for industrial use can be expected for ethyl alcohol.

Cost comparison will be made below between ethylene produced from ethyl alcohol and that from petrochemical process. As the method for this cost comparison, production cost of ethylene with ethyl alcohol as raw material will be calculated first. Results will then be compared with the market price of ethylene from petrochemical process as described in the section dealing with price of raw material.

(1) Premises for cost calculation

(a) Plant capacity and process
To be 60,000 tons/year and isothermal reaction fixed bed type process.

(b) Purity of product
There are two grades for ethylene: polymer grade and chemical grade. Of these grades, stricter polymer grade has been employed (99.95 mol %).

(c) Number of operating days
To be set at 330 days a year.

(d) Plant investment cost
8 million US dollars as estimated by Study Team.

(e) Raw material and utilities consumption
Refer to Table C-1.

Table C-1 Raw Material and Utilities Consumption
(Isothermal reaction fixed bed type process)

	Polymer Grade
Raw Material 100% Ethyl alcohol per ton of Ethylene (MT)	1.75
Utilities Consumption (per ton of ethylene)	
Steam (MT)	1.08
Power (kWh)	235
Cooling Water (m^3)	180
Fuel (kcal)	0.360×10^6
Catalyst (kg)	0.03 - 0.1

Source: Collection of Development and Technology Data on Fuel and Chemical Raw Materials by Biomass

(f) Price of raw material
Calculation was made for two cases: $416/kl which is average cost of ethyl alcohol by the fermentation process and $279/kl which is the production cost in Brazil.

(g) Number of operation personnel
Set at 40 persons.

(h) Others
Premises used for production cost calculation on ethyl alcohol were used.

(2) Results of cost calculation

Results of cost calculation are shown in Table C-2. For further details refer to Appendix Table 6.

Table C-2 Average Cost of Ethylene Produced from Ethyl Alcohol

(US$/MT)

		World Average	Brazil
Variable costs	Raw material costs	910	611
	Utilities and chemicals costs	81	81
Fixed costs		32	32
Total		1,023	724

(3) Cost comparison

For the production cost of ethylene from ethyl alcohol, the world average and results of calculation on the Brazilian case described above were used. Production cost of ethylene from petrochemical process has not been published. Therefore, the market price was used as reference.

Table C-3 Cost Comparison

(US$/MT)

Calculation of Cost of Ethylene from Ethyl Alcohol		Cost of Ethylene from Petrochemical Process (Market Price)	
World Average	1,023	Japan	800
Brazil	724	Europe	750
		USA	490

From Table C-3, it will be noted that the average world production cost of ethylene from ethyl alcohol is higher than the market prices in Japan, Europe and the United States.

However, when production cost calculation is made for the example in Brazil where ethyl alcohol, raw material of ethylene, is available at lower cost, we see that ethylene production cost has already reached the level of that in Japan and Europe where naphtha is used as feedstock for petrochemical process, while in the United States where natural gas is used as raw material for ethylene the cost of ethylene from ethyl alcohol is still higher than from petrochemical process. Production of ethylene from ethyl alcohol offers the following advantages:

- Raw material for fermentation process is a reproducible resource such as molasses and sugar cane.
- Ethylene is a sole product of this process and no by-products are produced as in the case of petrochemical process. This will simplify process configuration, and greatly facilitate plant operation and acquisition of operation techniques. In addition, equipment investment cost will be made smaller in scale.
- Savings on foreign exchange by substituting for petroleum, as well as promotion of agriculture, can be accomplished.

Aside from these advantages, ethylene from ethyl alcohol will become more advantageous in cost over ethylene from petrochemical process if oil price rises in future. Thus, production of ethylene from ethyl alcohol is considered an extremely significant technology in countries where molasses, sugar cane, etc. as raw materials of ethyl alcohol are available at low cost.

However, it is also required that production of ethylene from ethyl alcohol should be studied in each country under the framework of a comprehensive industrial policy which will cover use of whole products in the downstream of ethylene production.

3. Fuel Use

Use of ethyl alcohol as fuel is the latest use that emerged against a backdrop of soaring petroleum prices. Ethyl alcohol is now consumed in large volumes in Brazil, the United States, etc. by being blended with gasoline or simply as it is.

Merits and demerits of ethyl alcohol when blended with gasoline as automotive fuel are generally said to be as follows:

Merits:

- As ethyl alcohol blended is produced from reproducible resources, it is desirable from the viewpoint of ecological environment.

- If surplus agricultural products are used as raw material, it will help expand and stabilize the market for agricultural products.
- As ethyl alcohol resources are undepletable, it will lead to conservation of oil.
- It improves octane vating of fuel. (When 10% of ethyl alcohol is blended into gasoline, the octane number improves by two or three points. In the United States where stepwise control on the use of alkyl lead is being implemented, ethyl alcohol as octane rating improver is now gaining more attention.)
- It lowers the mixed vapor temperature and improves filling efficiency (increase in blended volume).
- It lowers combustion temperature and reduces NO_x (less polution by exhaust gas than gasoline).
- Addition of anhydrous ethyl alcohol up to around 20% hardly affects engine performance so that conventional engine can be used as it is.

Demerits:

- When water content in blended fuel reaches 5 to 6%, phase separation tends to occur to make it unusable as blended fuel.
- While gasoline consists of many components with the boiling range between 20~200°C, ethyl alcohol comprises single component with low boiling point of 78.3°C. Because of this, blended fuel tends to cause vapor lock and percolation more often than gasoline (Measures to modify fuel feed system are necessary).
- As ethyl alcohol has a high latent heat of vaporization, its saturated vapor is too lean to make starting in cold area difficult (Requires equipment of preheater or the use of auxiliary fuel to support starting).
- As its heat of combustion is low at 60% compared to gasoline, the capacity of fuel tank must be made larger. Also the tank may rust because of its absorption property.
- Its exhaust gas contains acetaldehyde which has an irritating odor.
- Its price still compares unfavorably to gasoline.

Regarding its use as fuel aside from the use as automotive fuel in either the blended form with gasoline or in the form of single substance, studies are being made to use it for internal combustion engine by blending with gas oil or as boiler fuel in various countries.

We would like to introduce the interim report of the study commissioned by the Resources and Energy Agency of the Japanese Ministry of International Trade and Indsutry conducted in Japan with respect to the adaptability of ethyl alcohol to various applications as compared to existing fuels in the following paragraphs. It sould be noted however that this study was conducted under the particular circumstances of Japan with respect to oil, environmental pollution control regulations and meteorological conditions so that its findings may not necessarily apply to other countries with different conditions.

3.1 Substitution for Gasoline

The subject of this study was alcohol blended gasoline which is produced by blending either ethyl alcohol or methyl alcohol with gasoline. The study was directed to specific points discussed below. In the following description, alcohol is defined to mean both ethyl alcohol and methyl alcohol.

- Change in basic properties as liquid fuel when gasoline is blended with alcohol.
- Effect on human health and environment if alcohol blended gasoline is used on a large scale.
- Compatibility with Existing Systems
  Effects of properties of the blend on storage, deterioration of quality in the distribution stages, materials and driving performance of automobiles, etc.
- Effects on economy, industry and social system.

Although the study is still in the stage of interim report, the following is an outline of its findings:

3.1.1 Basic properties

(1) Octane number and heat of combustion

Octane number will improve when gasoline is blended with alcohol.

(a) Improvement in reformed gasoline is greater than that in cracked gasoline.
(b) Blending ratio and the rise in octane number hold a substantially linear relationship.
(c) As far as octane number is concerned, no significant difference exists between methyl alcohol and ethyl alcohol.
(d) In the range where alcohol content in the blend is greater, improvement in Motor octane number is greater than that in Research octane value. As for heat of combustion, alcohol is lower than gasoline and therefore the heat of combustion drops in proportion to the increase in the ratio of alcohol blended.

(2) Increase in volatility

By blending alcohol with gasoline, vapor pressure will rise due to azeotropic phenomenon. Boiling point at front-end and intermediate fractions in distillation curve will drop while vapor-liquid ratio will increase. Increase in volatility is greater for ethyl alcohol than for methyl alcohol.

As measures against this problem, studies have been made on the effect of increasing higher boiling range fractions in gasoline, etc. However, this attempt has not yet produced adequately satisfactory effect.

(3) Quality stability

No particular change is noted when alcohol is blended with reformed gasoline with smaller olefin contents. When alcohol is blended with cracked gasoline with larger olefin contents, there is the possibility of evaporation residues being formed in the mixture during storage. Oxidation stability test has also indicated reduction in stability period.

(4) Solubility, separation of water and solubilizer

Alcohol and gasoline will well mix with each other in normal temperature range but commingling of a small amount of water will separate the mixture into two phases.

The quantity of water that will cause phase separation (threshold moisture value) varies depending on type of alcohol, blended volume, temperature, etc. Generally, if content of ethyl alcohol in the mixture is less than 10%, threshold moisture value causing phase separation is more than about 0.5% at 0°C. It is considered that phase separation can be prevented by reducing water content in ethyl alcohol, or taking effective steps to prevent mixture of water into fuel in distribution and application stages.

As regards methyl alcohol, when its content in the mixture is 10%, threshold moisture value causing phase separation is about 0.1% at 0°C. Since presence of water in such an extremely small amount causes phase separation, sufficient measures against infiltration of water must be taken.

Higher alcohols are highly effective as solubilizer that will increase solubility of alcohol blended gasoline and will inhibit phase separation due to mixture of water.

3.1.2 Effect on human health and environment

To study effect on human body from labor safety hygienic standpoints, test was conducted on rats for acute and subacute toxicity, as well as for mutagenicity. Test results showed no difference from those on conventional gasoline.

For effect on environment, tests were conducted to study decomposition by microorganisms, intake by and accumulation in fish, and effect on aquatic plants. However, no difference from conventional gasoline was noted.

3.1.3 Compatibility with existing systems

(1) Effect on distribution equipment

Among distribution equipment currently in use, there are some that are not suited for alcohol blended gasoline. However, this problem can be technically solved. Thus there is fundamentally no problem in this area.

(2) Effect on driving performance of automobiles

Automobiles fueled by alcohol blended gasoline presented no particular problems in driving performance. However, under environment control and meteorological conditions in Japan, some deterioration in driving comfort was noted. When changes in fuel properties such as phase separation occur, this affects driving performance.

(3) Effect on functions of automobiles

When tests with alcohol blended gasoline were conducted on vehicles now on market without any adjustments or modifications for this fuel, results showed following problems: some vehicles cannot completely satisfy the emission standards in Japan. On some cars, low temperature starting characteristics are adversely affected, as well as normal temperature and high temperature drivability. And there is the possibility that faults or failures will occur in fuel system parts and material, thereby lowering reliability and stability.

Based on these results, study was made on the possibility of technical countermeasures.

3.1.4 Effect on economic, industrial and social systems

With technical study on use of alcohol blended gasoline as a base, effect on social and economic systems was assessed by means of a simulation model.

3.2 Substitution for Kerosene, Gas Oil, and Fuel Oil

Use of alcohol not only as substitute for gasoline, but as substitute for middle distillate petroleum products, i.e. kerosene, gas oil and fuel oil, is drawing attention worldwide. However, its study has just begun and technical data on this study has not been accumulated as much as on the study of alcohol blended gasoline.

Investigation in Japan is directed to the understanding of basic properties resulting from blending of alcohol with middle distillates. The following is an outline of the results of this investigation:

3.2.1 Basic properties of ethyl alcohol blended kerosene

(1) Basic properties

(a) Ethyl alcohol's boiling point is 78.3°C which is much lower than kerosene's. As a result, ethyl alcohol alone tends to evaporate as liquid temperature of blended kerosene rises.
(b) Blended kerosene's flashing point is equal to ethyl alcohol's at 13°C so that blended kerosene will be more easily ignited than kerosene alone.
(c) Heat of combustion of ethyl alcohol blended kerosene will drop by about 3.5% per every 10% increase in ethyl alcohol content.
(d) There are no problems in oxidation stability and storage stability compared with kerosene.

(2) Phase separation and solubilizer

With increase in ethyl alcohol content in the mixture, threshold moisture value causing phase separation will increase. When ethyl alcohol content is changed from 10, to 20 and to 30 vol %, threshold moisture value causing phase separation changes from 0.10 to 0.15 and 0.22 vol %, respectively. Higher alcohols exhibited excellent effect as solubilizer.