CITRUS PRODUCTS.*

[The following article has been supplied by the courtesy of the Director of the Imperial Institute. It is of great interest to local growers of citrus and it should be studied with care, especially by those who are developing large citrus areas and are faced with the problem of converting their crops into saleable citrus products.—Ed., *T.A.*]

THE following article is based on a memorandum recently supplied to the Empire Marketing Board by the Imperial Institute:—

The most important citrus products from a commercial standpoint are the following:—

1. *Citrate of Lime and its derivative Citric Acid.*
2. *Concentrated Juice.*
3. *Raw Juice.*
4. *Essential Oils.*

The principal fruit concerned is the lemon, but the lime is also a valuable source of the products, while increasing qualities of oranges are also being utilised, especially in the United States. It may be mentioned that pineapple juice and pineapple waste, which are obtained in large quantities from the canning factories, are now used in the United States as an important source of citrate and citric acid.

1. CITRATE OF LIME AND CITRIC ACID.

Although citric acid is present, together with small amounts of other organic acids, in the juice of citrus fruits, it is not feasible to extract the acid direct from the juice. The citric acid is always first separated by means of the sparingly soluble calcium salt. For this purpose the hot juice, after suitable preliminary treatment, is neutralised by the addition of whiting or ground chalk, or ground limestone if sufficiently pure; the citrate of lime which is precipitated, is filtered off, washed and dried. The citrate may be prepared either from freshly-extracted juice or from the concentrated juice. Details of the method of preparing calcium citrate are given in the Appendix to this article.

Citric acid is prepared from the citrate of lime by treatment with sulphuric acid and is purified by re-crystallisation.

A very pure grade of citric acid can be obtained by the fermentation of sugar with certain moulds, and within the last few years this process has been established on a commercial scale, both in Europe and America.

The imports of citrate of lime and of citric acid into the United Kingdom, with the countries of origin, are shown in Table I.

It will be seen from the figures that Italy is by far the most important source of both products. The industry in that country is highly organised and it should be noted that the lemons used for the preparation of the essential oil and citrate of lime are the surplus fruit remaining over after the needs of the important export trade in fresh lemons have been satisfied. Unusually favourable conditions in the fruit industry may therefore result in restriction of the supplies of lemons available for the citrate and citric

* From the *Bulletin of the Imperial Institute*, Vol. 27, No. 3, 1929.

acid industries. On the other hand if there is a reduced demand for fresh fruit the surplus is used for the production of oil and citrate, the latter of which is at once consigned to an organisation at Messina (the Camera Agrumaria) at a price fixed in advance. The average production of citrate in Sicily is stated to be 7,000 to 8,000 tons per annum, and some time ago large stocks had accumulated at Messina. These, however, have been substantially reduced during recent years and last year amounted to about 10,000 tons.

As the great bulk of the world's supply of citrate has been produced in Sicily, the Camera Agrumaria has been able to control the market and to fix the selling price. Latterly as a result of this control the manufacture of citric acid in Italy has been largely developed and less citrate has been available for manufacturers in other countries. By arrangement with the Italian producers, the manufacture of citric acid in Germany was abandoned several years ago and Germany now imports the acid instead of the citrate from Italy. Table IA gives the exports of citrate of lime and of citric acid from Italy during recent years.

A recent development in the Italian industry is the formation of "Cifac" (Consorzio Italiano Fabbriche Acido Citrico), a syndicate of all the Italian citric acid manufacturers with offices in Messina, the object of which is to control the supply, distribution and price of the citric acid made by the firms concerned. It is understood that the firms comprising the syndicate will have first call on the citrate made in Sicily and that only such quantities will be exported as the firms cannot immediately handle. The effect of this arrangement will be felt most in countries, such as the United Kingdom, which are wholly or mainly dependent on imported supplies of citrate and citric acid. It should stimulate, however, the production of citrate in other countries and may also have an influence on the development of the manufacture of citric acid from sugar by fermentation processes.

The United States (California) is a producer of citrate of lime, the surplus lemon and orange crop being employed in its manufacture as well as pineapple juice and waste. Concentrated lime juice is also imported from the West Indies, and citrate of lime from Italy for the manufacture of citric acid. The fermentation process is now being employed on a commercial scale in the Eastern States.

The production of citrate of lime in the British West Indies has practically ceased and the exports now consist of raw or concentrated lime juice.

Citrate of lime was formerly made in British Guiana from lime juice, but the manufacture failed to give remunerative results and ceased in 1921.

The production of citrate of lime was undertaken in East Africa in 1921, but was soon discontinued and no developments have since taken place. Judging, however, from enquiries received recently at the Imperial Institute from both Kenya and Tanganyika, interest is again being taken in the product in those countries.

Small quantities of citrate of lime have been produced recently in Cyprus from locally-grown lemons and consignments which reached this country were of satisfactory quality.

To sum up: it may be stated that there is a good demand for citrate of lime in this country at the present time owing to the limitation of exports from Italy. British manufacturers of citric acid have stated that they would welcome additional supplies from Empire sources and these, if of good quality, would meet with a ready sale.

As regards the future demand, the possibility of an increased production of citric acid by fermentation methods has to be taken into account, but at present it is not possible to estimate the extent to which this new process will be utilised commercially.

The standard strength of commercial citrate of lime is 64 per cent. of citric acid. The price in London has recently been about £22 per "pipe" of 6 cwt. (on basis of 64 per cent. citric acid content).

2. CONCENTRATED JUICE.

The chief citrus fruits used in the preparation of concentrated juice are lemons (in Italy) and limes (in the West Indies). The raw juice as expressed from the fruits is usually concentrated by evaporation either in open pans or preferably in steam-heated stills.

In making concentrated lime juice in a steam-heated still, the oil which distils over is collected and marketed as "distilled oil of lime." The value of this oil is an important item in the financial returns obtained from the process.

Concentrated juice forms a convenient medium for the transport of citric acid in those cases where, owing to the absence of suitable whiting or chalk, or through other causes, it is impracticable to make citrate of lime. The juice is used not only as a source of citrate of lime and ultimately of citric acid, but is also employed directly for certain industrial purposes.

The trade returns of the United Kingdom do not differentiate between concentrated and raw juice, or between lemon and lime juice. The total imports of such juices into this country have been as follows :—

—	1924.	1925.	1926.	1927.
	gallons.	*gallons.*	*gallons.*	*gallons.*
Total	424,810	497,982	540,625	467,109
From British West Indies	281,527	368,608	264,260	184,092
Italy	88,586	101,600	256,534	266,930

Speaking generally, it may be said that juice from the British West Indies consists of both concentrated and raw lime juice, while that from Italy is mainly raw lemon juice. Some idea of the quantity of concentrated lime juice imported into this country may be obtained from the figures given in Table II which show the exports from the chief producing countries.

The exports of concentrated lime juice from the British West Indies have fallen much below the figures of former years, owing to the damage caused by root diseases and withertip disease in Dominica which has resulted in a greatly reduced yield of fruit in that island.

Other British countries which are producing concentrated juice on a small scale are the Union of South Africa and Cyprus. In both cases lemons are used as a source of juice.

Concentrated lime juice was prepared in East Africa in 1921, but the manufacture was not continued on a commercial scale.

In view of the established market in this country for concentrated lime juice, its production could be safely undertaken as an alternative to the preparation of citrate of lime. It is important, as indicated above, that the essential oil expressed with the juice should be recovered during the process of evaporation as its value adds considerably to the financial return obtained.

The juice is concentrated until it contains about 100 oz. of citric acid per gallon and is exported in casks containing 40 to 50 gallons. The present price in London is £28 per pipe of 108 gallons containing 64 oz. of citric acid per gallon. The price of concentrated juice containing larger amounts of citric acid per gallon is proportionally higher.

3. RAW JUICE.

Raw citrus juice, prepared from limes, lemons and oranges, is used for making beverages. As explained in the preceding section on concentrated juice it is not possible to give the imports of raw citrus juices into the United Kingdom. The exports from the chief producing countries, so far as figures are available, are shown in Table III.

The production of raw lime juice in the West Indies, as in the case of the concentrated juice, has been greatly affected by diseases.

The demand for raw lime juice is seasonal and largely influenced by the character of the summer weather. The state of the market is an important factor in deciding whether raw juice can be profitably shipped and it is therefore necessary for producers to keep in close touch with importers in this country. The present price of raw lime juice in London is about 4s. 6d. per gallon.

During the last three or four years there has been a very large increase in the export from Italy of raw lemon juice, which is being increasingly utilised for the production of beverages.

4. ESSENTIAL OILS.

The chief essential oils produced from citrus fruits are the following :— Lemon oil, Lime oil, Orange oil, Bergamot oil and Mandarin oil. The oils are obtained from the peel by pressure and in the case of limes and oranges also by distillation.

In making the expressed oils, the oil cells in the peel are ruptured by pressure or by rotating the whole fruit in an écuelle, and the oil which exudes is collected. The finest lemon oil is obtained in Sicily by pressing the peel in contact with a sponge, which absorbs the oil. Recently, pressing machines have been introduced in Sicily for the purpose. Expressed lime oil is chiefly made in the West Indies by the process of écuelling.* In the case of limes and oranges the fruit after being écuelled is submitted to pressure whereby the juice is expelled together with a further quantity of oil.

Distilled lime and orange oils are obtained as by-products in the manufacture of the concentrated juice, as mentioned in section 2. Citrus oils prepared by distillation are of lower quality and value than expressed oils, owing to changes brought about during the process of distillation.

It is not possible to state the imports of the various citrus oils into the United Kingdom, but the exports from certain producing countries are shown in Table IV. Other important exporting countries are Spain and France. Hitherto, these countries have not published figures showing the export of citrus oils except that in 1928 the total export of all citrus oils from France is given as the equivalent of 74,005 lb.

The principal source of supply of lemon oil is Italy, although increasing quantities are now being produced in California. The latter oil is chiefly marketed in the United States. There is always a good demand for lemon oil and during 1928 the price in London rose steadily from 8*s*. per lb. in January to 12*s*. 6*d*. in July and to 14*s*.-15s. at the end of the year. The present price is 15*s*. 6*d*.-16*s*. per lb. in London.

The rise in price is attributed in the market to a reduction in the Italian production. The Imperial Institute has recently been informed that owing to the large demand for fresh lemons last season much of the fruit which would have been used in Italy for the manufacture of oil and citrate was exported and that consequently the amount of oil produced was very low.

Lime oil has been realising high prices owing to a good demand and shortage of supplies from the West Indies due to diseases and the effect of the recent hurricane. Up to 34*s*. per lb. has been paid recently in London for the distilled oil, and the range in price during 1928 was 24*s*. to 30*s*. per lb. The London price of the hand-pressed oil ranged from 35*s*. to 40*s*. per lb. during 1928; this oil is at present scarce and worth nominally 65*s*. per lb.

* An écuelle is a saucer-shaped vessel made of tinned copper, the inside of which is covered by short spikes, about ½ in. long. The fruit is placed in the écuelle and by a rapid rotatory motion the oil cells are ruptured and the oil so released is collected through a tube leading from the bottom of the écuelle.

Table I.

Total Imports of Citrate of Lime and Citric Acid into the United Kingdom.

Particulars.	1924.	1925.	1926.	1927.	1928.
...,	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
CITRATE OF LIME					
Total	3,599,680	4,326,560	5,587,344	4,812,528	(a)
From :					
Italy	3,553,984	4,311,776	5,464,368	4,496,016	(a)
Spain	—	11,424	119,392	309,792	(a)
Other Foreign Countries	896	—	—	—	(a)
British West Indies	40,320	3,360	3,584	—	(a)
Other British Empire	4,480	—	—	6,720	(a)
CITRIC ACID					
Total	542,080	782,544	624,512	674,576	(a)
From :					
Italy	506,464	738,752	554,960	602,000	(a)
Netherlands	24,976	7,840	18,816	17,584	(a)
France	10,640	16,240	22,512	38,080	(a)
Other Foreign Countries	—	18,592	28,224	16,912	(a)
British Empire	—	1,120	—	—	(a)
Re-exports from the United Kingdom.					
CITRATE OF LIME	—	—	—	—	(a)
CITRIC ACID	57,568	89,600	68,800	21,504	(a)

(a) Information not yet available.

Table IA.

Exports of Citrate of Lime and Citric Acid from Italy.

Citrate of Lime.

Particulars	1924.	1925.	1926.	1927.	1928.
	lb.	*lb.*	*lb.*	*lb.*	*lb.*
Total	8,322,890	10,313,223	10,132,665	6,846,455	3,587,141
To :					
United Kingdom	3,474,705	4,418,063	4,646,021	4,637,643	2,308,901
France	2,009,072	2,265,470	2,631,217	2,208,812	1,254,430
Germany	378,313	—	441	—	(a)
United States	2,458,374	3,628,367	2,632,099	—	—
Citric Acid.					
Total	4,256,244	6,119,811	4,544,388	4,412,552	7,358,147
To :					
United Kingdom	528,007	704,156	595,028	578,272	1,209,676
France	285,278	601,201	580,477	562,179	1,147,285
Argentina	511,693	582,902	619,278	491,851	759,492
United States	805,789	754,201	190,920	103,397	63,273
Germany	541,455	1,140,231	179,236	688,283	1,330,710

(a) Information not yet available,

Table II.

Exports of Concentrated Citrus Juice.

—	1924.	1925.	1926.	1927.	1828.
	gallons.	*gallons.*	*gallons.*	*gallons*	*gallons.*
LEEWARD ISLANDS (Lime Juice)					
Dominica: Total	237,369	111,778	104,014	106,971	90,371
To:					
United Kingdom	19,514	1,512	88	6,521	(*a*)
United States	217,855	110,266	102,364	100,030	(*a*)
Antigua: Total	—	290	2,050	5,250	2,350
To:					
United Kingdom	—	290	2,050	—	(*a*)
United States	—	—	—	5,250	(*a*)
WINDWARD ISLANDS (Lime Juice)					
St. Lucia: Total	33,718	40,858	35,234	38,064	18,028
To:					
United Kingdom	2,240	—	120	—	9,448
Canada	220	—	—	—	—
United States	31,258	40,858	35,114	38,064	8,580
Grenada: Total	7,331	9,075	6,520	11,048	18,720
To:					
United Kingdom	1,831	3,450	2,520	5,350	18,040
United States	5,500	5,625	4,000	5,698	680
TRINIDAD AND TOBAGO (Lime Juice)					
Total	7,505	6,171	7,886	4,488	(*a*)
To:					
United Kingdom	5,562	1,680	1,128	—	(*a*)
United States	1,743	4,491	6,758	4,488	(*a*)
British North America	200	—	—	—	(*a*)
JAMAICA (Lime Juice)					
Total	54,206*	87,755*	21,399*	5,027	43,791*
To:					
United Kingdom	34,834	85,365	17,096	—	(*a*)
United States	10,408	975	518	4,820	(*a*)
BRITISH GUIANA (Lime Juice)					
Total	9,650	8,430	4,974	5,249	8,124
To:					
United Kingdom	—	—	160	93	8,124
United States	9,650	8,430	4,814	5,156	—
	lb.	*lb.*	*lb.*	*lb.*	*lb.*
MARTINIQUE (Lime Juice)					
Total	36,597	81,571	—	(*a*)	(*a*)
ITALY†					
Total	1,500,466	2,248,053	2,270,541	1,287,058	841,945
To:					
United Kingdom	87,083	54,234	125,663	(*a*)	(*a*)
Czecho-Slovakia	6,834	—	—	(*a*)	(*a*)
United States	1,373,921	2,174,639	2,142,232	(*a*)	(*a*)

(*a*) Information not yet available.

* Including raw juice; separate figures for 1923-26 and 1928 not available.

† The juice exported from Italy is described in the Trade Returns as "lemon and lime juice"; most, if not all, consists of lemon juice.

Table III.

Exports of Raw Citrus Juice.

—	1924.	1925.	1926.	1927.	1828.
	gallons.	*gallons.*	*gallons*	*gallons*	*gallons.*
LEEWARD ISLANDS (Lime Juice)					
Dominica: Total	348,324	313,247	268,760	173,848	306,090
To:					
United Kingdom	233,902	227,210	198,077	105,255	(*a*)
British North America	32,488	29,891	11,386	20,886	(*a*)
United States	71,097	51,786	55,587	44,601	(*a*)
Montserrat: Total	22,551	6,497	31,184	33,697	2,422
To:					
United Kingdom	8,579	6,497	31,184	21,551	(*a*)
British North America	13,532	—	—	11,619	(a)
Antigua: Total	1,650	—	2,950	—	840
To:					
United States	1,200	—	—	—	(*a*)
WINDWARD ISLANDS (Lime Juice)					
St. Lucia: Total	8,490	23,428	43,893	17,509	12,598
To:					
United Kingdom	700	23,028	42,921	10,950	10,762
Canada	1,200	400	971	6,559	1,796
Barbados	—	—	1	—	—
Bermuda	6,340	—	—	—	—
St. Vincent	—	—	—	—	40
United States	250	—	—	—	—
St. Vincent: Total	175	438	10	(*b*)	(*b*)
To:					
Barbados	175	438	10	—	—
JAMAICA (Lime Juice)					
Total	54,206*	87,755*	21,399*	27,554	43,791*
To:					
United Kingdom	34,834	85,365	17,096	22,175	(*a*)
United States	10,408	975	518	3,103	(*a*)
BRITISH GUIANA (Lime Juice)					
Total	135	(*b*)	(*b*)	(*b*)	(*b*)
To:					
United Kingdom	135	(*b*)	(*b*)	(*b*)	(*b*)

(*a*) Information not yet available.

(*b*) Not shown in Trade Returns.

* Including concentrated juice; separate figures for 1923-26 and 1928 not available.

Table III.

Exports of Raw Citrus Juice.—(continued).

	1924.	1925.	1926.	1927.	1928.
	gallons.	*gallons.*	*gallons.*	*casks.*	*casks.*
NORFOLK ISLAND* (Lemon Juice)					
Total	(a)	(a)	(a)	226	170
To:					
Australia	(a)	(a)	(a)	220	(a)
New Zealand	(a)	(a)	(a)	6	(a)
	lb.	*lb.*	*lb.*	*lb.*	*lb.*
ITALY†					
Total	1,140,672	1,718,283	4,239,048	5,466,581	5,983,345
To:					
United Kingdom	784,405	1,025,811	2,262,605	(a)	(a)
France	99,428	33,951	9,259	(a)	(a)
Germany	192,464	457,018	1,726,000	(a)	(a)
United States	9,259	142,860	109,129	(a)	(a)

* Years ended June 30th.

(a) Information not yet available.

† The juice exported from Italy is described in the Trade Returns as "lemon and lime juice"; most, if not all, consists of lemon juice.

Table IV.

Exports of Citrus Oils.

1. Exports of Lemon Oil.

	1924.	1925.	1926.	1927.	1928.
	lb.	*lb.*	*lb.*	*lb.*	*lb.*
ITALY					
Total	1,653,579	1,712,299	1,371,405	1,259,756	1,384,507
To:					
United Kingdom	538,245	483,776	383,388	Figures not yet available	
Australia	82,742	39,564	42,135		
France	182,278	222,330	189,492		
Germany	184,346	174,154	122,390		
Netherlands	51,365	30,801	30,655		
United States	474,457	589,161	484,607		

2. Exports of Lime Oil.

LEEWARD ISLANDS					
Dominica:					
Ecuelled:					
Total	11,795	10,306	9,381	7,828	*
To					
United Kingdom	1,877	2,134	608	3,532	*
United States	9,918	6,457	8,479	3,673	(a)
Distilled:					
Total	37,244	35,373	33,471	31,346	*
To					
United Kingdom	14,458	22,531	11,750	17,423	(a)
United States	21,416	8,817	18,291	13,923	(a)

* The preliminary Trade Returns for 1928 show a total export of 32,174 gallons of lime oil, including both écuelled and distilled oils.

(a) Information not yet available.

Table IV.

Exports of Citrus Oils.—(continued).

2. Exports of Lime Oil.—(continued).

	1924.	1925.	1926.	1927.	1928.
	lb.	*lb.*	*lb.*	*lb.*	*lb.*
LEEWARD ISLANDS *continued*					
Antigua:					
Total†	—	—	—	1,246	934
To:					
United States	—	—	—	1,246	(*a*)
Montserrat:					
Ecuelled:					
Total*	—	152	34	41	(*a*)
Distilled:					
Total	484	—	—	—	(*a*)
WINDWARD ISLANDS					
St. Lucia:					
Hand-pressed:					
Total†	2,710	4,400	5,078	3,335	4,526
To:					
United Kingdom	581	563	792	193	71
United States	2,129	3,837	4,286	3,142	4,384
Canada	—	—	—	—	71
Distilled:					
Total*	8,970	8,494	9,377	8,606	10,030
To:					
United Kingdom	536	813	1,393	95	1,018
United States	8,434	7,681	7,205	8,511	8,810
Canada	—	—	779	—	202
Grenada:					
Total*	952	1,125	2,457	8,019	(*a*)
To:					
United Kingdom	952	1,125	2,457	7,846	(*a*)
United States	—	—	—	173	(*a*)
TRINIDAD AND TOBAGO					
Total*	(*b*)	934	3,728	900	4,282
To:					
United Kingdom	(*b*)	934	2,708	865	(*a*)
British West Indies	(*b*)	—	631	—	(*a*)
United States	(*b*)	—	389	35	(*a*)
BRITISH GUIANA					
Total*	3,426	2,646	2,396	3,361	3,806
To:					
United Kingdom	3,426	2,646	2,396	2,049	3,806
United States	—	—	—	312	—
3. Exports of Orange Oil					
LEEWARD ISLANDS					
Dominica:					
Total	1,319	2,278	805	2,638	(*a*)
To:					
United Kingdom	—	140	—	35	(*a*)
United States	1,319	2,067	770	2,503	(*a*)

(*a*) Figures not available.
(*b*) Not shown in Trade Returns.
† Converted from gallons into lb. assuming 1 gall. = 8·8 lb.
* Converted from gallons into lb. assuming 1 gall. = 8·65 lb.

Table IV.

Exports of Citrus Oils.—(continued).

3. Exports of Orange Oil.—(continued).

	1924.	1925.	1926.	1927.	1928.
	gallons.	*gallons.*	*gallons.*	*gallons*	*gallons.*
ST. LUCIA					
Total	—	1	⅓	—	—
To:					
United Kingdom	—	1	—	—	—
United States	—	—	⅓	—	—
	lb.	*lb.*	*lb.*	*lb.*	*lb.*
JAMAICA					
Total	84,453	103,519	64,000*	88,000*	(*a*)
To:					
United Kingdom	(*a*)	21,027	(*a*)	(*a*)	(*a*)
Canada	(*a*)	2,900	(*a*)	(*a*)	(*a*)
United States	(*a*)	79,142	(*a*)	(*a*)	(*a*)
ITALY					
Total	279,548	263,049	278,228	303,568	287,483
To:					
United Kingdom	40,034	37,393	31,200	(*a*)	(*a*)
France	47,499	52,810	61,189	(*a*)	(*a*)
Gremany	22,798	20,642	26,385	(*a*)	(*a*)
Netherlands	18,201	21,874	5,990	(*a*)	(*a*)
United States	131,107	114,926	129,094	(*a*)	(*a*)
	4. Exports of Bergamot Oil.				
ITALY					
Total	354,228	391,100	336,771	379,621	412,361
To:					
United Kingdom	46,623	50,548	55,530	(*a*)	(*a*)
France	165,199	159,198	136,563	(*a*)	(*a*)
Germany	32,800	37,289	33,455	(*a*)	(*a*)
Netherlands	12,535	15,406	10,593	(*a*)	(*a*)
United States	55,045	80,916	72,614	(*a*)	(*a*)
	5. Exports of Mandarin Oil.				
ITALY					
Total	8,834	11,964	12,897	19,317	18,104
To:					
United Kingdom	2,068	2,055	1,929	(*a*)	(*a*)
France	1,817	2,809	2,835	(*a*)	(*a*)
Germany	562	564	648	(*a*)	(*a*)
Australia	522	661	170	(*a*)	(*a*)
United States	3,261	4,147	6,506	(*a*)	(*a*)

* Production.

(*a*) Figures not available.

APPENDIX.

MANUFACTURE OF CITRATE OF LIME. (CALCIUM CITRATE).

The following particulars have been kindly supplied to the Imperial Institute by Messrs. Kemball, Bishop and Co., Ltd :—

In preparing citrate of lime from lemons *the skins* are removed and squeezed on a sponge to extract the essential oil and are afterwards put into brine and exported for the manufacture of candied peel. The inside of the lemon, which is so skilfully peeled that it is still firm and solid, is crushed in a press to extract all the juice possible.

In the case of limes in the West Indies, the skins of the fruits are not removed, the friuts being crushed whole, either with or without previous "écuelling."

The juice which is obtained by crushing is run through a strainer so that it is practically clear, as any pulp left in the juice spoils the subsequent filtration and washing of the citrate of lime. Moreover, if pulp is left in the citrate of lime it will be impossible to get a really high percentage of citric acid.

The neutralisation of the juice is best effected by means of whiting or chalk. Whiting is made from chalk crushed under water; it is extremely fine. Chalk in most cases is quite satisfactory, but it requires crushing and should be sifted to remove any lumps. The latter are liable to be unacted on by the weak acid, and will remain in the citrate, lowering the percentage of citric and causing loss to the citric acid manufacturer.

Limestone and coral, although consisting of carbonate of lime, like chalk or whiting, are usually so crystalline and hard that they are unable to finish the neutralisation of lemon juice. Very fine grinding might, however, get over this difficulty.

The vessel usually employed for the neutralisation of the juice by whiting or chalk, is a tub, say 10-12 ft. in diameter and 5-6 ft. high. The tub is provided with an agitator the full diameter of the tub, about 1 ft. high and 3 in. thick. The agitator should make 14-16 revolutions a minute, and should always be right at the bottom of the tub.

These big agitators should be so made that they can be pulled up in their bearings, in order that in an emergency they can be raised clear of the solid matter in the tub; otherwise, they may become stuck and have to be dug out. After the trouble is past, they can be lowered again gradually until they are in their proper position as near the bottom of the tub as possible.

After a little water has been placed in the tub, all the whiting is put in with the agitator revolving, and a steam jet is started to heat the mixture; when the temperature has been raised to 150°F. the juice is run in, taking care that the liberated carbon dioxide does not cause the tub to overflow.

So long as there is brisk effervescence more juice is necessary. Juice should be added cautiously until a hot sample from the tub gives only a faint effervescence with a little sulphuric acid, thus showing that the amount of whiting left is very small.

To make sure that citric acid is not in excess, a sample of the hot mixture should be tested with a little whiting mixed into a "cream" with water. This is better than using dry whiting to show up traces of excess of acid.

The temperature is now raised to 180°F. and if the test with sulphuric acid still shows a faint effervescence and the test with "cream" of whiting shows a negative result the mixture can be filtered.

The filter may be a shallow tank with an outlet from the bottom, with loose strips of wood laid on the bottom, and a cloth supported on the strips and coming to the top of the tank at all the four sides. The strips of wood keep the cloth off the bottom of the tank and so allow the liquor to run freely into the chamber thus formed, to the outlet of the tank and thence to the drain.

The facility with which the waste liquor will filter away from the citrate of lime depends on the degree of excellence obtained in filtering the juice, and also on the quality of the whiting or chalk used. As these factors vary it is difficult to suggest the proportions of the tank. It should, however, hold all the charge at once, which may be as much as 3,000 gallons; perhaps 14 ft. by 20 ft. by 2 ft. deep would be suitable. It is necessary to ensure that the liquor shall drain rapidly, before it gets at all cold. Citrate of lime is distinctly more soluble in cold than in hot water; cold liquor or water, therefore, means a loss of citrate in the water drained away.

It is always advisable to wash out as much possible of the liquor that remains in the cake by means of hot water. If the citrate is only drained, it leaves a good deal of impurity in it.

After allowing all moisture possible to drain out of cake, the wet mass is cut off the cloth and dried. This can be done in rooms with shelves heated by steam pipes, or even by fires, but there must be plenty of ventilation so that the water vapour is carried away in the air. Citrate will come to no harm up to 300°F.

It is most important that the citrate should be dried quickly as it decomposes rapidly when damp. The decomposition converts the calcium citrate into calcium carbonate and what was once a good citrate may rapidly become a bad citrate with low citric acid content and high calcium carbonate content.

As whiting is in excess in the tub, from the beginning to the end of the process, no acid can be present to attack the iron spindle of the agitator, etc. Too great an excess of whiting, however, reduces the citric acid content and is therefore objectionable.

In cases where neither whiting nor other suitable form of carbonate of lime is available, quicklime, made by burning limestone in a kiln, may be used, but the process as described above must be modified to some extent.

In this case the acid juice must go into the tub first and iron work is therefore liable to suffer. To prevent this it is usual to cover the spindle, etc., with lead.

The juice is heated and quicklime (which has been previously slaked with water to a thin cream) is added. It must be not added in excess, if the best citrate is desired, because excess of lime brings down iron and other impurities.

If by accident too much slaked lime is added, so that the mixture turns litmus blue, a good excess of juice must be added to get it sharply acid again, and it should be allowed to stay acid for say half-an-hour to take up the iron, etc., precipitated. After this, lime is again added more cautiously.

The final test is when a sample of the hot mixture will give very little or no effervescence with "cream" of whiting, and at the same time is acid or neutral to litmus.

The rest of the process is exactly as described before.

The purity of the chalk, or other form of limestone, used for neutralisation is of great importance. Iron, alumina, phosphoric acid and mangesia must be only present in traces. All these harm the product and produce loss. If magnesian limestone (dolomite) were used, possibly one-half of the total citric acid would be lost in the draining water.

Some citrates drain very poorly on an ordinary filter, and they hold so much water that they are very difficut to dry. There are two possible ways of overcoming this, but both require apparatus. One is to use a vacuum filter instead of an ordinary filter, and the other is to replace the filter by a filter press, into which the mixture can be pumped at high pressure. Judging by the appearance of some of the citrates from Sicily, the latter method is probably that at present employed in that country.