

Production and Quality Improvement of Satsuma Mandarin Juice in Japan

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In the citrus industry of Japan, the year 1972 marked a turning point that the production of Satsuma mandarin exceeded a level of 3 million tons for the first time, and measures for production curtailment were taken up, contrary to those to increase production so far promoted. In addition, measures to increase citrus juice consumption were strongly adopted in view of the ceiling demand for fresh fruit for eating. As a result, a marvellous leap in the juice production has been recorded: within only about 10 years, the use of Satsuma mandarin for producing juice has reached as much as 700,000 tons.

However, as the production of Satsuma mandarin shows great yearly variations, and it is influenced by the import liberation of oranges caused by a global trend of citrus overproduction, there are many problems for the stable growth of citrus industry of Japan, in spite of the remarkable increase in the demand for processing.

Taking the such background into consideration, the trend of mandarin juice production and problems related to the quality improvements of the juice will be discussed in this paper.

Trend of production and consumption for processing of Satsuma mandarin

Production of Satsuma mandarin in Japan showed a marvellous increase from 2 million tons in 1969 to 3 million tons in a period of only 3 years. The planted area in 1980 was

approximately 140,000 ha, which showed a decrease by more than 30,000 ha as compared to 1972 area. However, 24% of it was the area newly planted in 1965-1975, where fruit yields will increase with the maturing of trees, so that the total production is expected to increase, ranging between 3 and 3.6 million tons for some time to come (Table 1).

As to the consumption for processing, the increase of consumption for canning to a level more than 200,000-300,000 tons is hardly expected because of stagnant export. On the other hand the consumption for producing juice has increased markedly: it increased from about 90,000 ton in 1970 to a level at 6 times that only within 5 years, and still continued, although it showed yearly variations caused by biennial bearing of Satsuma mandarin. Finally, it exceeded 1 million ton, i.e., 27.8% of the total production of mandarin, in 1980.

Construction of fruit juice factories and production of mandarin juice

In view of the production trend of Satsuma mandarin, the Ministry of Agriculture and Forestry planned "The project to increase demand for fruit processing", by which construction of fruit juice factories for mandarin and apple was implemented by subsidies in 1970-1974. The total capacity of the all factories is 285,000 tons (Table 2), on the basis of 10,000 to 20,000 tons of mandarin for 1 season, 8 hrs work per day, and 77 days of

Table 1. Production and utilization of Satsuma mandarin in Japan

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Planted area (ha)	163,000	167,000	171,300	173,100	172,400	169,400	164,000	158,600	153,200	147,500
Bearing area (ha)	137,000	144,200	151,000	156,300	160,300	160,700	157,700	153,900	149,400	143,400
Total production (t)	2,552,000	2,488,000	3,568,000	3,389,000	3,383,000	3,665,000	3,088,000	3,539,000	3,026,000	3,618,000
Production/10 a (kg)	1,860	1,730	2,360	2,170	2,110	2,280	1,950	2,300	2,025	2,523
Fresh fruit for eating (t)	2,186,800	2,135,900	2,947,000	2,693,800	2,837,800	2,884,200	2,261,200	2,547,000	2,260,310	2,302,500
Export (fresh fruit) (t)	24,795	25,851	21,719	24,151	21,231	18,500	19,400	20,900	13,040	16,000
Canned fruit (t)	246,100	183,000	293,400	306,500	182,000	224,600	245,300	247,700	205,700	293,000
Jam (t)	1,350	970	760	700	750	700	800	650	750	
Juice (t)	93,000	142,300	305,000	363,800	341,000	537,000	561,400	722,800	546,200	1,006,500
Total (t)	340,400	326,270	599,160	671,000	524,000	762,300	807,500	971,150	752,650	1,299,500

Source: Ministry of Agriculture, Forestry and Fisheries

work. By extending working hours and working days, it can treat more than 1 million ton of fruit.

Table 2. Juice processing factory in Japan

Year	Number of factories	Total capacity (tons of fruit)	
		Per year	Per day
1970-71	4	53,000	690
1971-72	3	25,000	320
1973	7	126,000	1,460
1974	6	81,000	940
Total	20	285,000	3,410

Source: Ministry of Agriculture, Forestry and Fisheries.

To expand the fruit juice consumption, it is not enough to increase only quantitative capacity of producing juice, but the product must have a high quality to be recognized internationally and accepted by consumers as a natural fruit juice. Facilities required for that purpose were examined, and it was made clear that the facilities enabling to produce frozen concentrated fruit juice by the cut-back method are needed. Thus, the formerly used chopper-pulper juice extractors were replaced by the In-line extractors, and the puddle-type finishers by the screw-type finishers. In addition, frozen storage facilities, fully automatic bottling procedures, etc. were introduced, resulting in a rapid modernization of processing facilities.

According to the construction of these juice producing factories, the production of mandarin juice has increased markedly, as shown in Table 3. If there were no these factories available in 1972, the bumper harvest year, the slump of fresh fruit price would have been more serious. The construction of factories promoted as a subsidy project was quite timely, indeed. However, as the amount of juice to be produced is determined firstly by the production of mandarin, a new problem to be solved urgently, i.e., fruit juice overproduction, has arisen.

Table 3. Trends in Satsuma Mandarin and Natsudaidai juice production in Japan [converted to 1/5 concentrates (t)]

Year	Satsuma mandarin	Natsudaidai
1967	2,649	1,657
1970	7,509	2,950
1972	25,412	4,128
1975	48,644	3,276
1977	70,498	3,439
1978	55,051	2,472
1979	99,217	4,993

Source: Ministry of Agriculture, Forestry and Fisheries.

Quality improvements of Satsuma mandarin juice

The Satsuma mandarin is originally a cultivar to be used as the fresh fruit for eating, and its easy peeling and seedlessness are excellent properties not comparable to other citrus cultivars. Characteristics of chemical components and problems related to juice quality will be presented below.

Color tone: Of carotenoids of Satsuma mandarin, monol fraction mostly composed of cryptoxanthin accounts for approximately 70% (Table 4)⁸⁾. Due to this fact, fruit juice of Satsuma mandarin shows brilliant orange color, not comparable to other citrus.

Table 4. Carotenoid pattern of several citrus fleshes

	Total carotenoid (mg%)	Carotenoid pattern (%)					
		H	M	D	DM	DD	P
Naruto orange	0.43	5.7	9.3	11.3	20.8	50.4	2.5
Sanpoka	0.58	3.4	12.7	13.2	14.5	54.0	2.1
Navel orange	0.59	2.1	19.7	6.6	21.7	45.9	4.1
Valencia orange	1.48	2.9	16.0	10.0	15.0	50.4	5.9
Kunenbo	0.93	9.7	59.0	4.1	9.6	8.9	7.6
Yonezawa U.	2.23	3.2	73.1	4.4	5.2	10.7	3.3
Ponkan	0.64	15.1	34.2	9.3	13.9	22.1	5.4

Abbreviation: H: hydrocarbon, M: monol, MM: Monol monoepoxide, D: diol, DM: diol monoepoxide, DD: diol diepoxide, P: polyol.

Table 5. Varieties used for blending to Satsuma mandarin juice

Excellent	Fairly good	No good
Valencia orange	Trovita orange	Navel orange
Fukuhara orange	Natsudaidai	Hyuganatsu
Ponkan mandarin	Kinkoji	Iyo
	Ujukitsu	Sanboka
	Tankan mandarin	Daidai
	Yuge-hyokan	Kunenbo
	Hanayu	
	Seminole	

Essential oil: Flavor of citrus fruits is attributed to essential oils contained in oil glands of pericarp. In Satsuma mandarin, monoterpene hydrocarbons account for nearly 95% of the essential oils and 90% of the former is *d*-limonene. This composition is similar to that of orange. In addition, sesquiterpene hydrocarbons such as β -elemene, etc., and terpene-alcohols such as linalol, etc. are present as minor components. These minor components are abundant in November when the juice production begins, and are decreased in the following February (close to the end of juice production). By the sensory tests, the minor components are inferred to be closely related to the flavor of essential oils²⁾. Kita et al.⁵⁾ identified 2 acetates as the source of the flavor specific to Satsuma mandarin, and found the plenty of sesquiterpene and esters as the characteristics of the essential oil composition of Satsuma mandarin.

Off-flavor caused by heating: A smell caused by heat treatment in the process of fruit juice production of Satsuma mandarin is called off-flavor or ipomeamarone-like smell and is the greatest defect in the quality of juice. It was recently found that dimethyl sulfide (DMS) derived from S-methylmethionine sulfonium and hydrogen sulfide are the cause of the deterioration of flavor.⁷⁾

Bitter substance: Fruit juice of Satsuma mandarin often shows bitterness, which is caused by limonoids. The limonoid content in flesh is closely related to maturing of the fruit: it is high in immature fruit and decreases with the maturity. In the fruit fully matured on trees, limonoids disappear almost

Table 6. Effects of other citrus juices blended on the quality of Satsuma mandarin juice (1970-1972)

Materials used for blending	Brix	Citric acid	Brix acid ratio	pH	Amino nitrogen	AsA	Flavanon	Pulp	Color value a	Flavor
<Reamer>										
		%			mg%	mg%	mg%	%		
Ponkan mandarin	11.7	0.86	13.6	3.73	35	26	120	13	5.8	a
Kunenbo	11.6	0.85	13.6	3.73	36	25	116	10	3.3	b
Kinkōji	10.9	0.75	14.5	3.80	36	24	114	12	4.4	b
Ujukitsu	11.0	0.75	14.7	3.90	36	26	117	8	5.3	b
Kawano natsudaikai	11.4	0.82	13.9	3.78	36	26	124	8	4.3	b
Valencia	11.7	0.95	12.3	3.69	39	30	128	10	2.3	a
Trovita·orange	11.6	0.95	12.2	3.55	35	28	93	8	4.6	b
<In Line>										
Fukuhara orange	11.3	0.92	12.0	3.60	39	28	156	12	3.2	a
Trovita·orange	11.4	0.92	12.4	3.64	40	28	200	11	2.6	b
Ponkan mandarin	11.4	0.90	12.7	3.66	37	26	166	11	3.7	a
Yuge-hyokan	11.4	0.99	11.5	3.53	35	27	153	10	3.5	b
Tankan	11.4	0.90	12.7	3.60	36	28	200	8	3.8	b

Blending ratio = Satsuma mandarin 9: other citrus juice 1

Sensory evaluation of flavor: a = good, b = comparatively poor

completely, so that their juice is highly evaluated for taste, giving almost no bitterness by sensory tests¹⁾.

The greatest defects of Satsuma mandarin fruit juice are related to smell such as lacking of flavor and refreshingness, and deterioration of flavor by heating. Results of studies so far done to improve this aspect are summarized as follows:

1) Quality improvement by blending

Studies on fruit juice production of Satsuma mandarin in Japan were initiated by Shiga, Kono, Matsui and others. Matsui et al.⁶⁾ proposed that the Reamer juice extractor devised by them can give a better quality of juice as compared to previously used chopper-pulper type extractor, and that adding of orange juice is necessary to improve flavor of mandarin juice.

Later, blending experiments with more than 20 species of citrus were carried out in Okitsu Branch of Fruit Tree Research Station, and it was found that 10% blending of Valencia, Fukuhara orange, or Ponkan was effective in improving quality of Satsuma mandarin juice (Table 5 and 6)⁴⁾. Particularly, the flavor of Fukuhara orange is regarded to be mild and

highly preferable.

2) Experiments on production of frozen concentrated fruit juices

From the viewpoint that processing technology is to exploit new demands, the most dramatic technology development in the history of fruit drinks might be the production of frozen concentrated fruit juices by the cut back method. By this method, the fresh juice without heat treatment is immediately added to the juice, which has been concentrated to 60° Brix, to adjust the sugar content to 45° Brix and stored below -18°C by refrigeration.

In Japan, experiments to produce frozen concentrated fruit juices was initiated by Okamoto, Tomiki and others. Ito et al.³⁾ tried to select cultivars adapted to the cut back method, and found out that Valencia and Fukuhara orange are superior to others for the method, out of 9 cultivars tested.

At present, more than 90% of fruit juice is consumed in this form in Florida, but the consumption was not increased at all in Japan. However, as the product has superior advantages in flavor strengthening and quality-keeping effect, effort has to be continued to

increase its consumption.

3) Quality improvement by adding essential oils of pericarp

Satsuma mandarin juice obtained by the In-line extractor has a better flavor than those obtained by other type extractors. This is considered due to the essential oils in pericarp which are mixed into juice during the process of extraction. However, when the fruit juice is stored for a long period, the essential oils are oxidized, and it sometimes causes deterioration of juice quality.

With oranges, cold press oil from fruit pericarp or extraction residue, or recovery essence obtained during the concentrating process of juice are used to add flavor to concentrated juice, but it is difficult to obtain these materials with Satsuma mandarin because its pericarp is weak and contains less amount of essential oils.

Ifuku et al.²⁾ examined yield and property of essential oils of Satsuma mandarin during a period from December to March. The maximum yield was 0.038% (in December), and the flavor was best when sampled in November. To improve the flavor of Satsuma mandarin, it was made clear that the addition of the essential oils by 0.025-0.05% gave the best result.

As mentioned above, the flavor improvement is the most important key point of quality improvement of Satsuma mandarin juice. In this case, it is necessary to develop juice products, not only with orange-like flavor added, but also with the best use of the flavor specific to Satsuma mandarin. In addition, it is also a great problem in future to develop a new technology to prevent deterioration of flavor

which occurs during the storage of fruit juice, i.e. technology for maintenance and stabilization of flavor components.

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