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Current Situation of Potato Processing in Japan

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Abstract

In Japan, about 36% of the total production is used for the starch industry, and 23% for food processing. From the 1970s onward, the share of potato production for food processing use remarkably increased. Potato starch is used for traditional foods and thick malt conversion. Until 1986, the manufacture of potato chips accounted for the major part of the increase of food processing. Thereafter the processing of frozen fried potatoes became more important and in recent years the demand for products processed without oil has increased rapidly. Since the initiation of the national potato breeding program in 1902, continuous efforts have been made, and a large number of varieties for starch production were bred. In food processing, Toyoshiro which remain the leading variety was first bred for the manufacture of potato chips, and Hokkaikogane was released for the production of frozen fried potatoes. Although new varieties are being bred to meet new demands, there are major problems, namely, the competition in the starch and processing market with imported products.

Discipline: Crop production
Additional key words: breeding, potato Chips, Solanum tuberosum, starch, utilization

Introduction

Although potatoes (*Solanum tuberosum* L.) were introduced to Japan at the beginning of the 17th century[15], the cultivation did not spread until the end of the 19th century. On the other hand, sweet potatoes which were introduced approximately at the same time, at once spread throughout the south-western region of Japan and became one of the most important upland crops, due to their tolerance of natural disasters such as typhoons and drought[8].

The spread of potato cultivation was promoted by the Meiji era (1868-1911) government which adopted a European type of agriculture by accelerating the development of Hokkaido, a northern island. At first, the promotion of potato cultivation in the Hokkaido region aimed mainly at meeting domestic consumption. The area of cultivation increased rapidly since potatoes were used as processing materials for starch in the 1900s. As potato is a crop suitable for areas with a cool climate, Hokkaido remains the main center of production of the crop[2,5,15].

On the other hand, in the warmer regions, potatoes have gradually been cultivated for fresh use as a vegetable.

Production

The yield of potatoes increased steadily by approximately two times from 16 t/ha in 1959 to 30 t/ha in 1989. Such a remarkable increase of yield was associated with the introduction of improved potato

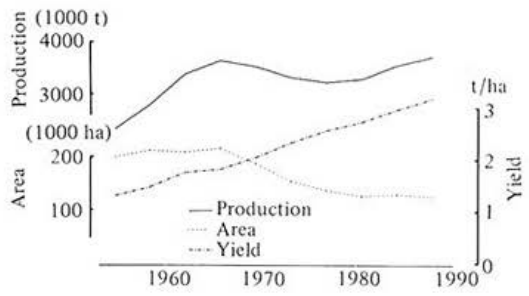

Fig. 1. Trend of cultivated area, production and yield in Japan

seeds, effective control of diseases and pests, and application of fertilizer[21]. Therefore the total production of potatoes, about 3,500,000 t, was maintained during this period, in spite of the large decrease in the acreage of the planted area (Fig. 1).

The 1989 statistics showed that Hokkaido accounted for about 72% of the total production (3,586,500 t) and 58% of the total cultivated area (119,740 ha)[3].

Utilization

About 36% of the total production is used for the starch industry. The use as starch material surpasses that of feed, which is a characteristic of potato use in Japan[2]. Half of the potato starch is converted to thick malt syrup, which is used in the food industry, the rest being mainly used as a mixture of food products[3]. When water is added, upon heating, potato starch gelatinizes at relatively low temperatures, and shows a high viscosity[28]. These characteristics are suitable for the manufacture of fish meal sausage, boiled or baked fish paste 'Kamaboko' or 'Chikuwa', Japanese noodle 'Udon' and other traditional foods.

The per capita consumption of potatoes which was 17.5 kg in 1960, decreased markedly to 12.9 kg in 1974. This trend was reversed with an increase to 17.8 kg in 1989. Before the 1960s, Japan was a developing country and people ate potatoes as a source of energy. Along with the improvement of the economic situation, there was a preference

Table 1. Supply and demand of potatoes in Japan[3]

Year	Domestic production*	Trade*		Total supply*	Feed*	Seed*	Material for starch*	Shrinkage & loss*	Crude food*[a]	Per capita /year (kg)
		Import	Export							
1960	3,594	-	22	3,572	547	328	1,007	55	1,635	17.5
1965	4,056	-	12	4,044	601	395	1,382	129	1,537	15.6
1970	3,611	-	6	3,605	396	298	1,365	156	1,390	13.4
1975	3,216	28	-	3,289	151	216	1,168	241	1,453	13.0
1980	3,421	211	-	3,632	91	224	1,417	160	1,740	14.9
1985	3,727	200	-	3,927	60	245	1,582	178	1,862	15.4
1989	3,587	478	-	4,063	47	240	1,291	285	2,200	17.8

*Unit: 1,000 t.
a): Culinary and processing; yield rate (pure food) is 90%.

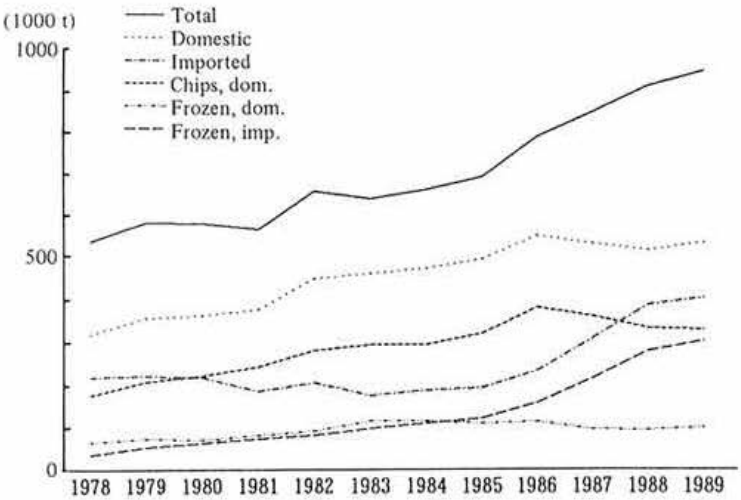

Fig. 2. Potatoes used for food processing in Japan

Table 2. Chronology of potato improvement in Japan, cultivars and classification of use[15]

1800s	Many varieties were introduced from North America (U.S.A.). 1873; Early Rose, Yukikata (Snow Flake), 1877; Ezonishiki (Green Mountain), 1890?; America-Taihaku (American Wonder), 1895; Hebron (Early Beauty of Hebron).
1900s	1902; Breeding program was started, 1902–3; Introduction of true seeds from France by private company, and selection of Ekishirazu, 1905; Kamiyaimo (Cimbal's Phöenix), 1907?; Danshakuimo (Irish Cobbler).
1910s	1916; First cross was performed, 1917?; May Queen.
1920s	Many varieties were introduced from Europe (Germany). 1926–; Hybridization breeding became the main program, and many varieties were used as breeding materials, 1922; Pepo, 1923; Deodara.
1930s	Many relative and wild species were introduced. 1937; Tayamashu, 1938*; First cross breeding varieties: Benimaru(S), Myojo(S), Hokkai-shiro(S), 1939; Inter-specific hybridization was started.
1940s	1942*; Bifukashiro(S), 1943*; Norin no.1(S), 1945*; Norin no.2(S), Norin no.3(S), 1947; Establishment of seed foundation stock farms.
1950s	1952*; Nemurobeni(S), 1953*; Chitose(S), 1954*; Kennebec (C, introduction no.1), Oojiro(C), Wheeler (C, introduction no.2), 1955*; Unzen(D), Tachibana(D), 1956; Hochprozentige (from Germany), 1958*; Yoraku(S) (first variety derived from inter-specific hybrid), 1959*; Niseko(S).
1960s	1960*; Rishiri (S, late blight resistance derived from inter-specific hybrid), Shimabara(D), 1961*; Eniwa(S), Yukijiro (P, for mashed potato), 1962*; Chijiwa(D), 1965*; Hokkai-aka(S), 1967*; Shiretoko(S), 1969*; Bihoro (S, high starch 25.0%), Tarumae(S).
1970s	1971*; Dejima(D), 1974*; Waseshiro(C, P), 1976*; Toyoshiro (P, for chips), 1977*; Setoyutaka(D), 1978*; Tunika (S, introduction no.3), Nishiyutaka(D), 1979*; Hatsufubuki(S).
1980s	1981*; Konafubuki(S), Hokkaikogane (P, for fried potatoes), 1986*; Toyo-akari(S), Meiho(D), 1987*; Kita-akari(C, P), Ezo-akari(C).

(S): Starch extraction, (P): Processing, (D): Double cropping, (C): Culinary.
* Year of release.

for other foods, leading to a decrease of consumption of potatoes. From 1975 onward, the increase of the consumption was associated with the increase of the processing of potatoes[10] (Table 1).

Recently, the consumption of processed potatoes has been rapidly increasing, especially in the case of potato chips and frozen fried potatoes[26]. The production of potato chips increased by about 10 times within 10 years from 1975, and reached a market value of 100 billion yen[25]. After 1986 the production slightly decreased, while that of frozen fried potatoes remarkably increased. However presently there is an increase in the amount of imported frozen potatoes mainly from the U.S.A., due to price competition and stable supply (Fig. 2). Recently the processing of frozen potatoes without the use of oil, including frozen packaged salad and croquettes, and pre-peeled or cut potatoes has been rapidly increasing[7]. These products are mainly consumed in fast-food restaurants, and sold in take-out food shops or supermarkets.

Leading varieties

From the end of the 19th century to the beginning of the 20th century, a number of American

and European varieties were introduced and evaluated repeatedly. After 1902, a national potato breeding program was started while variety tests, line separation and pure line selection were carried out. As a result many introduced varieties were selected as recommended varieties and in 1916 artificial crossing was initiated[15] (Table 2).

At first the variety Benimaru for starch production which was released in 1938, followed by Norin no.1 in 1943, developed by hybridization breeding, still remained the leading varieties. Recently, there has been an increase in the planting area of a newly bred variety Konafubuki[1] which was released in 1981 and exhibits excellent characteristics such as high starch content and yield for the starch industry. In food processing, about 90% of potato chips are manufactured from Toyoshiro[20], the first variety bred for this purpose and released in 1976. Hokkaikogane[17] released in 1981, is used for the manufacture of frozen fried potatoes (Table 3).

Institutes engaged in breeding and seed production

The climatic conditions of Japan, which extends from north to south between latitude 45° and 25°N, vary widely. Therefore, three public institutes are engaged in breeding research[16] as follows:

(1) Hokkaido National Agricultural Experiment Station (1902–) is playing a leading role in potato breeding in Japan. The main activities cover the breeding of culinary varieties for spring and summer cropping as well as varieties for the starch industry and for food processing[10].

(2) Hokkaido Prefectural Konsen Agricultural Experiment Station (1957–) is in charge of breeding varieties for cool climate summer cropping under long day length, and carries out studies on genetical improvement of starch quality in potato[14].

(3) Nagasaki Prefectural Agricultural Experiment Station (1949–) is engaged in the breeding of culinary varieties for double cropping in south-western Japan.

Besides the above breeding stations in the major producing areas, several prefectural agricultural experiment stations are carrying out evaluation for the adaptability of breeding lines. Recently, some private companies have initiated potato breeding programs, but the level still remains low.

The National Center for Seeds and Seedlings (1947–) in its 8 farms is engaged in the production of fine Foundation Stock Potatoes countrywide for distribution to the seed multiplication farms of the Potato Seed Growers' Cooperative Associations and then farmers. Recommended varieties of potatoes with sound seeds are supplied through this system[2,21].

Breeding objectives

1) Materials for starch industry

Potatoes to be used for the starch industry must exhibit a high productivity and cost performance[26]. Disease and insect resistance, high-yielding ability with high starch content, and good adaptability to mechanized cultivation are prerequisites in addition to superior starch quality[29]. High starch content is related to late maturity, and also exhibits a negative correlation with high yield in most cases[22]. Breeding

Table 3. Leading varieties in Japan (1988)[3]

Variety name	Cultivated area[a] (ha)	Characteristics	Purpose or uses
Irish Cobbler	40,672(32.6)	Early maturity	Marketable
Benimaru	20,286(16.3)	Late maturity, high yield	Starch
May Queen	20,215(16.2)	Long oval, good for boiling	Marketable
Norin no. 1	9,626(7.7)	Late maturity, high yield	Starch, processing, marketable
Toyoshiro	9,555(7.7)	Low reducing sugars content	Processing(chips)
Konafubuki	6,883(5.5)	High starch content	Starch
Dejima	4,554(3.7)	Double cropping	Marketable
Waseshiro	3,630(2.9)	Early maturity	Marketable, processing(chips)
Nishiyutaka	3,488(2.8)	Double cropping	Marketable
Eniwa	1,275(1.0)	Tuber late blight resistance	Starch
Hokkaikogane	920(0.7)	Long oval, yellow flesh	Processing(frozen), marketable

a): Cultivated area includes double cropping area, and numerals in parenthesis indicate percentage.

objectives are indicated in Fig. 3. The use of the back-crossing method with hybrids exhibiting a high starch content[6] which are derived from diploid landraces and wild species (*S. demissum, S. chacoence, S. stoloniferum,* etc.), enabled to breed a large number of varieties with a high starch content. Hochprozentige, a German variety derived from a wild species, is also used as high starch gene donor. The starch content in the newly bred varieties increased by nearly 10%, and continuous efforts have been made to develop disease and insect pest resistance and early maturing character (Table 2). Konafubuki which is resistant to the Y-virus and Toyo-akari[9] which is resistant to cyst-nematodes both contain more than 20% starch and are high-yielding varieties.

2) Food processing

The varieties used for the production of potato chips and frozen fried potatoes which are processed with oil, must be characterized by both a high dry matter content and low reducing sugars content. Uniformity of solid distribution within a tuber, is an important trait especially for the production of frozen fried potatoes[24]. High levels of reducing sugars lead to dark discoloration of the products. Not only the reducing sugars content at harvest, but also the pattern of increase during a long storage period in winter and the response to reconditioning are important[19] (Table 2).

Among the existing varieties, Eniwa, which was released in 1961 for the starch industry, was found to be an excellent parent with a low reducing sugars content, and from various combinations with Eniwa, Toyoshiro was bred, which is a leading variety for the production of potato chips. From a cross between Toyoshiro and Hokkai no.51 (long oval shape and high dry matter content) Hokkaikogane, which is suitable for the production of frozen fried potatoes, was selected. This variety is suitable for the processing of pre-peeled and cut potatoes too, due to the very weak discoloration in the raw and cooked stage, and firmness (not mealy) as cooking type. Also Kita-akari[18] which is a very mealy cooking type of potato with a high solids content and weak discoloration is well suited to the production of mashed salad and croquettes. By back-crossing with *S. tuberosum* ssp. *andigena*, cold chipping[4] potato clones (low reducing sugars content under low storage temperature) have been introduced[12].

Breeding methods

Successful breeding work starts with the selection of parents with a good combining ability and genetical traits. Next, crossing must be mainly performed outdoors, when the temperature is cool (below 20–22°C) and under long day length in early summer. To obtain satisfactory flowers, sometimes long-day treatment and late planting are applied. Pollen can be stored at a low temperature, but to avoid

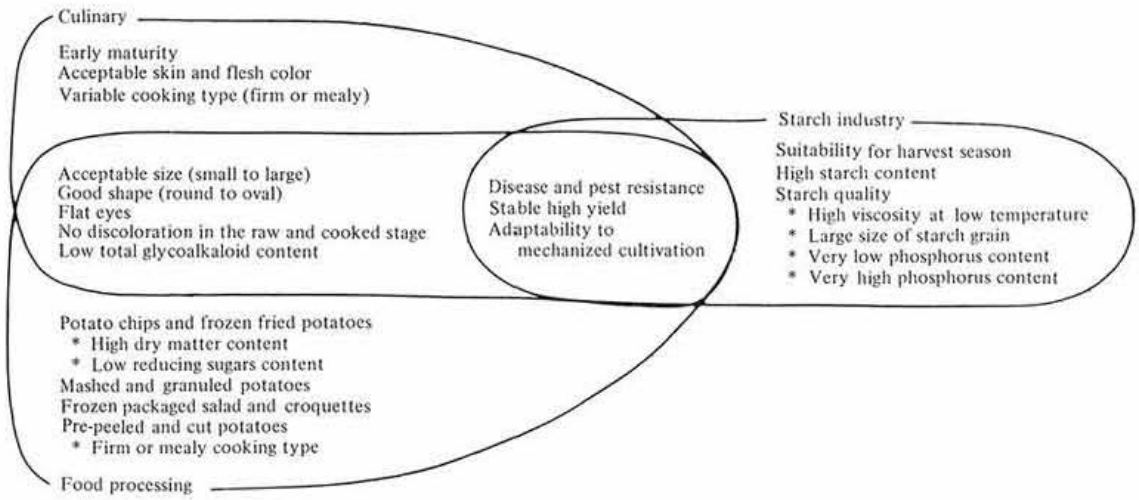

Fig. 3. Breeding objectives in Japan

Table 4. Potato breeding scheme at the Hokkaido Nat. Agr. Exp. Sta.[14,16,19]

Year	No. of plants (/plot)	No. of clones	Status and test categories	Note
1st	1		Crossing	At least one parent with cyst-nematode resistance. Production of approximately 500,000 seeds.
2nd	1	150,000	Seedling	Selection for maturity, stolon growth habit, tuber shape, specific gravity, reducing sugars content, cyst-nematode resistance, late blight resistance.
3rd	1 (single plant)	20,000	Clone	Selection for maturity, growth habit, tuber shape and size, internal quality (brown spots, hollow, etc.), eye depth, raw discoloration, starch content.
4th	6 (single row test)	1,500	Clonal line	Selection for maturity, growing type, yield, starch content, tuber shape and size, internal quality (brown spots, hollow, etc.), raw discoloration, cooking and processing quality.
5th	36	150	Preliminary yield performance	Same as in the 4th year.
6th	30 (three replications)	40	Yield performance	Selection is conducted mainly for yield, starch content, cooking and processing quality. Test for resistance to diseases and insect pests.
7th	Replications (4 exp. sta. fields)	10	Yield performance, Local adaptability, Disease resistance	Same as in the 6th year. Numbers are given and accessions released to prefectural experiment stations for several tests.
8–10th	Replications (8 exp. sta. fields & farmers fields)	2–3	Yield performance, Local adaptability, Disease resistance, Performance for recommended varieties	Same as in the 7th year. Sent to farmers' fields of main producing regions.
11th–		1	Commercialization under approval of MAFF*	Name, Norin numbers are given.

* NAFF: Ministry of Agriculture, Forestry and Fisheries.

unconscious selection, fresh pollen which was stored for less than one week should be used.

In the second year, crossed seeds are sown in the form of single seed grain at an interval of 2 cm^2 in seed boxes. Seedlings are raised in the first generation in the greenhouse, and selected mainly based on major gene-inherited traits[19,23]. Late maturity and wild type progeny are eliminated based on the growth habit, the presence of stolons growing horizontally and photoperiod sensitivity. Thereafter the seedlings are transplanted in pots. After harvest from the pots, clones are selected based on the tuber shape, skin and flesh color, specific gravity and cyst-nematode resistance. Based on the determination of the reducing sugars content of the tubers the varieties are selected for combinations suitable for the production of potato chips and fried potatoes.

After the third year, progeny clones are selected in field trials based on agronomic and qualitative traits[11,12,14,22]. In the early clonal generations, accurate measurements are often replaced by visual inspection. The release of a new variety requires at least 10 years of testing (Table 4).

Conclusion

The prospect for the production of Japanese potatoes is closely linked with the world trade. Half of the potato starch produced is competing with other starch products made from imported corn and cassava. Also, the production of frozen fried potatoes competes with that of imported products. In order to increase the consumption of potatoes produced in Japan, it is essential to supply high quality potatoes for the processing industry at a reasonable cost and to develop a stable supply system. For the promotion of new demand[27] for potatoes, collaborative work between breeders and researchers dealing with food processing is necessary. For example, the production of new potatoes for edible pigment[13] which is a by-product of the starch industry has been improved. In Japan, such work has just started.

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