Lofty Nijo: A High Quality Malting Barley Variety Released from an Australian-Japanese Collaboration

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ABSTRACT

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A new malting barley variety, Lofty Nijo, was bred in Australia through a collaborative breeding program between a Japanese brewing company and Adelaide University. The variety is early flowering and maturing, with similar yield potential to Schooner except in lower rainfall areas, and is not zinc efficient. It produces plump grains with low screenings similar to Schooner and more uniform and plumper grains than Franklin. Lofty Nijo has a well-balanced malting quality profile. It shows high values in malt extract, diastatic power, apparent attenuation limit and Hartong index (VZ45) and low values in wort beta-glucan and viscosity. The Kolbach index of this variety is lower than Schooner and Sloop, however, it is higher than Franklin. A pilot-scale brewing trial indicated that Lofty Nijo is as suitable for Japanese brewing as the world's leading varieties, such as Franklin. Lofty Nijo should therefore offer a premium malting barley variety in Australia for export markets. The breeding, agronomic performance and quality profile of the variety is described in this paper.

Key words: Agronomic performance, breeding, malting barley, malting quality, new variety, pilot-scale brewing.

INTRODUCTION

Australia is one of the major malt suppliers to Japanese brewing companies, therefore a stable supply of quality barley and malt from Australia is of great interest and concern. However, varieties such as Schooner are no longer popular with our brewers because of their lower extract, diastatic power and fermentability, compared with other leading varieties of the world, such as Alexis and Harrington. The main reason why they prefer malt with high diastatic power may be attributed to the ingredients used in brewing. By law, starch adjuncts can comprise a maximum of one-third of the ingredients for brewing beer in Japan. High diastatic power is necessary to ensure complete degradation of these starchy substances. Therefore, Sapporo Breweries, one of Japan's major brewing companies, needed to formulate a plan to assist in ensuring the stable supply of malt with these desirable quality characteristics. As a consequence, a collaborative breeding program in Australia with Adelaide University was established[2]. We aimed to create a new variety by combining our germplasm in conjunction with the refined breeding and quality assessment program of the University. The program has progressed thanks to our partner, and the valuable advice of the Australian maltsters. In 2000, we released a new malting barley variety, Lofty Nijo, from the collaborative program. A detailed profile of the variety is summarised in the following sections.

MATERIALS AND METHODS

Breeding and field trials

In 1986, the original cross Kita A 66-1 / Hokuiku 19, was made in Plant Bioengineering Research Laboratories (PBRL), Sapporo Breweries Ltd., Gumma, Japan. The seed parent Kita A 66-1 is characterised by excellent malting quality and the pollen parent Hokuiku19 was subsequently registered as Ryofu, which is the leading variety in Hokkaido, the northern island of Japan. From this cross, a number of F2 selections were made and single plant selection was carried out from F3 to F5 generations. In 1993, one selected line (86C76) was designated SA93013 and sent to South Australia. SA93013 passed yield trials run by the Adelaide University-Sapporo Breweries Collaborative Breeding Trials to enter Stage 3 yield trials. In 1998 it was named SBWI-1 and was tested in the SARDI (South Australian Research And Development Institute) Stage 4 trials at 21 locations around the state (Fig. 1). During the yield trials, malting quality of the line was evaluated by PBRL. SBWI-1 was named Lofty

TABLE I. Crops used for the malting quality analyses in this paper.

Year	Trials	Site
1997	UA[1] Stage 3	Clinton, Tuckey, Weetulta
1998	UA Stage 3	Brinkworth, Yeelana
	SARDI[2] Stage 4	Cooke Plains, Lameroo
1999	UA Stage 3	Brinkworth, Weetulta
	SARDI Stage 4	Arthurton, Brentwood, Cummins, Salter Springs, Wanilla

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Nijo in 2000 for commercial release. In this paper the agronomic data was compiled from the South Australian Barley Stage 4 Trials in 1998, 1999 and 2000.

Micromalting and malt analysis

Malt quality data for this paper was prepared from the crops listed in Table I. Barley samples were shipped to Japan and micromalted in the Phoenix Micromalting Apparatus of PBRL a few months after harvest. All samples achieved greater than 95% germination at the time of malting according to a 4 mL germination test[1]. The following program was used:

a) Steeping - Ex-steep moisture was targeted to reach 43.5% for all the samples. Since the water absorption rate was expected to be variable among samples, steeping time was estimated for each sample prior to malting using a small portion (50 g) of sub samples. Therefore, steeping time was variable among samples. Steeping comprised of the repeated cycle of 5 hr immersion and 7 hr air-rest both at 15°C. Samples were intermittently put into the micromalter to allow them to be steeped for the required time to reach the desired moisture. After steeping, moisture of the samples was measured by the method described above. No aeration was applied throughout steeping. The containers were then placed back in the micromalter for germination.

b) Germination - 15°C for 139 hr, no gibberellic acid was added.

c) Kiln - 100% fresh air, 0% recirculation for 13.5 hr at 55°C; 100%, 0% for 8 hr at 65°C; 50%, 50% for 3.5 hr at 75°C; 50%, 50% for 4 hr at 83.5°C. Rootlets were removed prior to analysis.

The following quality characters were determined using the European Brewing Convention (EBC) recommended methods: malt yield, malt moisture, filtration time, wort clarity, colour, boiled wort colour, extract (fine grind, 0.2 mm), total and soluble nitrogen, apparent attenuation limit, diastatic power, Hartong index (VZ45), viscosity, wort beta-glucan, and friability.

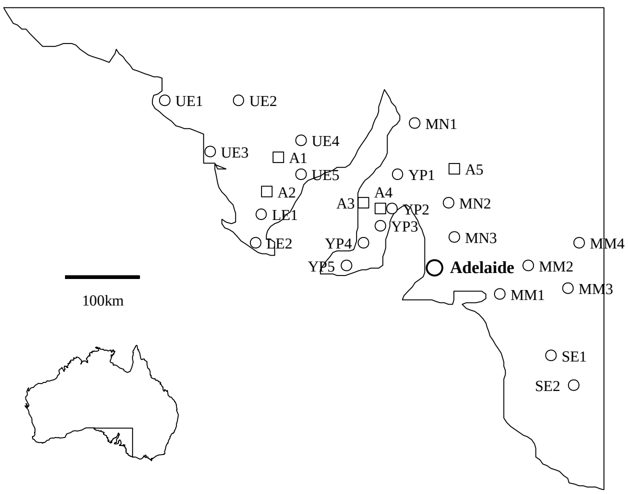

FIG. 1. South Australian Barley Stage 4 Trial Sites and some Adelaide University Stage 3 Trial Sites. Upper Eyre Peninsula: Streaky Bay (UE1), Minnipa (UE2), Elliston (UE3), Mangalo (UE4), Wharminda (UE5); Lower Eyre Peninsula: Cummins (LE1), Wanilla (LE2); Yorke Peninsula: Bute (YP1), Port Clinton (YP2), Arthurton (YP3), Brentwood (YP4), Warooka (YP5); Mid North: Crystal Brooke (MN1), Salter Springs (MN2), Turretfield (MN3); Murray Mallee: Cooke Plain (MM1), Borrika (MM2), Lameroo (MM3), Paruna (MM4); South East: Keith (SE1), Mundulla (SE2). Adelaide University Sites: Tuckey (A1), Yeelana (A2), Weetulta (A3), Clinton (A4), Brinkworth (A5).

Pilot-scale malting and brewing

a) Pilot-scale Malting - A 100 kg barley aliquot (>2.5 mm screen) of 1998/99 Crop (Sandiland, South Australia) was sent to Brewing Research Laboratories (BRL, Sapporo Breweries Ltd., Yaizu, Shizuoka, Japan). Steeping comprised of 2 cycles of 6 hr immersion and 6 hr air-rest at 14°C. Germination lasted for 144 hr at 14°C with no gibberellic acid applied. The kilning program was; 5.0 hr at 55°C, 5.5 hr at 60°C, 2.0 hr at 65°C, 1.5 hr at 75°C and 4.5 hr at 83.5°C. The airflow was 100% fresh air during

TABLE II. South Australian stage 4 barley variety trial results for yield (t/ha; mean of 1998, 1999 and 2000) (Source: Field Crop Evaluation Program, SARDI).

Variety	Yorke Peninsula	Mid North	Murray Mallee	South East	Lower Eyre Peninsula	Upper Eyre Peninsula	State Average
Lofty Nijo	3.04^{a}	3.52^{a}	1.89^{a}	3.60^{a}	2.70^{a}	1.60^{a}	2.58^{a}
Franklin	2.82^{a}	3.15^{b}	1.94^{a}	3.35^{a}	2.78^{a}	1.51^{a}	2.44^{b}
Schooner	3.02^{a}	3.48^{a}	1.98^{a}	3.27^{a}	2.94^{a}	1.87^{b}	2.65^{ac}
Sloop	3.02^{a}	3.64^{a}	2.06^{a}	3.57^{a}	2.83^{a}	1.84^{b}	2.69^{c}

Superscript letters indicate the results of t-test in each column. Difference between values with same letters is not significant at 1% level.

TABLE III. Important agronomic characteristics of Lofty Nijo and the control varieties.

			Disease Resistance[1]				
Variety	Plant Height (cm)	Maturity	Scald	SFNB[2]	NFNB[3]	Screening (<2.5mm, %)	Hectolitre Weight (g)
Lofty Nijo	67.5	early	6.8	7.4	4.5	18.7	65.3
Franklin	62.2	very late	2.3	8.2	2.0	72.3	66.6
Schooner	58.5	early-mid	6.3	5.8	2.0	16.0	67.2
Sloop	60.1	early-mid	5.8	6.9	3.0	20.7	66.0

[1] Decimal rating from 1(highly resistant) to 10 (highly susceptible).
[2] Spot form of net blotch.
[3] Net form of net blotch.

kilning. Rootlets were removed prior to analysis. The pilot malt was sampled and the malting quality was analysed in PBRL.

b) Pilot-scale Brewing - The Lofty Nijo pilot malt was brewed according to the standard methods of BRL pilot brewing (400 litre mashing). As controls, Manley and Franklin commercial malts were also brewed according to the same recipe. Wort and beer samples were analysed at BRL. Foam retention of the pilot brew beers was assessed by three methods, ASBC sigma 20°C, NIBEM and FCT[7]. Sensory evaluation was applied for each brew directly after lagering, and after one month of storage at 20°C, after bottling.

RESULTS

Agronomic performance

The yield data of Lofty Nijo for three years (1998-2000) are summarised in Table II in comparison with the other SA malting varieties, Franklin, Schooner and Sloop. Lofty Nijo shows similar yield potential to Schooner in state wide average. Although the average yield was lower than Sloop, in some areas such as Yorke Peninsula, Mid North and South East, which are known to be major malting barley producing regions, Lofty Nijo yielded similar to Sloop. The new variety is not efficient on either manganese or zinc deficient soils and is less tolerant to boron toxicity than Schooner and Sloop.

Table III shows the other important agronomic traits of the variety. Lofty Nijo is a mid to high plant height and a early-maturing variety with good screening and hectolitre weight. It is more susceptible than the control varieties to the major diseases in the state, such as barley leaf scald (*Rhynchosporium secalis*), spot form , and net form of net blotches (*Pyrenophora teres*). The variety is also susceptible to cereal cyst nematode.

TABLE IV. Malting quality of Lofty Nijo in comparison with the control varieties as determined in micromalting tests in PBRL (average of three years; 1997, 1998 and 1999).

Variety	Lofty Nijo	Franklin	Schooner	Sloop
Ex-steep Moisture (%)	43.4[a]	43.3[a]	43.3[a]	43.3[a]
Steeping Time (hr)	43[a]	42[a]	42[a]	37[b]
Malt Yield (%, db)	91.2[a]	91.6[ab]	91.1[ab]	91.5[b]
Wort Clarity	1.0[a]	1.1[b]	1.1[b]	1.0[a]
Colour (EBC)	2.9[a]	2.6[b]	3.0[c]	3.0[c]
Boiled Wort Colour (EBC)	4.9[a]	4.5[b]	4.9[ac]	5.0[c]
Extract (%, db)	81.1[a]	80.0[b]	79.9[c]	79.3[c]
Total Nitrogen (%)	1.66[a]	1.77[b]	1.68[ab]	1.73[ab]
Soluble Nitrogen (%)	0.650[a]	0.608[b]	0.718[c]	0.730[c]
Kolbach Index	39.8[a]	34.9[b]	43.4[c]	43.0[c]
Apparent Attenuation Limit (%)	85.4[a]	83.2[b]	79.8[c]	82.1[d]
Diastatic Power (WK)	259[a]	311[b]	222[c]	287[a]
Hartong Index (VZ45)	37.0[a]	30.9[b]	31.1[b]	32.2[b]
Viscosity (mPas)	1.50[a]	1.55[b]	1.53[c]	1.49[d]
Friability (%)	88.6[a]	75.1[b]	87.1[a]	89.0[a]
Wort Beta-glucan (mg/litre)	77[a]	183[b]	83[c]	49[d]
Extract Yield (%)	74.0[a]	73.3[b]	72.8[c]	72.6[c]

Superscript letters indicate the results of t-test in each row. Difference between values with same letters is not significant at 1% level.

Malting quality

The malting quality for Lofty Nijo and the control varieties for three years (1997, 1998 and 1999) are summarised in Table IV. Comparing the control varieties, Lofty Nijo shows significantly higher values in extract, apparent attenuation limit, Hartong index (VZ45) and extract yield. The diastatic power of Lofty Nijo is lower than Franklin but higher than Schooner. The difference in diastatic power is not significant between Sloop and Lofty Nijo. Total nitrogen level of the variety is similar to Schooner and Sloop but lower than Franklin. Soluble nitrogen and the Kolbach index values were between Franklin and the two varieties, Schooner and Sloop. Wort viscosity, friability and wort beta-glucan values of Lofty Nijo were in desirable ranges.

Pilot-scale malting and brewing

Prior to pilot-scale malting of Lofty Nijo, preliminary micromalting experiments were made to estimate the optimal malting recipe, where ex-steep moisture was set at three different levels: 41.5%, 43.0% and 44.5%. The experiments were carried out in March 2000, approximately three months after harvest. Based on the malt quality data (Table V), we decided that the optimal ex-steep moisture should be 44.5%, where steeping time was calculated to be around 47.5 hr.

The pilot-scale malting started in June, six months after harvest. The ex-steep moisture reached 46.1%, which was higher than targeted. Malting quality data is shown in Table VI with the control (commercial) malts. Although the pilot malt seemed to be over modified, especially in terms of protein degradation, it was regarded satisfactory for the pilot-scale brewing.

Problems were not encountered during wort production of either Lofty Nijo or the control brews (Table VII). The Lofty Nijo wort had higher values for colour, total nitrogen, polyphenol and free amino nitrogen (FAN) than Franklin and Manley. Wort viscosity and pH were lower for Lofty Nijo than the controls. Fermentable sugar levels were the highest in the Lofty Nijo wort.

TABLE V. The preliminary micromalting of Lofty Nijo (batch PM9935, kilned 21/3/2000) at PBRL.

	Ex-steep Moisture (%)		
	41.5	42.8	44.9
Steeping Time (h)	33	39	49
Malt Moisture (%)	4.0	3.5	3.5
Filtration Time (min)	13	12	10
Wort Clarity	1	1	1
Colour (EBC)	2.9	2.9	3.0
Boiled Wort Colour (EBC)	5.1	5.6	5.4
Extract (%, db)	81.7	81.3	81.2
Total Nitrogen (%)	1.66	1.66	1.66
Soluble Nitrogen (%)	0.659	0.681	0.721
Crude Protein (%)	10.4	10.4	10.4
Kolbach Index	39.6	41.1	43.4
AAL (%)	85.2	84.9	86.4
DP (WK)	201	185	222
Hartong Index (VZ45)	31.8	31.6	33.4
Viscosity (mPas)	1.48	1.46	1.43
Friability (%)	91.1	96.0	97.4
Wort Beta-glucan (mg/litre)	82	41	18

Fermentation processes were similar among the three brews with no problems observed (Table VIII). The Lofty Nijo beer showed higher values for colour, total nitrogen, polyphenol and FAN. The foam retention was expected to be relatively poor for Lofty Nijo considering the ASBC sigma 20°C, NIBEM and FCT values. The forcing test (FT-3) indicated that the Lofty Nijo pilot brew would be lower in colloidal-stability than the controls.

The sensory evaluation panel distinguished differences in flavour among the three pilot brew beers but there was no significant difference in sensory evaluation scores straight after bottling (Table IX). The Lofty Nijo beer was more flavour labile than Franklin and Manley according to the sensory evaluation scores and comments after one month of storage at 20°C.

DISCUSSION

Agronomic performance

The yield results indicate that the yield potential of Lofty Nijo is at the same level as Schooner in the state-wide average. However, in upper Eyre Peninsula (UEP), the yield of Lofty Nijo is significantly lower than Schooner and Sloop and similar tendencies were found in lower Eyre Peninsula (LEP) and Murray Mallee (MM). UEP and MM are lower rainfall areas. In LEP, where the annual rainfall is above 450 mm, there are two barley stage 4 sites, Cummins and Wanilla. The yield data of Lofty Nijo, is as good as Schooner in Cummins, but significantly lower in Wanilla. Relatively high yield performance of the new variety was found in Yeelana, a UA stage 3 site in LEP. Therefore it is assumed that some soil nutrient or endemic disease may have reduced the yield of Lofty Nijo in Wanilla, and in LEP as a whole. In Yorke Peninsula and South East, Lofty Nijo showed the highest yield among the four varieties. Therefore, Lofty Nijo is a variety suitable for production in medium to higher rainfall areas.

The maturity and plant type of Lofty Nijo is relatively similar to Australian mainstream varieties, in comparison with Japanese malting barley varieties. The Japanese varieties that had been sent to Australia at the beginning of the breeding project exhibited very poor yield in South Australia, generally less than half of Schooner. It was assumed that early maturity and long culms of the Japanese barleys should have been the major factors in reducing the yield potential[2]. Lofty Nijo was selected for maturity and plant type. The breeding of Lofty Nijo is a great advancement in terms of yield potential since the first batch of crossbreds were evaluated in this program.

Small grain size is sometimes a problem for the high quality variety Franklin. However, grain size of Lofty Nijo was as good as Schooner and Lofty Nijo could therefore be a better alternative.

Lofty Nijo does not have good resistance against the major leaf diseases in South Australia, scald and spot form and net form of net blotch (NFNB). NFNB was not a big issue in the state when Lofty Nijo was first tested in the stage 4 trials in 1998. However, NFNB is now widely spread in the barley growing areas of South Australia. No chemicals so far can perfectly control the progression of the disease. Therefore, the inoculum of NFNB has to be minimised. The production of Lofty Nijo should be limited to areas with lower inoculum of NFNB and proper chemical treatments applied such as seed dressing with effective chemicals.

Malting quality

Lofty Nijo showed a well-balanced malt quality profile. Extract was significantly higher than the other varieties. The ranking for Lofty Nijo was consistent over three successive years, and was the same when the extract values were adjusted for soluble nitrogen (Ex-SN). Therefore the high extract of Lofty Nijo is expected to be a relatively stable characteristic across sites and years, although further experiments are necessary to assess its genetic background.

The diastatic power was significantly higher than Schooner but significantly lower than Franklin. The commercial crop of Lofty Nijo also showed an acceptable level of diastatic power.

Apparent attenuation limit (AAL) was very high in Lofty Nijo compared with the controls. With regard to the

TABLE VI. Malting quality of a Lofty Nijo pilot malt and the controls (commercial malts) for the pilot-scale brewing.

Variety	Franklin	Manley	Lofty Nijo
Malt Moisture (%)	5.3	5.4	4.2
Filtration Time (min)	18	15	11
Wort Clarity	1	1	1
Colour (EBC)	2.9	3.6	4
Boiled Wort Colour (EBC)	5	6.3	7.4
Extract (%, db)	82.7	81	82.1
Total Nitrogen (%)	1.49	1.80	1.70
Soluble Nitrogen (%)	0.736	0.777	0.800
Crude Protein (%)	9.3	11.3	10.6
Kolbach Index	49.3	43.2	47.1
Apparent Attenuation Limit (%)	86.5	85.1	87.2
DP (WK)	361	507	274
Hartong Index (VZ45)	43.6	47.2	47.5
Viscosity (mPas)	1.48	1.47	1.43
Friability (%)	82	73.1	97.6
Wort Beta-glucan (mg/litre)	55	88	25

TABLE VII. Wort analysis data for the pilot-scale brewing of Lofty Nijo and the controls.

Pilot Brew No.	2081	2083	2085
Variety	Franklin	Manley	Lofty Nijo
Extract (%)	10.88	11.05	11.05
Final Attenuation (%)	73.1	72.8	73.7
Apparent Attenuation Limit (%)	89.9	89	90.3
pH	5.42	5.52	5.31
Colour (EBC)	5.3	6.3	7.3
BU	29.2	32.6	32.9
Total Nitrogen (mg/100 mL)	68	73	80
Polyphenol (mg/litre)	227	212	276
FAN (mg/litre)	147	147	188
Viscosity (mPas)	1.56	1.58	1.51
Fructose (g/100 mL)	0.14	0.15	0.16
Glucose (g/100 mL)	0.9	0.88	1.04
Sucrose (g/100 mL)	0.2	0.32	0.3
Maltose (g/100 mL)	4.57	4.71	5.26
Maltotriose (g/100 mL)	1.5	1.44	1.74
Maltotetraose (g/100 mL)	0.22	0.15	0.15
Maltopentaose (g/100 mL)	0.04	0.02	0.02
Maltoheptaose (g/100 mL)	0.03	0.03	0.03
Maltohexaose (g/100 mL)	tr.	tr.	tr.

thermostability of beta-amylase, Lofty Nijo, Franklin, Schooner and Sloop are categorised into type A, B, C and B, respectively. The type A is the most heat stable, type C the least and type B is intermediate. The difference in AAL may be attributed to the beta-amylase thermostability type, as shown by Kihara *et al*.[3]

Very high values were also observed for the Hartong index (VZ45) of the new variety. Hartong index (VZ45) represents the total activities of various enzymes secreted during germination except for alpha-amylase and the degree of malt starch degradation[4]. The high attenuation of the variety may be partially explained by the higher level of starch degradation in conjunction with the higher thermostability of beta-amylase. Further research is necessary to clarify this matter.

Total nitrogen level was generally lower than the control varieties, especially when compared with Franklin. In drier areas Franklin tends to produce thinner grains, which gives rise to high concentrations of nitrogen. Lofty Nijo exhibited less screenings than Franklin, which is the major reason for the difference in total nitrogen level. Kolbach indices are higher in Lofty Nijo than Franklin, which reflects the higher level of soluble nitrogen of the former variety. Protein modification of Franklin is known to be less intensive than Schooner and Sloop. Lofty Nijo may offer a better alternative in terms of the nitrogen issues.

TABLE VIII. Beer analysis results of the pilot-scale brewing of Lofty Nijo and the controls.

Pilot Brew No.	2081	2083	2085
Variety	Franklin	Manley	Lofty Nijo
Original Gravity (%)	11.05	11.12	11.19
Final Extract (%)	3.20	3.29	3.23
Final Attenuation (%)	71.0	70.4	71.1
Apparent Extract (%)	1.35	1.44	1.36
Apparent Attenuation Limit (%)	87.8	87.0	87.9
Alcohol (vol %)	5.12	5.11	5.19
Alcohol (w/w %)	4.02	4.02	4.08
pH	4.11	4.26	4.27
Colour (EBC)	4.2	5.0	5.6
Total Nitrogen (mg/100 mL)	50	56	62
Total Acidity (mL/100 mL)	15.4	16.9	16.9
BU (mg/litre)	18.8	20.7	20.6
Polyphenol (mg/litre)	201	183	235
Free Amino Nitrogen (mg/litre)	91	97	129
FT-3	2.97	2.29	4.75
ASBC sigma 20C	105	118	105
NIBEM	214	243	196
FCT	116	123	107
Acetaldehyde (ppm)	4.6	4.7	4.6
Acetone (ppm)	0.6	0.7	0.7
Ethanol Acetate (ppm)	22.3	22.5	27.7
n-Propanol (ppm)	8.7	9.0	9.1
Isobutanol (ppm)	7.9	7.1	7.3
Isoamyl Acetate (ppm)	1.5	1.3	1.8
Isoamyl Alcohol (ppm)	41.8	44.5	47.1
Fructose (g/100 mL)	0	0	0
Glucose (g/100 mL)	0	0	0
Sucrose (g/100 mL)	0	0	0
Maltose (g/100 mL)	0.06	0.08	0.05
Maltotriose (g/100 mL)	0.18	0.15	0.22
Maltotetraose (g/100 mL)	0.22	0.15	0.17
Maltopentaose (g/100 mL)	0.04	0.02	0.02
Maltoheptaose (g/100 mL)	0.02	0.02	tr.
Maltohexaose (g/100 mL)	tr.	tr.	tr.

Data for viscosity, friability and wort beta-glucan indicate that the cell wall degradation of Lofty Nijo should be satisfactory. These values were less desirable in Franklin. Franklin tends to show a relatively low degree of cell wall modification when grown in lower rainfall areas. Lofty Nijo seems to be able to overcome this problem, which means it is better adapted to lower rainfall than Franklin and can be grown in a wider area than Franklin.

Pilot-scale brewing

Compared with the preliminary malting data, pilot-scale malt was more intensely modified although both malts are derived from the same barley crop. No water sensitivity or dormancy was observed before steeping the first batch. The earlier batch was malted three months after harvest and the later one was stored for six months before malting. This indicates that the Lofty Nijo crop used for the present investigation needed up to half a year of storage after harvest before being ready for malting, although this character may vary year to year.

No particular problems were found in pilot brewing of Lofty Nijo and the resulting beer was acceptable considering the overall analysis data and sensory evaluation comments. The results suggest that the overall quality characters of Lofty Nijo are suitable for Japanese brewing, except for a concern about flavour stability found in this trial brew. Although the sensory evaluation score of Lofty Nijo beer straight after bottling exceeded Franklin and Manley beers, it became lower than the controls after one month storage, which implies the Lofty Nijo beer was flavour labile. A question may arise whether it is a common feature of beer brewed from Lofty Nijo malt or not.

The Lofty Nijo malt used for pilot-scale brewing was more intensely modified than the control malts as described above. Strecker degradation products such as 2-Me-propanal, 2-Me-butanal, 3-Me-butanal and phenylacetaldehyde were detected at relatively high levels in the Lofty Nijo pilot brew beer compared with the control beers (data not shown). Since these substances, which are regarded as indices of stale flavour, derive from degradation of alpha amino acids, it is possible that brewing highly modified malt may result in beer with these substances at high levels[6]. Based on this hypothesis, the flavour-lability of the Lofty Nijo beer could be explained by over modification of the malt used for the pilot brewing. The limited amount of the Lofty Nijo crop available allowed only one pilot brew, so further trials are necessary to determine whether Lofty Nijo has an inherently significant beer flavour stability problem.

Japan annually imports more than 130,000 MT of malt from Australia for brewing purposes, and a premium variety, Franklin, has kept a large share of the Japanese

TABLE IX. Sensory evaluation results for the pilot brews.

	Straight after lagering		After one month storage	
Variety	Sensory evaluation score	Average ranking	Sensory evaluation score	Average ranking
Lofty Nijo	75.6	2.1	72.4	2.7
Franklin	74.7	1.6	74.0	1.5
Manley	75.1	2.1	73.6	1.8

malt market[5]. Lofty Nijo may offer an alternative option for the premium market although the production would be limited to some extent. The first commercial crop will be malted in Australia and shipped to Japan for plant-scale brewing trials in Sapporo Breweries in 2001. The trials have great importance not only in Sapporo's barley breeding strategy but also for the breeding programs of Australia. If the results are satisfactory, it is possible that Lofty Nijo may become a useful quality parent for breeding barley for premium markets, such as the Japanese market.

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