# Assessment of Variability for Processing Potential in Advanced Potato Populations

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**Advanced clones and varieties in CIP's breeding program were evaluated under contrasting agroecologies in Peru to assess genetic variability and environmental influences on specific gravity, dry matter content, glucose content, and potato chip color. A selection of advanced clones was further evaluated for processing performance following different storage conditions, including cold temperature. Three contrasting environments of the coast, jungle, and highlands of Peru were used. Two breeding designs (Diallel and Line x Tester) were also evaluated for the determination of genetic parameters and assessment of parental value for processing characteristics. Greater variation for dry matter and glucose contents were demonstrated in a pre-breeding population based on cultivated native diploid species (*S. phureja* and *S. stenotomum*), than in the more advanced tetraploid breeding population. The clones or varieties Mariva, Atlantic, I-1062, POOS-16, Mex-32, Pirola, Tomasa Condemayta, LT-8, Y84.027, and C91.612 proved to be the most promising for processing as chips. The clone E86.011 and the late blight resistant selections 377369.7, 386529.3, and 85LB53.8 showed tolerance to cold temperature sweetening, or darkening of chips from potatoes processed following storage at 4° C. A high narrow sense heritability ($h^2$ = 0.74) was found for specific gravity, and conversely, little genetic variability was found for glucose content. The progenitors 378015.16 (TS-2), and LT-7, as well as the Polish clones PW88-6203 and Brda showed ability to transmit good processing attributes to their progenies. The utilization of contrasting, stressful environments that represent the diverse agroecologies of certain developing countries contributed to our ability to differentiate among materials and appreciate genotype x environment interactions.**

Processing is the fastest growing sector in the world potato economy. Approximately half the annual crop in the USA is now processed, and potato use in Europe's food service industry is rising sharply. The potato processing industry in many developing countries is also growing fast (FAO, 1995). In China, for example (Zhang and Guenthner, 1998), growing consumer income levels, changing rural and urban infrastructure, lower potato prices, greater foreign investment, and increasing numbers of fast-food restaurants are the main factors increasing the demand for processed potatoes.

Potatoes destined for the food service industry need to meet certain stringent

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requirements. They should be of uniform size and shape, with shallow eyes, good texture, high dry matter, and low reducing-sugar content under a range of production and storage temperatures. Potato varieties such as Russet Burbank and Bintje possess these characteristics and are grown successfully in the USA and Europe. However, these varieties are not suited to tropical and subtropical environments as their productivity is limited by climatic factors such as day length and temperature. In addition, these varieties are highly susceptible to diseases and pests, including late blight, viruses, bacterial wilt, and potato tuber moth. Successful production therefore depends on extensive use of pesticides, and healthy seed may need to be imported or grown in controlled conditions, both of which are expensive procedures.

Breeding programs at CIP and in many developing countries are therefore placing increasing emphasis on selecting varieties of potato that are suitable for the processing industry, as well as resistant to the most important diseases of the tropics. The objectives of this long-term study (begun in 1989) were to assess genetic variability for specific gravity (SG), dry matter (DM), and reducing-sugar (RS) content in advanced breeding materials and the effect of tropical growing conditions on these characteristics; evaluate the effects of cold storage and storage under ambient tropical conditions on processing qualities; and investigate the inheritance of specific gravity and reducing-sugar accumulation.

This investigation will help to determine the most efficient methods for identifying and selecting clones that are suitable for processing. Improving the availability of resistant varieties suitable for processing would allow developing countries to increase local production, expand emerging national processing enterprises, and eventually reduce imports of frozen potato products for the growing fast-food industry.

## Materials and Methods

### Testing sites

All evaluations were carried out at one or more of CIP's experiment stations in Peru: San Ramon (humid/hot climate all year, altitude 800 m, latitude 11° 08' S); La Molina (arid lowland climate, altitude 280 m, latitude 12° 05' S) during the winter (temperate to cool) and spring (warm) seasons; and Huancayo (highlands, temperate and rainy, altitude 3280 m, latitude 12° 07' S) during the summer.

### Plant material

Test materials for assessing processing quality attributes and their variability under a range of environmental conditions were selected from three types of clones. These are referred to in this paper as groups 1–3.

**Group 1**. The largest group of test materials (100 clones) was chosen from CIP's 'pathogen tested list' (PTL) of elite clones and varieties (> 100), and was tested at San Ramon and La Molina during winter, 1989. These materials are highly selected tetraploid clones with diverse production, resistance, and utilization traits. They all carry resistance or tolerance to at least one important pest, disease, or stress factor.

**Group 2**. Another group was a sample of 42 clones taken from a diploid *phureja/ stenotomum* population. This population was selected in the USA, from *Solanum phureja* and *S. stenotomum* parents, for heat tolerance, adaptation to long days, tuber appearance and high dry matter (Gautney and Haynes, 1983; Haynes and Haynes, 1983). These materials were tested only at La Molina during winter of 1989.

**Group 3**. A third group of approximately 80 clones was selected from CIP's broad-based breeding populations, also tetraploid, which are variously adapted to conditions in tropical and subtropical highlands and lowlands. Most of these clones carry resistance to late blight or viruses, but they have not been subjected to extensive international trials or released as commercial varieties. The materials were tested at all three of CIP's test sites over several years and only general conclusions of these trials are presented here.

Additional test materials for two studies of the inheritance of characteristics relevant to processing were drawn from segregating populations. These were represented by families originating from crosses between parents selected from the clonal material or populations described above (groups 1 and 3).

Together, these materials represented a wide genetic base from which to assess the general and specific combining ability for the main characteristics required for processing, and to identify the best progenitors and progenies for improving CIP populations and selecting superior clones.

**Experimental designs**

Results presented here on general evaluation of clones for their processing qualities are overviews from several years of trials, so designs are not presented in detail. In general, for the evaluation of the clonal material, trials followed randomized complete block designs (RCBD) with two or three replications of single 10 hill row plots. Yields were expressed as the weight of tubers on a whole plot basis (not reported here).

Tests for processing quality (see below) were usually conducted 10 days after harvest, once the chemical composition of the tubers had stabilized. However, in order to assess the impact of storage conditions on processing qualities, additional postharvest treatments were added to two trials. A group of 16 late blight resistant and frost tolerant clones plus two local varieties were planted in Huancayo in the summer of 1996/97. Yield was taken at harvest and processing characteristics were assessed 10 days after harvest, and after 30, 60, and 90 days in cold (4° C) or ambient (15–20° C) storage. During the winter season in La Molina, six advanced clones, selected over several years in different locations for their processing attributes were planted with two local varieties. An RCBD with three replications and 10 hill plot experimental units was used to evaluate early production and plant vigor. Yield and selected processing-related variables (dry matter content, glucose content and chip color) were evaluated 10 days after harvest, and chip color was tested at 30 and 90 days after cold or ambient storage, with and without reconditioning (potatoes are removed from cold storage and left at ambient temperature for two weeks to reconvert sugars before processing).

In order to assess the range of genetic variability for specific gravity and the inheritance of this character, a diallel mating design with reciprocals involving eight parents from the lowland tropics breeding population was used. The trial was established at La Molina during the spring and summer of 1990. Finally, in order to investigate in more detail the heritability of characters relevant to processing, 12 well known breeding lines and varieties, most of them resistant to potato leafroll luteovirus (PLRV), were crossed with three CIP progenitors for potato Y potyvirus (PVY) and potato X potexvirus (PVX), following a Line x Tester design (12 x 3). Thirty-six tuber families were planted during spring 1998 at La Molina and summer 1998/99 at Huancayo and distributed in an RCBD with three repetitions of 30 plants per family. In both sets of inheritance trials, yield was assessed on a per plot basis and processing characteristics assessed 10 days after harvest.

### Evaluation of processing quality

Dry matter content was determined directly as the ratio of dry weight/fresh weight. Between five and seven tubers (approximately 0.5 kg (total weight)) were taken at random from the harvested plot, cut into small cubes and mixed thoroughly. Two subsamples of approximately 200 g each were then dried in an oven at 80° C for 72 hours, or until constant dry weight was achieved. Specific gravity was calculated by measuring weight in air and weight in water, using 10 to 20 tuber samples (approximately 1 kg) per plot.

In the general evaluation of clones, a simple colorimetric test for glucose content (glucose test strip) was used as an indicator of the reducing-sugar content, assessed on the basis of five tuber samples cut in half lengthwise. A scale of 1 to 5 was used to indicate the following approximate measures: 1 = 0%, 2 = 0.10%, 3 = 0.25%, 4 = 0.50%, and 5 = > 2.0%; and the darkest measurement was recorded per sample. In the two trials on inheritance of characters relevant to processing, the Ross analytic laboratory method (Rodriguez, 1996) was used to quantify glucose content.

To evaluate chipping quality, three potato tubers per plot were cut perpendicular to the long axis, and six 0.5 mm thick slices taken from each half were used for frying and color tests. The slices were rinsed in water and fried at 176-180° C until the oil stopped bubbling. Chip color was measured using a scale of 1 to 5, where grade 1 is the lightest color (white to cream), 2 is light tan, 3 is dark tan, 4 brown, and 5 dark brown, according to a chart available from the PC/SFA (American Snack Food Association, Alexandria, VA, USA). Chip color between grade 1 and grade 3 is commercially acceptable. Oil absorption was determined as the percent of weight lost after applying 15,000 pounds/inch$^2$ pressure to 10 g samples of ground chip for 3 minutes using a mechanical press.

## Results

### Evaluation of advanced clones and varieties for processing characteristics (Group 1)

#### Dry matter content

Dry matter content evaluations of CIP's pathogen tested list (PTL) clones and varieties suggested the presence of considerable genetic variability for this characteristic (Figure 1). The highest values for dry matter content in La Molina, of about 24–26%, were observed for the following varieties: AKK69.1 (720052), Tomasa Condemayta (720072), Esperanza (720119), GLKS-58-1642.4 (800290), G-1 (278072.10), Mariva (720025), ARK-69.1 (675158), and Gabriela (720120). In San Ramon, dry matter of the same materials reached about 22–23%, with the varieties Dejima (800974), Esperanza (720119), G-1 (278072.10), CFJ-69.1 (676002), ARK-69.1 (675158), Yungay (720064), Linea-21, Linea-34, and Gabriela (720120) being the highest. The mean dry matter content for these clones was higher in the arid lowlands of La Molina (20.96%) than in the hot and humid San Ramon area (18.90%), confirming the detrimental effects of high temperatures on this variable previously reported by Hernandez (1989). However, some genotypes produced higher dry matter contents under warmer conditions than cooler ones (Linea 34, Linea 83, and

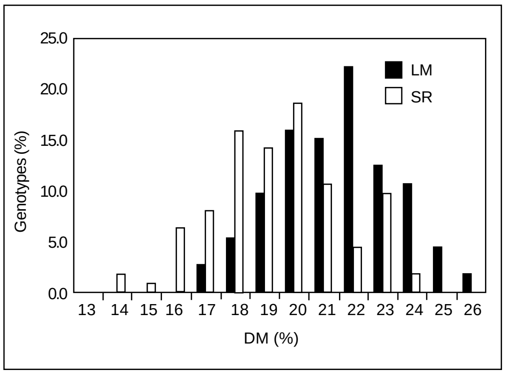


**Figure 1.** Frequency distribution of dry matter content (DM) of 100 clones from the pathogen tested list grown in La Molina (LM) and San Ramon (SR), group 1.

**Table 1.** Analysis of variance for processing parameters combining two environments; 100 from the pathogen tested list, group 1.

| Source | | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | d.f | Dry matter | | Glucose | | Chip color | |
| Environnent (E) | 1 | 382.730 | ** | 14.3111 | ** | 42.9549 | ** |
| Repetition(E) | 2 | 0.028 | | 0.00108 | | 0.0001 | |
| Genotype (G) | 99 | 12.204 | ** | 0.71581 | ** | 2.5054 | ** |
| G x E | 99 | 5.6612 | ** | 0.51266 | ** | 0.9978 | ** |
| Error | 198 | 0.2791 | | 0.00019 | | 0.0025 | |
| C.V. | | 2.660 | | 0.730 | | 1.830 | |
| Mean | | 19.890 | | 1.905 | | 2.740 | |

Note: ** = P > F < 0.0001.

Mex-750826), and others showed outstanding stability for this character (Yungay, Flor Blanca, CFE-69.1, Mex-32, and Huaycha).

Analysis of variance indicated a significant level of genotype x environment (G x E) interaction for dry matter, glucose content, and chip color ($P < 0.0001$) (Table 1). This finding was contrary to earlier reports (Shaw and Booth, 1982).

**Glucose content**

Frequency distributions for glucose content (Figure 2) and color of chips (Figure 3) also showed substantial variability among clones with a tendency for higher values in San Ramon, and there were significant differences between environments. For example, a higher percentage of genotypes with commercially acceptable Grades 1 to 3 for chip color occurred in La Molina (69%) compared to San Ramon (54%). Several varieties showed adequate processing characteristics under the conditions of San Ramon and La Molina: Mariva (720025), Atlantic (800827), GLKS-58-1642.4 (800290), I-1062 (575010), POOS-16 (575045), Mex-32 (720091), Pirola (800957), Esperanza (720119), Tomasa Condemayta (720072), CFE-69.1 (720053), and BI-2.9 (678011).

## Diploid Population (Group 2)

Evaluation of dry matter content and glucose content of the diploid *S. phureja*/ *S. stenotomum* population resulted in a negative correlation (r = –0.51), as previously found in tetraploids (Putz et al., 1982 cited by Ross, 1986).

**Dry matter content**

The frequency distribution for dry matter content in the diploid population (Figure 4) showed a greater range of variability (16.2–30.5%) than did that for the tetraploid PTL material (Figure 1). A comparison

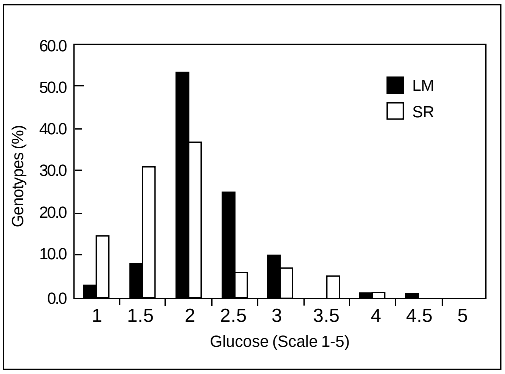


**Figure 2.** Frequency distribution for glucose content of 100 clones from pathogen tested list grown in La Molina (LM) and San Ramon (SR), group 1.

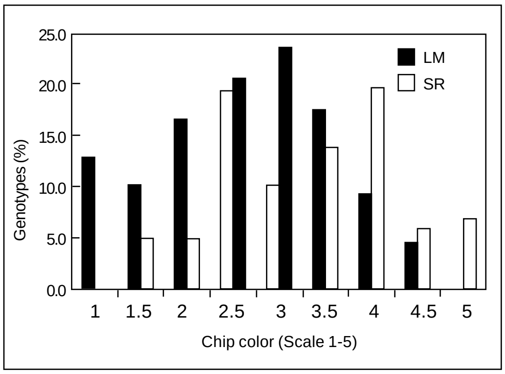


**Figure 3.** Frequency distribution of chip color of 100 clones from CIP's pathogen tested list grown in La Molina (LM) and San Ramon (SR), group 1.

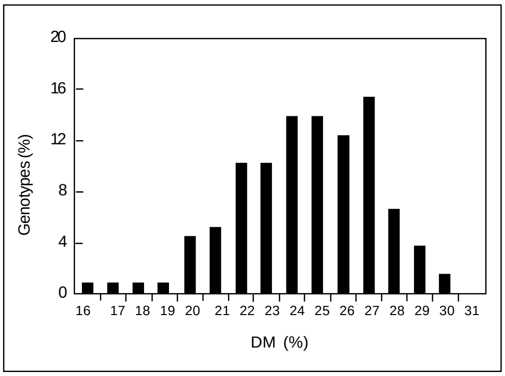


**Figure 4.** Frequency distribution of dry matter content (DM) in a sample of 42 clones from the *phureja/ stenotomum* diploid population, group 2.

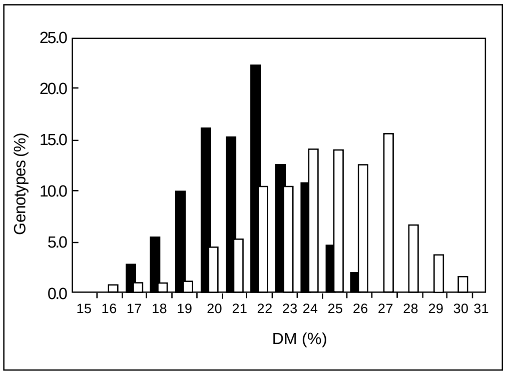


**Figure 5.** Comparison frequency distribution of dry matter content (DM) in samples of two population 4X (PTL) and 2X (*phureja/stenotomum*) grown in La Molina (groups 1 and 2).

of the dry matter frequency distribution for diploid and tetraploid clones (both grown at La Molina) showed a greater concentration of values around a lower mean for the tetraploids than the diploids (Figure 5).

Wide variability for chip color was also found in tetraploid and diploid clones, with the former appearing more disperse. A similar distribution was found for glucose content. Considering the overall range of variation, the *phureja/ stenotomum* population is an excellent source of improvement for dry matter content. Six clones were found to have high specific gravity in the range of 1.121–1.141, and low glucose content in the range of 0–0.10%. These are highly suitable for crossing with tetraploid clones as they produce a relatively high frequency of 2n gametes.

### Advanced breeding clones (Group 3)

Materials from CIP's lowland tropics virus-resistant population were evaluated over different seasons at all three test sites. Five clones were found to be suitable for processing as french fries, chips, or both. Table 2 describes a group of successful progenitors of virus resistance whose clonal evaluation revealed favorable postharvest characteristics. The National Potato Program and Tacna and Ica Universities in Peru have released some of these as commercial varieties, including Y84.027 as María Bonita, LT-8 as Costanera, and C91.612 as María Reiche.

### Effect of storage conditions

Measurements taken on the harvest from breeding materials in Huancayo showed that weight loss during ambient storage was higher (reaching levels of 8%, the

**Table 2.** Advanced progenitors with good processing quality and potential for use, La Molina, winter, 1994, group 3.

| Clone | Resistance | Yield (kg/plant) | DM (%) | Gl (%)[1] | Use[2] |
|---|---|---|---|---|---|
| LT-8 | PVX, PVY | 0.850 (±1.35) | 20.94 (±1.05) | 0.05 | CH,FF |
| Y84.027 | PVY | 1.150 (±3.84) | 18.93 (±2.95) | 0.05 | CH,FF |
| X86.011 | PVX | 1.070 (±2.30) | 20.19 (±1.85) | 0.06 | CH |
| 88.108 | PLRV, PVX | 1.000 (±3.09) | 24.38 (±1.03) | 0.05 | CH |
| C91.612 | PVY, PVX | 1.200 (±2.40) | 22.50 (±0.92) | 0.06 | FF |

Note: DM = Dry matter.

[1] Gl = glucose content (acceptable below 0.25).

[2] CH = chips; FF = french fries.

maximum loss found in any clone) than during cold storage (4%). The clone 386647.29 showed minimum weight loss of 2.2% after 90 days of ambient storage. Although the average dry matter content was relatively high (> 24%), significant differences were found between clones for dry matter, specific gravity, glucose content, and oil absorption. Changes in dry matter content during storage are shown in Figure 6A. The clones 386647.17, 377369.7, and 386529.3 showed the highest values of dry matter content at harvest with an average of 27.13, 26.20, and 26.11%, respectively. Figure 6B illustrates how glucose content changes over time, confirming previous reports of a greater increase during cold storage than during storage under ambient conditions (Burton, 1989; Ordoñez and Limongelli, 1980; Dogras et al, 1989). Clones with low and stable levels of glucose content under low temperature storage included 377369.7, 386529.3, and 85LB53.8.

Relatively low oil absorption is an important quality for processing, having economic as well as health advantages. Several clones had oil absorption levels below the average (36.65%). For example, clone 377369.7 showed absorption levels of 32.7% at harvest and 31.6% after 30 days of ambient storage, and clone 386647.29 showed 33.3% at harvest and 29% after 30 days of ambient storage.

The close significant relationship between dry matter and specific gravity found in earlier experiments (Ratovski et al., 1981) was confirmed in this study. Significant negative correlation of dry matter content with oil absorption and of specific gravity with oil absorption were obtained under both storage conditions (Table 3), confirming that higher dry matter content will generally result in lower oil absorption (Gamble et al., 1987; Kozempel et al., 1991).

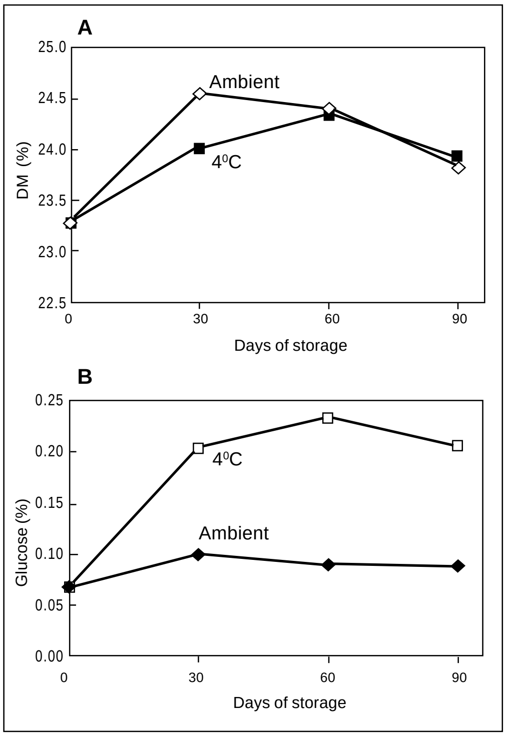


**Figure 6A and B.** Change with time under two storage regimes (cold storage at 4°C or under ambient conditions) of **A** dry matter content (DM) and **B** glucose content in 16 late blight resistant and frost tolerant clones gown in Huancayo, Peru.

**Table 3.** Correlations among dry matter content (DM), specific gravity (SG), oil absorption, and glucose content (GC) of 16 late blight and frost tolerant clones, at harvest and after storage, group 3.

| R | Harvest | Ambient storage | | | Cold storage (4°C) | | |
|---|---|---|---|---|---|---|---|
| | | 30 | 60 | 90 | 30 | 60 | 90 |
| SG-DM | 0.774 ** | 0.912 ** | 0.747 ** | 0.725 ** | 0.880 ** | 0.928 ** | 0.613 * |
| SG-oil | -0.893 ** | -0.565 | -0.458 | -0.473 | -0.605 * | -0.538 * | -0.645 ** |
| SG-GC | -0.362 | -0.181 | -0.181 | -0.235 | -0.622 ** | -0.560 * | -0.563 * |
| DM-oil | -0.804 ** | -0.606 * | -0.500 * | -0.296 | -0.528 * | -0.420 | -0.303 |
| DM-GC | -0.124 | -0.256 | -0.341 | -0.162 | -0.457 | -0.537 * | -0.386 |
| Oil-GC | 0.350 | 0.100 | 0.026 | 0.387 | 0.292 | 0.164 | 0.727 ** |

Note: * = significant (P < 0.05); ** = highly significant (P < 0.01).

**Table 4.** Yield and chip color of selected clones under two storage conditions, La Molina, winter 1995, group 3.

| Clone | Yield (kg/plant) | DM (%) | Chip color[1] | | | | |
|---|---|---|---|---|---|---|---|
| | | | Ambient 30 days | 4°C 30 days | Ambient 90 days | 4°C 90 days | R |
| E86.694 | 1.160 a | 21.4 | 1.5 | 3.5 | 1.0 | 4.0 | 2.5 |
| E86.011 | 0.909 ab | 22.8 | 1.0 | 1.0 | 2.0 | 1.5 | 1.5 |
| LT-8 | 0.827 b | 20.5 | 1.5 | 3.0 | 1.5 | 3.5 | 3.5 |
| E86.604 | 0.777 b | 21.5 | 1.0 | 4.0 | 1.0 | 4.0 | 3.0 |
| E86.300 | 0.765 b | 22.2 | 1.0 | 3.0 | 2.0 | 2.5 | 2.5 |
| MARIVA | 0.745 b | 22.4 | 2.0 | 3.5 | 2.0 | 3.5 | 3.0 |
| E86.692 | 0.743 b | 21.7 | 1.0 | 3.5 | 1.0 | 4.5 | 2.5 |
| E86.695 | 0.750 b | 22.3 | 1.0 | 3.5 | 1.0 | 3.5 | 3.0 |

Duncan test for yield/plant ($P < 0.05$).

[1] Scale used: 1-5, where 1= lightest color (white or pale yellow) and 5= darkest color (dark brown). Colors in the 1-3 range are commercially acceptable. R = reconditioning at ambient temperature following 90 days cold storage.

Most of the clones tested produced a good chip color following storage under ambient conditions, although three were very poor. In contrast, only four clones (377369.7, 386529.3, 85LB53.8, and 385542.7) produced a good chip color after cold storage.

The performance of clone 377369.7 is notable. With resistance to late blight, high yield, high dry matter content, and low glucose levels after storage at 4° C, good chip color, good texture, and acceptability, this clone has great potential for processing or as a progenitor in breeding programs, providing its yield and quality are stable in different production environments.

The results of tests on advanced clones already selected for their processing qualities are shown in Table 4. Clones E86.694 and E86.011 produced the highest yields. All clones fried very well at harvest and after ambient storage. Some browning of chips occurred in samples stored at 4° C, but reconditioning for two weeks after cold storage resulted in acceptable chip color. One clone (E86.011) produced chips of excellent color after all storage conditions. Although these clones (E86 series) were selected primarily for their processing characteristics, no extreme susceptibility to viruses or late blight was observed.

## Heritability of key processing characteristics

CIP's lowland tropics breeding population was found to harbor a large range of genetic variability for dry matter content. The effect of the growing environment on this characteristic was highly significant, with a lower mean during the summer (SG = 1.062, dry matter 18.3%) than during the spring (SG = 1.075, dry matter 20.2%). These results indicate that warmer temperatures are detrimental to the quality and yield of processed products.

Interestingly, G x E interactions were insignificant in this population study, indicating that progenies with high specific gravity under favorable environmental conditions (spring) still ranked high under unfavorable conditions (summer). This finding, together with high narrow sense heritability estimates ($h^2 = 0.74$), indicates that intercrossing progenitors with high specific gravity will permit rapid progress in breeding for this trait. In addition, advanced clones selected from this population produce acceptable and relatively stable yields under both cool and warm conditions.

The CIP progenitors 378015.16 (TS-2), 378017.2 (LT-7), and to a lesser extent 575049 (CEW-69.1), showed the ability to transmit high specific gravity to their

**Table 5.** Estimation of combining ability effects using a diallel design with reciprocals, Group 3.

| **Progenitors** | **Combining ability effects (GCA)** | | | |
|---|---|---|---|---|
| | **Yield** | **SG** | **RS(1)** | **RS(2)** |
| 378015.16 (TS-2) | 168.2 | 8.2 | 0.001 | -0.006 |
| C83.119 | -16.8 | -4.2 | -0.019 | 0.023 |
| 378017.2 (LT-7) | 664.6 | 3.1 | -0.028 | -0.032 |
| I-1039 | -89.6 | -2.5 | 0.012 | 0.001 |
| Katahdin | -4.3 | -5.0 | -0.032 | -0.003 |
| 377250.7 | -70.6 | -2.3 | 0.012 | -0.015 |
| 377964.5 | 7.9 | 0.1 | 0.014 | -0.007 |
| 575049 (CEW-69.1) | -59.3 | 2.6 | 0.390 | 0.040 |
| SE (gi) | 25.95 | 0.72 | 0.016 | 0.012 |
| SE (gi-gj) | 39.94 | 1.08 | 0.026 | 0.018 |

Note: RS(1), measured 10 days after harvest; RS(2), measured 60 days after harvest (ambient).

progenies as indicated by their respective general combining abilities (Table 5). In genetic research on reducing-sugar content, it was found that average levels in the segregating population were acceptable for processing into french fries and chips. However, little genetic variability was found for this trait. The CIP clones 378017.2 (LT-7) and 378015.16 (TS-2) and the variety Katahdin transmitted the tendency for low reducing sugar content to their progenies. Conversely, the clone 575049 (CEW-69.1) transmitted a tendency for higher reducing-sugar content to its progenies, making it a less suitable parent for processing unless it is crossed with a low reducing-sugar progenitor. Clones I-1039 and 575049 (CEW-69.1) have shown useful levels of resistance to late blight and early blight, respectively. Unfortunately, whereas they are well adapted to warm agro-ecologies and have good parental value for yield, uniformity, and early production, several of the clones noted here for their processing quality are susceptible to late blight and viruses. Furthermore, the presence of high levels of toxic glycoalkaloids was found in 378017.2 (LT-7) and (378015.16 (TS-2), noted here for their low reducing-sugar contents; this might complicate their use as progenitors.

Combined analysis (data not shown) of results from progeny tests of 12 well known breeding lines and varieties, evaluated in La Molina and Huancayo, indicated that lines PW88.6203, PW88.6065, Achirana, Brda, G7445(1), Fregata, and Berolina had good parental value measured as high general combining ability (GCA) for specific gravity, and the clones PW88.6203 and Brda showed high GCA for chip color. Clones PW88.6203 and Brda also possess high GCA for yield and agronomic characteristics. Among the testers used in this design, the progenitor TXY.2 was the best parent for vigor and uniformity of plants, yield (number of tubers), and specific gravity. These families were also evaluated in North China (Inner Mongolia) in comparative studies of parental value for virus resistance and chipping quality, and for clonal selection. A group of more than 20 selections with multiple virus resistance and good yields will soon be evaluated for their processing potential.

## Discussion

These preliminary evaluations of CIP populations and advanced clones for processing quality have identified a useful range of variability and a number of promising clones with good processing characteristics. The majority of these also contain resistance to at least one important disease, such as late blight or common viruses. Clones with tolerance to cold storage have also been identified.

Evaluation of segregating populations for processing parameters provided valuable genetic information that will enhance effective management of the breeding populations and improve identification of progenitors that can transmit good processing qualities to their progenies. At the same time, the evaluation allowed progenitors transmitting undesirable traits, such as high glycoalkaloid content, to be eliminated from the breeding program.

The test sites represented a variety of different environments (lowlands and highlands, cold and warm, dry and humid). These results will therefore facilitate the choice of varieties best suited to different agro-ecologies in developing countries, as well as highlighting G x E interactions. As a result, selected progenies, clones, and progenitors are now available for distribution and further trial in appropriate regions.

Research at CIP is continuing to identify superior progenitors and clones with important resistances. Breeding for good processing quality is now being given secondary importance. For example, the evaluation of processing potential has recently been superimposed on assessment of the variability for resistance to PLRV in the current recombination cycle of CIP's lowland tropics virus-resistant population, by way of genetic analysis (North Carolina Design II) conducted across environments. This will help to identify new progenitors that consistently transmit good processing characteristics as well as resistance to their progenies.

Considerable progress has therefore been made towards meeting the increasing demand for processing and dual-purpose potato varieties. Frequencies and levels of disease resistance in CIP populations are now high enough, and variability for postharvest quality sufficient, to permit selection for both resistance and utilization characteristics. Additional, robust genetic experiments, crossing the best progenitors with testers of poor quality, would also be required to give postharvest quality equal priority to disease resistance. Selection for long or oblong shaped tubers for the frozen french fry industry could also be emphasized on an experimental basis now that populations containing sufficient levels of important primary characteristics are available, and environmental influences on quality parameters are better understood.

Participatory research on the management of these potential varieties in farmers' fields and with different end users, as well as their incorporation into local seed systems, are critical areas for cooperation with national research programs in the short-term. Increased communication between breeding and selection programs is also needed to fully assess the response of selections and population samples to the most relevant environments and production practices.

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