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# "AmaRosa," a Red Skinned, Red Fleshed Fingerling with High Phytonutrient Value

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**Abstract** The diversity of traits in varieties of potato outside of its South American birthplace is a small subset of that available in the Andean center of origin. Among the traits that evoke most interest are skin and flesh pigments. Recent studies have pointed to the high antioxidant activity and potential healthful benefits from these pigments or other antioxidant compounds. The market for potatoes with unusual color patterns has been supplied largely by heirloom varieties of uncertain origin and the highly successful Yukon Gold. Interest has intensified and been transformed into a

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focused effort in the breeding of specialty varieties, remarkable for their unusual colors. The purpose of this paper is to describe a new potato variety in the Fingerling Class with red skin and red flesh.

**Resumen** La diversidad de caracteres en variedades de papa fuera de su lugar de origen en Sudamérica, es un pequeño subgrupo del que esta disponible en su centro de origen andino. Entre los caracteres que atraen más interés son los pigmentos de la piel y de la pulpa. Estudios recientes han enfatizado a la alta actividad antioxidante y a los potenciales beneficios para la salud de estos pigmentos u otros compuestos antioxidantes. El mercado de papas con patrones de color inusuales se ha surtido grandemente por variedades antiguas de origen incierto y por la altamente exitosa Yukon Gold. Se ha intensificado el interés y se ha transformado a un esfuerzo enfocado en el mejoramiento de variedades de especialidad, que sobresalen por sus colores poco comunes. El propósito de este artículo es describir una nueva variedad de papa en la clase de variedaes tipo dedo con piel y pulpa rojas.

**Keywords** Antioxidants · Fingerling · Anthocyanin · ORAC

## Introduction

The diversity of traits in varieties of potato outside of its South American birthplace is a small subset of that available in the Andean center of origin. Among the traits that evoke most interest are skin and flesh pigments. Recent studies have pointed to the high antioxidant activity and potential healthful benefits from these pigments or other antioxidant compounds (Al-Saikhan et al. 1995; Brown et al. 2003, 2005, 2007, 2008; Brown 2005, 2008; Andre et al. 2007; Hale et al. 2008; Reddivari et al. 2007). The market for potatoes with unusual color patterns has been supplied largely by heirloom varieties of uncertain origin and the highly successful Yukon Gold. Interest has intensified and been transformed into a focused effort in the breeding of specialty varieties, remarkable for their unusual colors. The purpose of this paper is to describe a new potato variety in the Fingerling Class with red skin and red flesh.

## General Description

AmaRosa (POR01PG22-1) resulted from a cross made in 2000 by Dr. Charles Brown (USDA/ARS, Prosser, WA) between PA97B23-2 and Red bulk pollen (Fig. 1). The red flesh trait stems from N40-2 from Cornell University and selections from crosses ND4255-3R x Bison and Fontenot x 3261-5R, true seed of which were provided by Robert Johansen of North Dakota State University. AmaRosa was

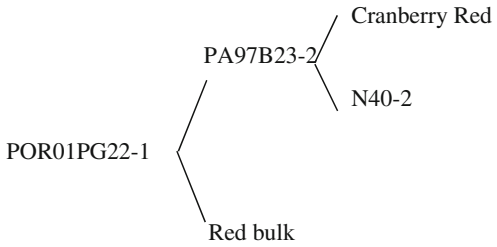


**Fig. 1** Pedigree of AmaRosa resulted from the hybridization between PA97B23 (female) and bulk of red flesh bulk pollen (male). N40-2, a red skin red flesh clone was kindly provided by R. L. Plaisted of Dept of Plant Breeding, Cornell University, Ithaca, NY

selected from seedlings by Dr. Charles Brown and Steven James of the Central Oregon Experiment Station of Oregon State University from tuberlings planted at Madras, Oregon in 2001. It was multiplied and re-selected at the Oregon State University Powell Butte Potato Research Site from 2005 to 2006. It was planted in replicated trials in Washington State (2004–2007). On the basis of promising performance for its market class it was submitted to the Western Regional Red/Specialty Trials in the western U.S, including OR, ID, WA, CA and TX in 2006 and 2007. Oregon State University has taken the lead on the release of this variety. The release will be made jointly by the experiment stations of Oregon, Idaho, and Washington, and USDA/ARS.

AmaRosa is a mid-season specialty potato with red skin and red flesh. This selection is unique among commercially available potato varieties in that plants set a large number of smooth, small, fingerling-shaped tubers with red skin and red flesh. AmaRosa tubers have higher total anthocyanin and hydrophilic oxygen radical absorption capacity (H-ORAC) than the variety All Blue. Tubers are ideal for boiling, baking, and microwaving, and chips made from AmaRosa tubers retain their red color and have a rich red color and very good taste. AmaRosa could be a good candidate for the organic sector due to its resistances to common scab and to tuber

**Table 1** Plant characteristics of AmaRosa compared with those of Red LaSoda and Dark Red Norland

| Characteristic | AmaRosa | Red LaSoda | Dark Red Norland |
|---|---|---|---|
| Vine maturity | Mid-season | Early | Early |
| Growth habit | Semi-erect | Erect | Semi-erect |
| Leaf type (silhouette) | Open | Open | Open |
| Leaflet shape (terminal) | Narrowly ovate | Broadly ovate | Medium ovate |
| Terminal Leaflet waviness | Slight | Absent | Slight |
| Flower color | Purple | Purple-Violet | Purple |
| Pollen production | Abundant | Some | Abundant |
| Berry production | Moderate | Low | Low |

Foliage characteristics were observed at Corvallis, OR

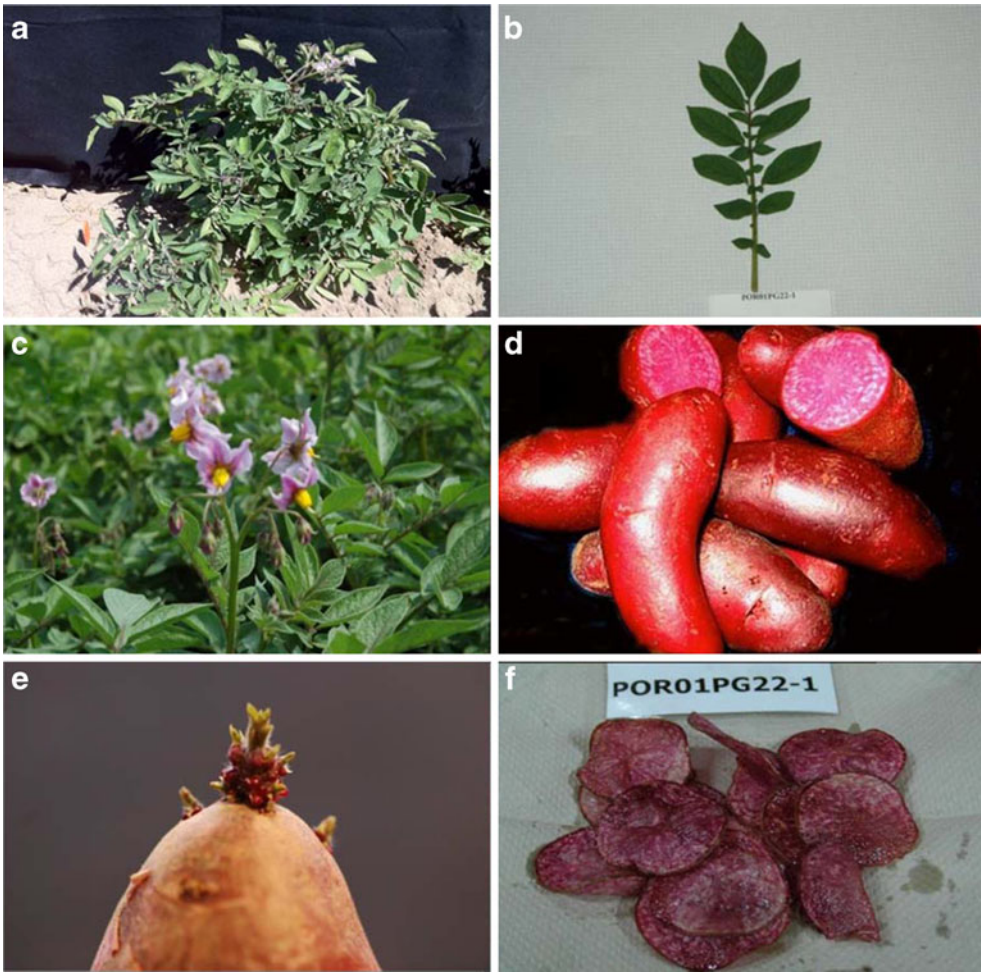


**Fig. 2** AmaRosa canopy (**a**), compound leaf (**b**), inflorescence (**c**), tubers (**d**), light sprout (**e**), and potato chips (**f**)

**Table 2** Physical tuber characteristics of AmaRosa as compared with those of Red LaSoda and Dark Red Norland

| Characteristic | AmaRosa | Red LaSoda | Dark Red Norland |
|---|---|---|---|
| Skin color[1] | Bright red (4.4) | Red (2.8) | Red (3.0) |
| Flesh color[1] | Red (3.5) | White (1.1) | White (1.1) |
| Skin texture | Smooth | Smooth | Smooth |
| Size[2] | Small (2.5 oz.) | Large (8.0 oz) | Large (6.7 oz) |
| Shape[3] | Long (4.8) | Oval (2.2) | Oval (2.4) |
| Thickness | Round | Flattened | Flattened |
| Eye depth | Shallow (3.9) | Very deep (1.8) | Deep (3.1) |
| Eye number[4] | 11 | 10 | 11 |
| Eye distribution | Evenly distributed | Evenly distributed | Evenly distributed |
| Eyebrow prominence | Absent | Medium | Slight |
| Tuber set | Large (7.7) | Low (5.4) | Low (5.2) |
| Dormancy | Medium | Early | Early |

[1] Rating 1–5 with 1 = light and 5 = dark from 14 (skin color) and 10 (flesh color) Western Regional Specialty Trials. Skin color LSD (0.05)=0.4, flesh color LSD (0.05)=0.3

[2] Average tuber weights from 12 Western Regional Specialty Trials. LSD (0.05)=1.0

[3] Shape rating 1–5 with 1 = round and 5 = long from 6 Western Regional Specialty Trials. LSD (0.05)=0.4

[4] Average number of eyes based on 60 medium sized tubers

infection by late blight. In Spanish rosa means pink. *Ama* can be derived from the verb *amar* = "to love" or can refer to the master of the house. i.e., *Ama de casa* = homemaker

## Plant Characteristics

Plants of AmaRosa have mid-season maturity and semi-erect growth habit (Table 1, Fig. 2a). The terminal leaflet

**Table 3** Light Sprout (LS) characteristics of AmaRosa as compared with those of Red LaSoda and Dark Red Norland

| Characteristic | AmaRosa | Red LaSoda | Dark red Norland |
|---|---|---|---|
| LS shape | Ovoid | Ovoid | Cylindrical |
| LS base - pubescence of tip | Medium | Strong | Medium |
| LS base - anthocyanin coloration | Blue-violet | Red-violet | Red-violet |
| LS Base - Intensity of coloration | Very Strong | Medium | Strong |
| LS tip habit | Intermediate | Closed | Open |

Data collected in Corvallis, OR in 2007

**Table 4** Yield components in trials at USDA/ARS Systems Site on Columbia River at Paterson, WA 2005, 2006, and in Toppenish, WA, 2007

| Genotype | Yield in size categories (T/ha) | | | |
|---|---|---|---|---|
| | Total yield | <113 g | 113–284 g | >284 g |
| All Blue | 72 a | 36 b | 32 a | 3b |
| AmaRosa | 56 b | 43 a | 13 b | 1 b |
| Yukon Gold | 65 ab | 7c | 29 a | 19 a |

is narrowly ovate with slight waviness (Table 1, Fig. 2b). Flowers are purple and produce abundant pollen under normal field conditions (Table 1, Fig. 2c). AmaRosa is both male and female fertile under greenhouse conditions. Berry production under field conditions is moderate.

## Tuber Characteristics

AmaRosa produces a large set of small fingerling (long) tubers with bright red skin and red flesh (Table 2, Fig. 2d,) which are desired characteristics for the potato specialty market. The tubers have shallow eyes that are evenly distributed. Eyebrows appear absent in AmaRosa. Light sprouts of AmaRosa have very strong blue-violet anthocyanin pigmentation on the base and mainly green tips (Table 3, Fig. 2d), they are ovoid in shape and have medium pubescence on the tip of the base.

## Tuber Yield

Initial trials comparing AmaRosa with All Blue and Yukon Gold in Washington State locations (Table 4) showed that total yield was less than All Blue but not different from Yukon Gold. Yield of less than113 g size was greater in AmaRosa than the other two. As a varietal characteristic AmaRosa produces the bulk of its yield as smaller tubers compared to Red LaSoda and Dark Red Norland as seen in the Western Regional Trials (Tables 5 and 6). Total yield and yield of US#1 greater than 113 g is significantly lower than the control varieties. The total yield of AmaRosa was probably underestimated in some locations where harvest was automatic; as many tubers fell through the chain due to small size and fingerling shape. Judging from the Western Regional results (Table 5) total yield is definitely a concern for AmaRosa. Growers interested in small fingerling tubers are now purchasing special harvesters that can handle this type of tubers; the alternative is to harvest the tubers manually. The yield of tubers under 113 g from AmaRosa is directly useful in packing facilities dedicated to the small fingerlings specialty/gourmet markets. No differences were observed for specific gravity.

## Tuber External and Internal Characteristics

AmaRosa is rarely misshapen due to growth cracks or knobs (Table 5). Percent hollow heart is very low, which may be correlated to its smaller average tuber size. Shatter bruise, which is minimal, does not differ from Red LaSoda and Dark Red Norland.

## Tuber Biochemical Composition

AmaRosa had significantly higher total anthocyanins and hydrophilic oxygen radical absorption capacity (H-ORAC) than All Blue while total carotenoids and

**Table 5** Yield and specific gravity of AmaRosa, Red LaSoda and Dark Red Norland summarized from 18 Western Regional Specialty Trials conducted in California, Idaho, Oregon, Texas and Washington (2006 and 2007)

| Variety | Total yield T/ha | U.S. #1 yield[1] T/ha | U.S. #1 % | <113 g T/ha | Specific gravity[2] g cm$^{-3}$ |
|---|---|---|---|---|---|
| AmaRosa | 27 | 6 | 18 | 24 | 1.072 |
| Red LaSoda | 59 | 48 | 82 | 5 | 1.073 |
| Dark Red Norland | 51 | 43 | 82 | 6 | 1.067 |
| LSD (0.05) | 8 | 7 | 11 | 7 | NS |

[1] Greater than 113 g

[2] Specific gravity was determined using the weight-in-air, weight-in-water method

**Table 6** Internal and external defects of AmaRosa, Red LaSoda and Dark Red Norland summarized from Western Regional Trials from 2006 to 2007

| Defect | AmaRosa | Red LaSoda | Dark Red Norland |
|---|---|---|---|
| Skinning[1,2] | 3.3 | 3.3 | 4.0 |
| Growth cracks[1,2] | 5.0 | 4.4 | 4.3 |
| Knobs[1,2] | 4.5 | 4.7 | 4.5 |
| Shatter bruise[1,2] | 4.6 | 4.7 | 4.6 |
| Blackspot bruise[1,2] | 3.5 | 4.0 | 4.5 |
| Hollow heart (%)[2] | 0.5 | 12.8 | 4.2 |

[1] Skinning, growth cracks, knobs, shatter bruise, and blackspot bruise rating 1–5 where 1 = severe occurrence and 5 = no occurrence of the defect

[2] LSD (0.05) = NS for all the defects evaluated

**Table 7** Total anthocyanins, total carotenoids, H-ORAC and L-ORAC of AmaRosa and All Blue evaluated in 2007 at six locations

| Entry | Total anthocyanins[1] | Total carotenoids[2] | H-ORAC[3] | L-ORAC[4] |
|---|---|---|---|---|
| AmaRosa | 18.2 | 128.2 | 9.5 | 46.1 |
| All Blue | 13.8 | 99.8 | 5.4 | 45.4 |
| LSD (0.05) | 1.7 | NS | 1.7 | NS |

Aberdeen, ID; Corvallis, Klamath Falls, and Powell Butte, OR; Paterson and Toppenish, WA

[1] Total Anthocyanins = mg per 100 g FW

[2] Total Carotenoids = micrograms per 100 g FW

[3] H-ORAC = micromoles of trolox equivalents per g FW

[4] L-ORAC = nanomoles of tocopherol equivalents per 100 g FW

**Table 8** Hydrophilic Oxygen radical absorbance capacity (H-ORAC) (micromoles Trolox equivalents per g DW) and total phenolics (mg gallic acid equivalents per gram DW). From Morrsion Farm, Mount Vernon, WA 2008. SE = standard error

| Genotype | H-ORAC | SE | Total phenolics mg/g DW | SE |
|---|---|---|---|---|
| AmaRosa | 86.6 | 6.2 | 5.4 | 0.4 |
| All Red | 74.0 | 6.0 | 4.9 | 0.4 |
| Ranger Russet | 40.0 | 0.8 | 2.8 | 0.1 |

**Table 9** Oxygen Radical Absorbance Capacity (μmole trolox equivalents per g DW) and total phenolics (mg gallic acid equivalents per g DW) in AmaRosa harvested at maturity (foliage killed at 110 days) and early (foliage killed at 70 days after planting).SE = standard error

| | H-ORAC | SE | Total Phenolics | SE |
|---|---|---|---|---|
| AmaRosa (Harvest at Maturity) | 86.6 | 6.2 | 5.4 | 0.4 |
| AmaRosa (Early Harvest) | 335.0 | 2.9 | 13.4 | 0.8 |

**Table 10** Culinary quality of AmaRosa compared with Red LaSoda and Dark Red Norland. All culinary qualities tested at Washington State University, Pullman, WA in 2006 and 2007

| Entry | Boiled (0–25)[1] | Baked (0–25)[1] | Microwaved (0–25)[1] | Total (0–75)[1] |
|---|---|---|---|---|
| AmaRosa | 17.7 | 17.9 | 18.5 | 54.1 |
| Red LaSoda | 18.6 | 20.3 | 17.7 | 56.6 |
| Dark Red Norland | 19.1 | 20.2 | 18.5 | 57.8 |
| LSD (0.05) | NS | NS | NS | NS |

**Table 11** Summary of taste panel results in Philomath, OR in 2006. "Overall Liking" is a composite of scores for appearance, color taste and texture. AmaRosa ranked highest when prepared as fried chips and seventh steamed. Numbers represent composite score of hedonic values (1–10 = best). SE = standard error

| Genotype | Overall liking fried chips | SE | Overall liking steamed | SE |
|---|---|---|---|---|
| AmaRosa | 7.3 | 0.5 | 5.7 | 0.6 |
| Yukon Gold | 7.1 | 0.5 | 6.2 | 0.5 |
| Purple Pelisse | 6.1 | 0.5 | 5.7 | 0.5 |
| All Blue | 5.3 | 0.4 | 4.6 | 0.5 |
| Red Gold | 5.2 | 0.4 | 5.2 | 0.5 |
| All Red | 4.3 | 0.5 | 4.9 | 0.6 |
| Klamath Pearl | 4.2 | 0.6 | 5.9 | 1.2 |
| Red Thumb | 4.2 | 0.5 | 5 | 0.7 |
| Jacqueline Lee | 4 | 0.4 | 6.7 | 0.6 |
| Russian Banana | 3.2 | 0.5 | 5.8 | 0.6 |

lipophylic oxygen radical absorption capacity (L-ORAC) were equivalent (Table 7). H-ORAC and L-ORAC are direct measurements of antioxidant capacity against hydrophilic and lipophilic chain-breaking hydroxyl radicals. Comparison of H-ORAC and total phenolics indicated that AmaRosa was higher than All Red and Ranger Russet (Table 8). In a comparison of 70 days and 120 days harvest the early harvest had a four-fold and three-fold greater expression of H-ORAC, and total phenolics, respectively, than the late harvest (Table 9). Clearly, AmaRosa is more nutrient-laden at an early harvest date and would be suitable as a baby potato.

## Culinary Quality

AmaRosa boiled, baked, and microwaved potato quality was equivalent to Red LaSoda and Dark Red Norland

**Table 12** Potato sensory attributes evaluated on boiled potatoes by a panel of consumers ($n$=112). Tests were performed at the Food Innovation Center, Portland, OR in January of 2010

| Clone | Overall liking[1] | Appearance[1] | Flavor[1] | Texture[1] |
|---|---|---|---|---|
| Yukon Gold | $6.63^{b}$ (1.80) | $6.84^{ab}$ (1.41) | $6.63^{b}$ (1.80) | $6.13^{b}$ (2.03) |
| AmaRosa | $7.28^{a}$ (1.57) | $6.75^{ab}$ (2.37) | $7.23^{a}$ (1.67) | $7.28^{a}$ (1.53) |

[1] Overall and attribute liking for appearance, flavor, and texture of boiled potatoes. The sensory test used a 9-point hedonic category scale with 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely ($n$=112, $p$<0.05). Standard deviations are in parenthesis

**Table 13** Disease ratings for AmaRosa, Red LaSoda and Dark Red Norland

| Disease reaction | AmaRosa | Red LaSoda | Dark Red Norland |
|---|---|---|---|
| Common scab[1] | 4.8 | 4.1 | 3.6 |
| PVY[2] (%) | 63 | 90 | 88 |
| PLRV[2] (%) | 48 | 50 | 55 |

[1] Evaluations made at California in 2007. Common scab rating 1–5 with 1 = high incidence of infection and 5 = none. LSD (0.05)=0.3

[2] Evaluations made at Hermiston, Oregon. Virus readings are from evaluation of tubers from plants grown under high virus pressure, 2006 and 2007. LSD (0.05) for PVY=9.8; NS for PLRV

(Table 10). Tubers are ideal for boiling, baking, and microwaving whole. A sensory evaluation test performed in 2006 (11 participants) gave high ratings to chips made from AmaRosa indicating potential for the chipping snack sector (Table 11). Chips made from AmaRosa tubers retain their red color (Fig. 2f). Steamed potatoes made from AmaRosa were also good. A much larger consumer test (112 participants) performed at the Food Innovation Center, Portland, OR using boiled potatoes also ranked AmaRosa highly (Table 12).

## Disease and Herbicide Reactions

AmaRosa was resistant to common scab (Table 13). AmaRosa showed moderate susceptibility to PVY and PLRV under field condition. This selection has a lower incidence of tuber late blight and is susceptible to foliar infection but slightly less susceptible than Dark Red Norland (Table 14). AmaRosa is very susceptible to damage caused by Metribuzin, a herbicide commonly used on potato. Crop failure may result from use of Metribuzin, thus herbicides other than metribuzin are imperative for early season weed control in AmaRosa fields.

## Protection, Seed Availability and Licensing

Plant Variety Protection (PVP) certification for "AmaRosa" has been applied for. Disease-free pre-nuclear plantlets and minitubers are available from the Foundation Potato Seed Program at the University of Idaho Tissue Culture Laboratory. "AmaRosa" will be licensed to the Potato Variety Management Institute (PVMI, a non-profit organization working on behalf of the Tri-State Potato Breeding Program) based on a prior agreement between OSU, the Oregon Potato Commission and PVMI. PVMI will offer this variety to interested parties without restrictions.

**Table 14** Summary of late blight evaluation for AmaRosa, Red LaSoda and Dark Red Norland, Corvallis, OR, 2006–2008

| Entry | Foliage infection[1] (1–9) | AUDPC[2] | Tuber infectio[3]% |
|---|---|---|---|
| AmaRosa | 8.25 | 1210.78 | 2.50 |
| Dark Red Norland | 9.00 | 1403.75 | 27.50 |
| Red LaSoda | 8.75 | 1356.46 | 37.41 |
| LSD (0.05) | 0.26 | 136.98 | 11.22 |

[1] Scale used was 1–9, highest number being most severe

[2] *AUDPC* Area Under Disease Progress Curve

[3] Percent of late blight infected tubers at harvest (40 randomly selected tubers, 10 per replication, 4 replications)

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