Potato as a Functional Food/Ingredient

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Where is Guelph? How do you pronounce Guelph?

- GWELF
Potential for improvement by selection for reducing sugar content after cold storage for three potato populations

A. da S. Pereira, G. C. C. Tai, R. Y. Yada, R. H. Coffin and V. Souza-Machado

Effect of Selection for Chip Colour on Some Economic Traits of Potatoes


Article first published online: 28 APR 2006
DOI: 10.1111/j.1439-0523.1994.tb00741.x

Inheritance patterns of reducing sugars in potato tubers after storage at 12°C and 4°C followed by reconditioning

A. da S. Pereira, R. H. Coffin, R. Y. Yada and V. Souza Machado
Outline

- Challenges/opportunities
- Nutrition/food waste
- Potatoes as a food source
  - Phytochemicals
  - Starch
  - Protein
- Bioplastics
- Antifungal
- Education
There is no question that the “right” food(s) (i.e., healthier choices) eaten in the right amounts is a means to preventative health care.

- How do we accomplish the above?
  - Promote certain foods
  - Prevent waste
  - Fractionate foods – value added ingredients
Challenges

- Population growth - predicted 9 billion 2050
  - Feeding the population
- Epidemic increases in chronic diseases (e.g., obesity, Type 2 diabetes, cardiovascular diseases)
- Food waste
- Water shortage/Fossil fuels
- Value added products from traditional food commodities
- Education - why obesity, undernourishment and chronic diseases?
Opportunities

- Food, diet, nutrition, health – reduce health care costs
- Potatoes more than a commodity
Nutrition statistics

- “2790 calories per person per day represents the average available food supply at the world level”
- “In the poorest countries the average falls to just 2120 but rises to 3430 calories per person per day in developed countries”
- “There is enough food available to feed the world, but large disparities in the distribution of food obstruct the fight against hunger”

“Loss assessments are generally unreliable, but it is estimated that roughly one-third of the edible food produced for human consumption is lost or wasted, which translates to about 1.3 billion tonnes per year. Per capita waste by consumers is between 95-115 kg a year in Europe and North America, while consumers in sub-Saharan Africa and South and Southeast Asia waste only 6-11 kg a year. In medium- and high-income countries food is to a great extent wasted at the consumer level, meaning that it is disposed of even if still suitable for human consumption. In low-income countries, however, much less is wasted at this level.”

Chart 97: Food losses and wastage are a problem in both developing and developed countries, but at different stages of the value chain

Average per capita food losses and wastage (2010)

- Consumption
- Pre-consumption

Source: FAO, Agriculture Department
The Progressive Increase of Food Waste in America and Its Environmental Impact

Kevin D. Hall, Juen Guo, Michael Dore, Carson C. Chow
Laboratory of Biological Modeling, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, Maryland, United States of America

Abstract

Food waste contributes to excess consumption of freshwater and fossil fuels which, along with methane and CO₂ emissions from decomposing food, impacts global climate change. Here, we calculate the energy content of nationwide food waste from the difference between the US food supply and the food consumed by the population. The latter was estimated using a validated mathematical model of metabolism relating body weight to the amount of food eaten. We found that US per capita food waste has progressively increased by ~50% since 1974 reaching more than 1400 kcal per person per day or 150 trillion kcal per year. Food waste now accounts for more than one quarter of the total freshwater consumption and ~300 million barrels of oil per year.

Undernourishment statistics

Map 19: Two thirds of the hungry live in just seven countries

Source: FAO, Statistics Division

Percentage of U.S. Children Who Are Obese

Source: Centers for Disease Control
Map Legend: The darkest red areas on the map (Pacific islands) represent obesity rates of 40% or more. The next darkest areas (US, Egypt, Saudi Arabia, Panama, and United Arab Emirates) represent obesity rates of 30-40%. Progressively lighter colors represent 20-30% obesity rates, 10-20% obesity rates, 5-10% obesity rates, and 0-5% obesity rates. The grey areas are not represented on the scale.


http://obesity.procon.org/view.resource.php?resourceID=004371#8
## Obesity statistics

<table>
<thead>
<tr>
<th>Top 10 &quot;Industrialized&quot; Countries</th>
<th>% Who Are Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. United States of America (2006)</td>
<td>33.9%</td>
</tr>
<tr>
<td>2. New Zealand (2007)</td>
<td>26.5%</td>
</tr>
<tr>
<td>3. Canada (2004)</td>
<td>23.1%</td>
</tr>
<tr>
<td>4. Israel (2001)</td>
<td>22.9%</td>
</tr>
<tr>
<td>5. United Kingdom (2002)</td>
<td>22.7%</td>
</tr>
<tr>
<td>6. Greece (2003)</td>
<td>22.5%</td>
</tr>
<tr>
<td>7. Lithuania (2006)</td>
<td>19.7%</td>
</tr>
<tr>
<td>8. Poland (2001)</td>
<td>18.0%</td>
</tr>
<tr>
<td>10. France (2007)</td>
<td>16.9%</td>
</tr>
</tbody>
</table>

Obese males aged 15-100

Maps generated using WHO infobase
https://apps.who.int/infobase/
Potatoes and potato products helping to feed humanity
Background - Potatoes

- World Production re: energy source - ranks fourth behind rice, wheat and maize
- Provides 5-15% dietary calories for various populations around the world
- Number one non-grain food commodity
  - More protein, vitamins, minerals than rice, wheat, sorghum and corn
  - Good source of antioxidants and phytochemicals
Potatoes, nutrition and diet

The potato is a good source of dietary energy and some micronutrients. But balanced diets need to include other vegetables and whole grain foods.

Potato is a versatile, carbohydrate-rich food highly popular worldwide and prepared and served in a variety of ways. Freshly harvested, it contains about 80 percent water and 20 percent dry matter. About 60 to 80 percent of the dry matter is starch. On a dry weight basis, the protein content of potato is similar to that of cereals and is very high in comparison with other roots and tubers.

In addition, the potato is low in fat. Potatoes are rich in several micronutrients, especially vitamin C - eaten with its skin, a single medium sized potato of 150 g provides nearly half the daily adult requirement (100 mg). The potato is a moderate source of iron, and its high vitamin C content promotes iron absorption. It is a good source of vitamins B1, B3 and B6 and minerals such as potassium, phosphorus and magnesium, and contains folate, pantothenic acid and riboflavin. Potatoes also contain dietary antioxidants, which may play a part in preventing diseases related to ageing, and dietary fibre, which benefits health.

Effects of potato preparation methods

The potato is a good source of dietary energy and some micronutrients, and its protein content is very high in comparison with other roots and tubers.

Potato is low in fat - but preparing and serving potatoes with high fat ingredients raises the caloric value of the dish.
Nutrition

- Thiamin: 0.106 milligrams
- Riboflavin: 0.02 milligrams
- Niacin: 1.44 milligrams
- Iron: 0.31 milligrams
- Phosphorus: 44 milligrams
- Potassium: 379 milligrams
- Calcium: 5 milligrams
- Vitamin C: 13.0 milligrams
- Protein: 1.87 grams
- Fat: 0.1 grams
- Fibre: 1.8 grams
- Carbohydrate: 20.13 grams
- Water: 77 grams
- Energy: 87 kcal

International Year of the Potato, 2008
# Nutrient Composition of Potatoes

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Range per 100 g raw whole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>0.8 – 4.2 g</td>
</tr>
<tr>
<td>Total fibre flesh</td>
<td>0.3 – 3.3 g</td>
</tr>
<tr>
<td>Starch</td>
<td>9.1 – 22.6 g</td>
</tr>
<tr>
<td>Iron</td>
<td>0.7 – 10.4 mg</td>
</tr>
<tr>
<td>Potassium</td>
<td>239 – 694 mg</td>
</tr>
<tr>
<td>Magnesium</td>
<td>10.8 – 37.6 mg</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>33.1 – 126 mg</td>
</tr>
<tr>
<td>Calcium</td>
<td>1.3 – 27.8 mg</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>4.6 – 40 mg</td>
</tr>
<tr>
<td>Hydrophilic antioxidant activity</td>
<td>128 – 565 mcg Trolox eq/ g</td>
</tr>
</tbody>
</table>

# Nutrition Facts - Potato

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Without skin (156g) (% RDA)</th>
<th>With skin (173g) (% RDA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin C</td>
<td>33</td>
<td>28</td>
</tr>
<tr>
<td>Thiamin (B1)</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Niacin (B3)</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Folate (B9)</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Pantothenic Acid (B5)</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Iron</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Magnesium</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Potassium</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td>Copper</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>Dietary Fibre</td>
<td>9</td>
<td>15</td>
</tr>
</tbody>
</table>

International Year of the Potato, 2008
# Nutrition - Comparison

## The potato, a healthy choice!

### Calories

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Potato</td>
<td>161 cal</td>
</tr>
<tr>
<td>White Rice</td>
<td>217 cal</td>
</tr>
<tr>
<td>Pasta</td>
<td>209 cal</td>
</tr>
<tr>
<td>Instant Oatmeal</td>
<td>364 cal</td>
</tr>
</tbody>
</table>

### Fiber

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>3.8 g</td>
</tr>
<tr>
<td>White Rice</td>
<td>0.7 g</td>
</tr>
<tr>
<td>Pasta</td>
<td>1.8 g</td>
</tr>
<tr>
<td>Instant Oatmeal</td>
<td>2.1 g</td>
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</table>

### Carbohydrates

<p>| | |</p>
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<tr>
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</thead>
<tbody>
<tr>
<td>Potato</td>
<td>36.59 g</td>
</tr>
<tr>
<td>White Rice</td>
<td>47.03 g</td>
</tr>
<tr>
<td>Pasta</td>
<td>41.82 g</td>
</tr>
<tr>
<td>Instant Oatmeal</td>
<td>15.43 g</td>
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</table>

Medium potato with peel (173g), oven baked - Cooked long-grain white rice (167g/250ml) - Cooked enriched pasta (macaroni) (148g/250ml) - Prepared plain instant oatmeal (145g/175ml)

http://www.metro.ca/conseil-expert/jardinier/panier-legumes/legumes-tubercules/pomme-terre/pomme-de-terre-valeurs-nutritionnelles.en.html#10305924
“A functional food is similar in appearance to, or may be, a conventional food, is consumed as part of a usual diet, and is demonstrated to have physiological benefits and/or reduce the risk of chronic disease beyond basic nutritional functions.”

“A nutraceutical is a product isolated or purified from foods that is generally sold in medicinal forms not usually associated with food. A nutraceutical is demonstrated to have a physiological benefit or provide protection against chronic disease.”

Many studies regarding the health benefits in relation to disease prevention, e.g., cardiovascular diseases, cancer, other chronic diseases

Potatoes are a good source of bioactives (e.g., antioxidants)
Phytochemicals - Bioactives

- Polyphenols
- Flavonols
- Anthocyanins
- Vitamins
  - Tocopherols
  - Carotenoids
  - Vitamin C
# Potato Good Source of Phytochemicals

<table>
<thead>
<tr>
<th>Phytochemicals</th>
<th>Potato</th>
<th>Blueberry</th>
<th>Per capita consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per capita</td>
<td>Per capita</td>
<td></td>
</tr>
<tr>
<td></td>
<td>consumption</td>
<td>consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potato (54 kg)</td>
<td>Blueberry (540 g)</td>
<td></td>
</tr>
<tr>
<td>Chlorogenic acid (polyphenol)</td>
<td>34 µg/ g fw</td>
<td>110 µg/ g fw</td>
<td>~ 31 x 1836 g</td>
</tr>
</tbody>
</table>
| Lutein (carotenoids)            | 11 µg/100 g fw  | 1 µg/100 g fw   | ~ 1100 x 5900 µg       | 5.4 µg

~ 31 x 1836 g
59.4 g

~ 1100 x 5900 µg
5.4 µg
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1V</td>
<td></td>
<td>Beacon Chipper V</td>
</tr>
<tr>
<td>2V</td>
<td></td>
<td>Waneta NY138 V</td>
</tr>
<tr>
<td>1M</td>
<td></td>
<td>Beacon Chipper M</td>
</tr>
<tr>
<td>2M</td>
<td></td>
<td>Waneta NY138 M</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>F06053, redcolored</td>
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<tr>
<td>4</td>
<td></td>
<td>F06058, purplecolored</td>
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<tr>
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<td>W2438-3Y</td>
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<td>6</td>
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<td>9</td>
<td></td>
<td>Tundra</td>
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<td>10</td>
<td></td>
<td>Nicolette</td>
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<td>W6803-3</td>
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<td>W6822-3</td>
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<td>W8641-4</td>
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<td>17</td>
<td></td>
<td>W8822-3</td>
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<tr>
<td>18</td>
<td></td>
<td>W8867-5</td>
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<tr>
<td>19</td>
<td></td>
<td>W8848-3</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>Snowden</td>
</tr>
</tbody>
</table>
Total Phenolics Content in Potato

3, red & 4, purple
Antioxidant Potential of Potato

![Graph showing antioxidant potential of potato varieties.](image)

Varieties: 1V, 1M, 2V, 2M, 3, 4, 5, 6, 1, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

 Trolox equivalent (μg/g dry wt)

- DM
- CHIPS

3, red & 4, purple
Potato starch as an ingredient

Manitoba Starch Products is Canada’s only potato starch manufacturing company. Centrally located in the heart of Canada’s fastest growing potato province, we are proud to be an integral part of the Canadian potato processing industry.
Technical Advantages

MSP Potato Starch is a superior grade native potato starch produced from potatoes grown and processed in Canada. Manitoba Starch Products maintains tight control of our raw material supply and manufacturing process. We are HACCP Certified and Kosher Certified. It is manufactured from potatoes grown in Canada and from starch extracted during manufacture of high quality fries and chips, also in Canada.

Potato starch’s unique properties make it an excellent choice for many food applications. It has the highest viscosity of any starch product due to its unique granular structure. Additionally, potato starch is gluten-free, appealing to gluten-free manufacturers as an excellent starch for maintaining moistness and creating an open texture. MSP Potato Starch has been tested to be very low in lipids and protein, which give it a clean texture and allow formulators to reduce their dependence upon expensive flavors.

Pure, unmodified potato starch has been used for centuries as a thickener in foods. More recently, it has been added to prevent caking, improve filtration, manage moisture in meats and baked goods and improve texture of gluten-free foods.
Potato starch as an ingredient – sole source/blend, gluten free

Gluten-Free
Potato starch is excellent as a replacer for wheat flour or cornstarch in gluten-free products. It is gluten-free and cooks to a nice thick paste which provides viscosity for creating good texture in baked goods. Potato starch cooks at a higher temperature than cornstarch, binds more water and has higher viscosity. Further, due to the lack of proteins and lipids, potato starch has less flavor interference.

Inclusion of potato starch in gluten-free applications provides a highly functional flour replacer. Potato starch can be blended with tapioca starch and rice starch for creating texture in baked goods. Use of this product has been widely accepted by gluten-free formulators and chefs for decades – both in home and at food manufacturing facilities. MSP potato starch is made in a facility, which does not contain any cross-contaminates or allergens. The following links contain recipes and formulation advice on using potato in gluten free applications.

MSP Potato Starch is consistently of the highest quality and available to target markets: Canada and North America.
Physiological Benefits of Fibre

- An increased throughput of the digestive tract
- Production of desirable metabolites
- Increase in fecal bulk and the production of short-chain fatty acids (SCFA) in the colon
- Protection against bowel cancer and other diseases, e.g. diarrhea and constipation
Starch and Health – Digestibility *in vitro*

- Rapidly digestible starch (RDS), Slowly digestible starch (SDS) and/or Resistant starch (RS)
- Hydrolysis index (HI)
  \[
  HI = \left( \frac{\text{area under hydrolysis curve of sample}}{\text{area under hydrolysis curve of white bread}} \right) \times 100
  \]
- Prediction of glycemic index (GI = HI + constant)
Glycemic Index

![Graph showing high and low glucose response](image)

Glycemic Index Foundation, 2010
Lynch et al., 2007
Nutritional fractions of starch

- Slowly digestible starch
- Quickly digestible starch
- Resistant starch
Starch components

- Total starch (TS)
- Digestibility
  - Rapid (RDS)
    - <20 minutes
  - Slow (SDS)
    - 20-120 minutes
  - Resistant (RS)
    - >120 minutes
    - Dietary fibre

Campbell and Reese, 2008
Englyst, et al. 1992
Nutritional fractions of starch

- Rapidly digestible starch
  - Rapidly digested in small intestine
  - Rapid increase in plasma glucose and insulin levels
- Slowly digestible starch
  - Slow but complete digestion in small intestine
  - Slower and more even glucose and insulin responses
- Resistant starch
  - The sum of starch digestion not absorbed in the small intestine of healthy human which enter large bowel and is fermented
  - Does not increase plasma glucose
Classification of Resistant Starch

- Physically inaccessible starch (Type I)
- Resistant starch granules (Type II)
- Retrograded starch (Type III)
- Chemically Modified starches (Type IV)
- Partly milled grains and seeds
- Raw starch from high-amylose corn, potato & banana
- Cooled, cooked high-amylose corn, potato & bread, etc.
- Starch by Cross-linking, esterification, and etherification, etc.
Genotype by environment interaction effects on fibre components in potato (*Solanum tuberosum* L.)

Stephanie Bach · Rickey Y. Yada · Benoit Bizimungu · J. Alan Sullivan
Examined eight elite potato clones and four commercial cultivars (checks) across six environments (three locations over two years) for their total dietary fibre (TDF), neutral detergent fibre (NDF), and soluble fibre (SF) content.

Significant genotypic (G), environmental (E) and GEI effects were found. The six environments differed in temperature and moisture levels, which were linked to levels of NDF and TDF.

Some genotypes had high levels of stability for fibre content

Identified some clones with high fibre – potential breeding lines (CV96044-3, F05081 (13.3% 14.4% TDF, respectively)
Genotype by environment interaction effects on starch content and digestibility in potato (*Solanum tuberosum* L.)

- Evaluated the digestible starch profile of 12 elite potato genotypes and commercial varieties in six environments, with the optimal profile defined as low RS and high RS.

- Genotype by environment (GxE) interaction analysis found significant (p=0.05) genotypic and environmental effects for all digestibility rate components; however, interaction effects were only significant for SDS.

- Optimal starch profiles were identified for two genotypes, CV96044-3 and Goldrush.

- The desirable starch profile in these potato cultivars can be exploited in breeding programs for the introgression of starch profile and other important characteristics, such as high yields and disease resistance.
The agronomic performance of eight elite potato clones and four cultivars were evaluated examining starch and fibre profiles in potato. The elite clones were bred and selected at Agriculture and Agri-Food Canada’s Potato Research Centre in Fredericton, New Brunswick for favourable starch and fibre content.

Yield trials were conducted in six environments (three locations over two years) in Ontario, Canada.

The effect of genotype, environment and genotype x environment interactions were measured using the GGE Biplot program.

Although significant genotypic, environmental and interaction effects were found, a superior elite clone was identified (F04037), with the best agronomic performance (4 kg m\(^{-2}\) and 82% large tubers) suitable for further breeding aspects.
Fractionated and modified biomolecules
SEM of resistant starch

Native potato starch

Cross-linked starch

Debranched starch

Starch citrate
Starch citrate as resistant starch for functional foods

Starch citrates (7% solid in water) after heating at 100°C for 30 min.
1: normal corn starch; 2: normal corn starch control; 3: normal corn starch citrate; 4: waxy corn starch citrate; 5: high amylose corn starch (Hylon VII) citrate. Citrate prevents gelatinization.

Protein

- 20g of solid in 100g potato
  - 18 g carbohydrates
  - 2 g protein
- Nutritional source of protein
  - Deficient in methionine and lysine
    - Synthetic gene
    - Plant protein
- Antioxidant
- Functional ingredient
Genetic modification to improve nutritional quality

- Ability to improve the nutritional content, especially protein
- Increased yields
- Safety and allergy testing
- Perception and acceptance
- Regulatory approval
Expression of a synthetic gene for improved protein quality in transformed potato plants


Dept. of Biochemistry, Louisiana State University & A.M. College and Louisiana State University Agricultural Center, Baton Rouge, LA 70803, U.S.A.

Dept. of Plant Pathology, Kansas State University, Manhattan, KS 66506 U.S.A.

Dept. of Veterinary Microbiology and Parasitology, Louisiana State University School of Veterinary Medicine, Baton Rouge, LA 70803, U.S.A.

http://dx.doi.org/10.1016/0168-9452(89)90156-8. How to Cite or Link Using DOI

Permissions & Reprints
Next-generation protein-rich potato expressing the seed protein gene AmA1 is a result of proteome rebalancing in transgenic tuber

Subhra Chakraborty1,2, Niranjan Chakraborty1, Lalit Agrawal6, Sudip Ghosh9, Kanika Narula6, Shubhendu Shekhar6, Prakash S. Naik9, P. C. Pande6, Swarup Kumar Chakraborty1, and Asis Datta1,2

1National Institute of Plant Genome Research, New Delhi 110067, India; 2Central Potato Research Institute, Shimla, Himachal Pradesh 171001, India; and 3Central Potato Research Institute Campus, M菩提puram, Uttar Pradesh 250110, India

Edited by Eugene W. Nester, University of Washington, Seattle, WA, and approved August 17, 2010 (received for review May 5, 2010)

Protein deficiency is the most crucial factor that affects physical growth and development and that increases morbidity and mortality especially in developing countries. Efforts have been made to improve protein quality and quantity in crop plants but with limited success. Here, we report the development of transgenic potatoes with enhanced nutritive value by tuber-specific expression of a seed protein, AmA1 (Amaranth Albumin 1), in seven genotypic backgrounds suitable for cultivation in different agro-climatic regions. Analyses of the transgenic tubers revealed up to 60% increase in total protein content. In addition, the concentrations of several essential amino acids were increased significantly in transgenic tubers, which are otherwise limited in potato. Moreover, the transgenics also exhibited enhanced photosynthetic activity with a concomitant increase in total biomass. These results are striking because this genetic manipulation also resulted in a moderate increase in tuber yield. The comparative protein profiling suggests that the proteome rebalancing might cause increased protein content in transgenic tubers. Furthermore, the data on field performance and safety evaluation indicate that the transgenic potatoes are suitable for commercial cultivation. In vitro and in vivo studies on experimental animals demonstrate that the transgenic potatoes are also safe for human consumption. Altogether, these results emphasize that the expression of AmA1 is a potential strategy for the nutritional improvement of food crops.

allergenecity | essential amino acids | nutritional health

PNAS 2010 107 (41): 17533-17538

www.pnas.org/cgi/doi/10.1073/pnas.1006265107
Fractionated and modified biomolecules
Fractionation and characterization of potato protein

Chemical characterization and functional properties of a potato protein concentrate prepared by large-scale expanded bed adsorption chromatography

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Fractionation and characterization of potato protein

Properties of acetylated potato protein preparations

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Potato protein as an antioxidant

Patatin, the tuber storage protein of potato (Solanum tuberosum L.), exhibits antioxidant activity in vitro.

Liu YW, Han CH, Lee MH, Hsu FL, Hou WC.
School of Pharmacy, Taipei Medical University, Taipei 110, Taiwan, Republic of China.

Abstract
The potato (Solanum tuberosum L.) tuber storage protein, patatin, was purified to homogeneity with a molecular mass of 45 kDa. The purified patatin showed antioxidant or antiradical activity by a series of in vitro tests, including 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical (half-inhibition concentration, IC(50), was 0.582 mg/mL) scavenging activity assays, anti-human low-density lipoprotein peroxidation tests, and protections against hydroxyl radical-mediated DNA damages and peroxynitrite-mediated dihydrorhodamine 123 oxidations. Using electron paramagnetic resonance (EPR) spectrometry for hydroxyl radical detections, it was found that the intensities of the EPR signal were decreased by the increased amounts of patatin added (IC(50) was 0.775 mg/mL). Through modifications of patatin by iodoacetamide or N-bromosuccinimide, it was found that the antiradical activities of modified patatin against DPPH or hydroxyl radicals were decreased. It was suggested that cysteine and tryptophan residues in patatin might contribute to its antioxidant activities against radicals.
Low temperature sweetening and acrylamide research at the University of Guelph
Long tradition of researching potatoes at Guelph
Notable example

Yukon Gold – bred by Gary Johnston (AAFC Guelph)
Cross between white potato (Norgleam) with a wild South American yellow-fleshed variety (W5279-4).

Low Temperature Sweetening

- Low temperature sweetening (LTS): exposure to <9-10°C induces the breakdown of starch into reducing sugars
- Accumulation of reducing sugars is undesirable; leads to nonenzymatic browning during chip frying operations
- Low temperature storage prevents sprout growth, reduces weight loss and losses due to senescence and storage rot
- Not many varieties tolerant to LTS – a commercial handicap??
Benefits to Chipping Industry

- Long term availability of tubers for processing

- Preservation of the processing quality after cold storage

- Minimizing crop loss by reducing tuber respiration, rot and shrinkage

- Reduction/elimination of chemical sprout inhibitors
Chip colour
Low Temperature Sweetening

AC Novachip

$4^\circ C$  $10^\circ C$
Low Temperature Sweetening

Four-year study (1997-2000) shows there is good evidence of a relationship between levels of ethanol and lactate, reducing sugars and chip colour quality:

<table>
<thead>
<tr>
<th>Year</th>
<th>Ethanol</th>
<th>Lactate</th>
<th>Reducing sugars</th>
<th>Chip colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>CT &gt; CS</td>
<td>CT &gt; CS</td>
<td>CT &lt; CS</td>
<td>CT &gt; CS</td>
</tr>
<tr>
<td>1998</td>
<td>CT ~ CS</td>
<td>CT ~ CS</td>
<td>CT ~ CS</td>
<td>CT ~ CS</td>
</tr>
<tr>
<td>1999</td>
<td>CT &gt; CS</td>
<td>CT &gt; CS</td>
<td>CT &lt; CS</td>
<td>CT &gt; CS</td>
</tr>
<tr>
<td>2000</td>
<td>CT &gt; CS</td>
<td>CT &gt; CS</td>
<td>CT &lt; CS</td>
<td>CT &gt; CS</td>
</tr>
</tbody>
</table>

CT = cold-tolerant tubers; CS = cold-sensitive tubers


### Activity of pyruvate decarboxylase (PDC) at 4°C

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>V/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>ND 860-2</td>
<td>0.19</td>
</tr>
<tr>
<td>Snowden</td>
<td>0.09</td>
</tr>
<tr>
<td>Monona</td>
<td>0.07</td>
</tr>
</tbody>
</table>

- **Tolerant**
- **Moderate**
- **Susceptible**
Low Temperature Sweetening

**Mechanism**

- Starch
- Glucose
- Pyruvate
- Lactate
- Ethanol
- Acetaldehyde
- ADH
- LDH
- PDC
- Respiration
- Weight loss

Anaerobic respiration
Low Temperature Sweetening

- Possible role of anaerobic respiratory pathway
- PDC the key enzyme regulating LTS-tolerance??
- Arabidopsis PDC1 gene (APDC1) is upregulated by cold and has a role in stress response
Hypothesis

Overexpression of Arabidopsis PDC1 in potato will increase LTS-tolerance by removing the excess carbon flux during cold temperature storage through anaerobic respiratory pathway and reducing the accumulation of reducing sugars in the tubers
RESEARCH ARTICLE

Alleviation of low temperature sweetening in potato by expressing Arabidopsis pyruvate decarboxylase gene and stress-inducible rd29A: A preliminary study

Reena Pinhero, Rinu Pazhekattu, Alejandro G. Marangoni, Qiang Liu and Rickey Y. Yada
Objectives

- Develop transgenic potato varieties with LTS-tolerance by overexpressing APDC1 by *Agrobacterium tumefaciens*-mediated transformation

- Study the processing qualities of transgenic tubers
Materials and Methods

- Varieties: Monona, Snowden, Dakota Pearl

- Transgenic potato development by overexpressing APDC1 gene by *Agrobacterium tumefaciens*-mediated transformation
Strategy to over express Arabidopsis PDC1 gene

- Cloning PDC1 from Arabidopsis using pGEM-T easy vector system
- Binary vector construction using cold-regulated rd 29A and constitutive cauliflower mosaic virus (35S) promoters
- Transgenic potato development by over expressing PDC1 using Agrobacterium tumefaciens mediated transformation
- Storage/processing studies on transgenic potato tubers
Two transgenic plants, T1 and T2 from Snowden. Tubers from greenhouse-grown plants
Effect of genetic modification on resistant starch

![Graph showing the effect of genetic modification on resistant starch over days after storage at different temperatures. The graph compares control and transgenic samples at 5°C and 12°C, with data points indicating changes in resistant starch percentage.](attachment:image.png)
Effect of Genetic modification on Sugars
Effect of Genetic modification on Chip color

Days after storage

Agtron Score

- Control 5°C
- Transgenic 5°C
- Control 12°C
- Transgenic 12°C

Days after storage

Agtron Score

30 40 50 60

14 28 42 56
A representative chip sample

Control

Transgenic

5°C

12°C

28 days after storage
Correlation of Chip Color and Reducing Sugars

![Graph showing the correlation between chip color score and reducing sugars percentage. The graph includes data points for different conditions: Control 5°C, 14°C, Control 12°C, 14°C, Control 5°C, 28°C, Transgenic 5°C, 14°C, Transgenic 12°C, 14°C, Transgenic 5°C, 28°C, Control 5°C, 42°C, Transgenic 5°C, 42°C, Transgenic 12°C, 42°C, and Control 12°C, 42°C. The correlation coefficient is r = -0.8149 with p < 0.05.]

Reducing sugars %
Chip color score

r = -0.8149
p < 0.05
Correlation of Chip Color and Sucrose

![Graph showing the correlation between chip color score and sucrose percentage, with data points for different conditions (Control 5°C, 14°C, Transgenic 5°C, 14°C, Control 12°C, 28°C, Transgenic 12°C, 28°C, Control 5°C, 42°C, Transgenic 5°C, 42°C, Control 12°C, 42°C, Transgenic 12°C, 42°C). The correlation coefficient is r = -0.6673 with p < 0.05.]

\[ r = -0.6673 \]
\[ p < 0.05 \]
Summary of Results (Snowden)

- Higher Agtron chip score for transgenic tubers

- Glucose, fructose and total reducing sugars (glucose + fructose) was lower in transgenic tubers during storage at 12°C and 5°C.

- Sucrose concentration was lower in transgenic tubers during all storage periods at 12°C and 5°C

- Significant negative Pearson correlation between chip color and reducing sugar and sucrose contents
Conclusions

1. Transgenic tubers stored at 5°C produced lighter colored chips
2. Glucose, fructose, sucrose and total reducing sugar contents were lower in transgenic tubers stored at 5°C and 12°C as compared to non-transgenic tubers.
3. Significant negative correlation was observed between chip color and total reducing sugars as well as sucrose.
4. Over expressing *Arabidopsis* PDC1 gene resulted in LTS-tolerance.
Acrylamide in Food and Cancer Risk

- Acrylamide is a chemical used primarily for industrial purposes.
- Acrylamide has been found in certain foods, with especially high levels in potato chips, French fries, and other food products produced by high-temperature cooking.
- Food and cigarette smoke are the major sources of exposure to acrylamide.
- Scientists do not yet know with any certainty whether the levels of acrylamide typically found in some foods pose a health risk for humans.
Acrylamide in Potato Chips

- Maillard browning reaction results in acrylamide (AA)
- Asparagine and reducing sugars precursors of AA
- AA, a probable human carcinogen (Mottram et al. 2002)
- Polyphenols reduce AA formation
Effect of genetic modification and storage on the physico-chemical properties of potato dry matter and acrylamide content of potato chips

Reena Pinhero\textsuperscript{a}, Rinu Pazhekattu\textsuperscript{a,1}, Kyly Whitfield\textsuperscript{a}, Alejandro G. Marangoni\textsuperscript{a}, Qiang Liu\textsuperscript{b}, Rickey Y. Yada\textsuperscript{a}

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http://dx.doi.org/10.1016/j.foodres.2012.07.013, How to Cite or Link Using DOI

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FRI paper results

- The dry matter from the untransformed potato contained high amylose content during the various storage periods whereas significantly ($p \leq 0.05$) higher phosphorus content was observed in the transgenic potato, before and after storage.

- Resistant starch was significantly ($p \leq 0.05$) higher in the transgenic potato before and after storage for 14 days at 12 °C.
FRI paper results

- Chips made from the transgenic tubers stored at 5 °C had significantly lower acrylamide content (i.e., 59–69% less) as compared to those from the untransformed controls.

- A high positive correlation (p ≤ 0.05) between acrylamide and glucose, fructose and reducing sugars and a lower correlation with sucrose was observed.

- High negative correlation (p ≤ 0.05) between chip score and acrylamide was also observed.

- Overexpression of *Arabidopsis* pyruvate decarboxylase in transgenic Snowden had increased resistant starch and higher dry matter contents of phosphorus, and decreased acrylamide levels in potato chips made from these potatoes.
Value added potential

- Bioplastics
- Antifungal
Bioplastic from agriculture resource
The applications of bioplastic products

- Plastic bags
- Packaging foams
- Molded articles
- Food trays
- Bottles
- Mulch films
- Insecticide films
Problem and efforts of starch based bioplastics

- Most thermoplastic starches suffer from
  - Weak mechanical properties
  - High moisture absorption
  - Structural irregularities due to biological source

- Efforts: Selecting different starches, blending with other polymers and/or biopolymers (most notable polylactic acid (PLA)) and incorporation of additives

- To improve miscibility, mechanical and barrier properties, and hydrophobicity
Agricultural Bioproducts Innovation Program - Biopotato Research

- Potato starch modification
- Modified starch for Food and Pharmaceutical Uses
- Potato-based Bioplastics
Potato → Starch → Thermoplastic starch → Film
Development of potato based bioplastic

Plasticization and extrusion of potato starch/poly-lactic acid blends with functional additives

Industrial starch: reactive extrusion

- Use continuous extrusion technology to alter material chemistry in bulk, crosslinking starch in the presence of hydrocolloid gum
- Modular environment of extruder acts as a series of reactors, customizable for residence time, temperature, and mixing conditions.

Ref: Lawton et al. 2010. ANTEC 2010, pp96-100.
Modified starch (hydrogel) for drug delivery

New starch-xanthan gum hydrogels synthesized by physical modification of starch xanthan gum blend followed by covalent cross-linking with sodium trimethaphosphate (STMP).

Potatoes – Anti-fungal technologies for the future
Late blight caused by a plant fungal pathogen called *Phytophthora infestans*
Plant Aspartic Proteinases

- Early-studied AP from plants: Cardosins
  - *Cynara cardunculus* L.
- Milk-clotting activity exploited in Portugal cheese making since Roman era
- Crystal structure of Cardosin A (right; 2 molecules per asymmetric unit shown)
- Unique attribute
  - Plant Specific Sequence (PSS)
Potato Aspartic Proteinase

- *Solanum tuberosum* AP - ‘StAP’
- StAPs: bifunctional proteins with both proteolytic and antimicrobial activities
  - Predicted structure of Potato Aspartic Proteinase
  - Model generated using Swiss Model Server
  - Expected bilobal structure typical of APs
  - PSS region shown in red
Potato PSI (StAP) monomeric structure ➔
Antifungal/antipathogen protein from potato
Atomic Force Microscopy

Atomic force microscopy
Softens/solubilizes membrane material

Bryksa B C et al. J. Biol. Chem. 2011;286:28265-28275
PSI: What is the nature of its membrane interactions?

Solid state NMR with Dr. Vladimir Ladizhansky (Dept. Physics, U. Guelph)

*In silico* atomic resolution simulations within our group:

MD simulation of a negatively charged membrane interacting with anti-fungal PSI
Importance of education

- General messaging
- Specific messaging
General messaging
General messaging

Specific messaging

Idaho is the single largest potato producing state in the US. Approximately 400,000 acres are planted annually accounting for nearly 34% of the nation’s fall harvested acreage. Over thirty varieties are produced in growing regions ranging from the high elevation seed areas of eastern Idaho, with 90-100 growing days, to areas of the Treasure Valley in western Idaho that have the warmest mean temperatures in the Northwest and up to 180 frost-free days. Potatoes in Idaho are produced for many markets. The manufacturing of french fries utilizes 60% of production. Other predominant markets include tablestock, dehydration, and seed; with additional potatoes being used in the chip and specialty markets.

The importance of potatoes in the Idaho economy has led to public support of potato industry. The creation of the Idaho Center for Potato Research and Education is an outgrowth of this support. The purpose of the organization is to advance the science of potato production and utilization through coordinated research, extension, and teaching programs.

http://www.cals.uidaho.edu/potatoes/
General messaging

http://www.apre.org/
There is a reason that the potato has been feeding humanity for 8000 years!
Welcome

Welcome to the Ontario Potato Board.

Working for over 35 years to provide high quality, healthy Ontario potatoes to excite your taste buds!
Acknowledgements

- Stephanie Bach, Univ. Guelph
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- Dr. Qiang Liu, AAFC, Guelph
- Dr. Alan Sullivan, Univ. Guelph
- Ontario Potato Board
- Canadian Snack Food Association
- BioPotato Program, AAFC
- Ontario Ministry of Food, Agriculture and Rural Affairs
- Natural Sciences and Engineering Research Council of Canada
- Canada Research Chairs Program
Muito Obrigado