Title: Enhancing the Potato Industry by Developing High Quality Health Promoting Cultivars and Optimizing Production, Disease Management, Storage and Marketing Practices

INTRODUCTION

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Provide a clear statement of the long-term goal(s), the critical need(s) of specialty crop industries being addressed, and supporting outreach objectives or research questions.

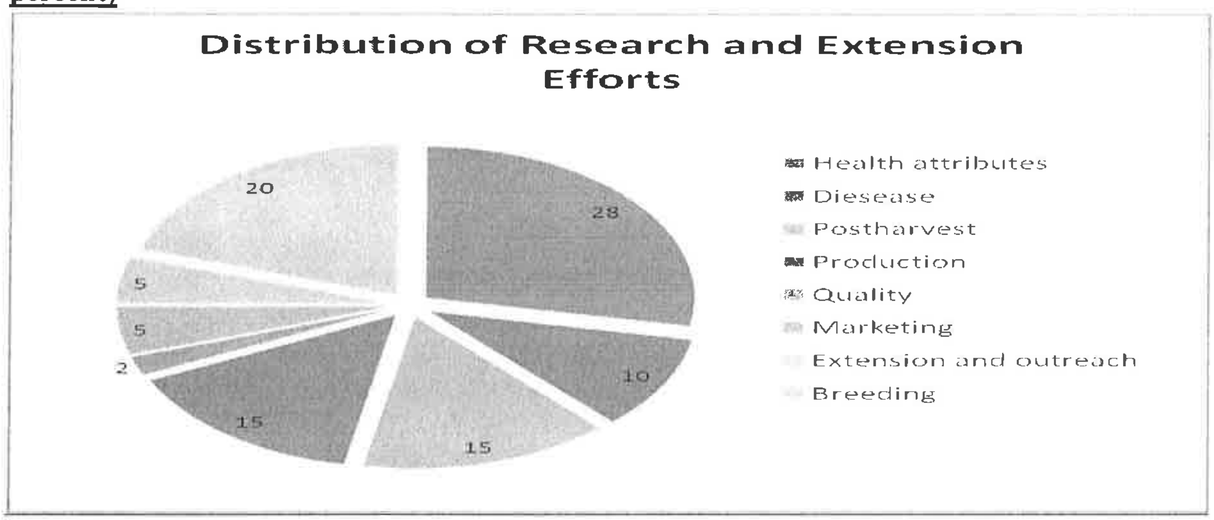
Long term goals:

Potato is an important vegetable specialty crop and a staple food that ranks third in annual global food production (Ross 1986). It is also the highest yielding crop per hectare among food crops grown on arable land, thus crop improvement in terms of nutritional and health properties potentially add value and impacts consumers and growers on a global food production scale. Prominent objectives of this project are: to create high quality new cultivars with high yields, to achieve sustainable production costs, to reduce use of pesticides and fungicides, and to develop more efficient use of water and fertilizers, while meeting consumer demand for a healthy and nutritious staple food. These objectives will be met through coordinating development of new cultivars with specific research goals on crop management and utilization of resources, human nutritional value, postharvest storage, control of pests and diseases and understanding social, economic and market factors that influence potato production, distribution and consumer preferences/ choices. This multistate, multi-institutional and multi-disciplinary collaborative research program focuses on potato, from breeding to storage and adding value through improving health attributes.

Specific goals:

1) Screen for better nutritional value and overall quality to increase marketability.
2) Develop new innovative and efficient crop production, disease management, and storage technologies and strategies.
3) Identify and quantify market potential of nutritionally improved potatoes.

Describe the legislatively mandated focus areas being addressed, and provide an estimate of the percentage of funds dedicated to each (sum of percentages should equal 100 percent)



Areas addressed:

1. **Research in plant breeding, genetics, and genomics to improve crop characteristics, such as:**
   -taste, quality, and beneficial phytonutrient content ;
   -environmental responses and tolerances;
   -nutrient management, including plant nutrient uptake efficiency;
   -pest and disease management, including resistance to pests and diseases resulting inreduced use of chemical inputs.
2. **Efforts to identify and address threats from pests and diseases, including threats to specialty crop pollinators;**
   -addressing losses in storage due to diseases
   *-potato virus **Y** resistance.*
3. **Efforts to improve production efficiency, productivity, and profitability over the long term (including specialty crop policy and marketing)**
   Nitrogen fertilization, irrigation, affecting tuber size, specific gravity, and nutrient concentration in the tuber
   Consumer Preference Investigation:

4. **Methods to prevent, detect, monitor, control, and respond to potential food safety hazards in the production and processing of specialty crops, including fresh produce.**
   -Developing sensors for early disease detection in storage
   -Maintaining quality in storage pressure bruise conditions

The identified research areas will be addressed through six Sub-Projects:

I. Screening for better nutritional value and overall quality to increase marketability

CO-PDs	**Key Personnel**	
David G. Holm,	Fahrettin Goktepe	CSU
J. Creighton Miller, Jr.	Douglas C. Scheuring	Texas A&M University
Harry L. Carlson	Jeffery W. Koym	Texas A&M University
Joe Nunez	Donald W. Kirby	University of California

Past Activities

More than 25 new cultivars have been developed/codeveloped and released by the Colorado and Texas Potato Breeding and Cultivar Development programs since 1997. Of all newly released cultivars accepted for certification in the US in 2007, those developed by these programs since 1997 comprise the greatest percentage of seed acreage in the United States.

II. Enhancing nutritive attributes

CO-PDs: Dr. Cecil Stushnoff (CSU), Dr. Bunning Marisa (CSU), Dr. Sastry Jayanty (SLVRC)

Consumers are increasingly aware of potential health benefits from diets rich in fruit and vegetables. While potato has not yet surfaced as a headline grabber in this respect, there is increasing evidence that some genotypes may possess health attributes that warrant more attention (Beals, 2007). Potato (*Solanum tuberosum L.*), a global staple food source provides high-quality protein and energy to millions world-wide. Less appreciated are several other positive nutritional attributes of potato as a food source, including a rich source of vitamins C and B6, phenolic antioxidants, potassium, magnesium, zinc and fiber. Convincing evidence for developing nutrient-rich potato cultivars was presented by several speakers at a recent symposium sponsored by the Potato Association of America at its 91st Annual Meeting, August 2007, Idaho Falls, ID (Anon., 2007).

III. **Identifying and addressing threats from pests and diseases**

CO-PDs	**Key Personnel**
Dr. Sastry S. Jayanty (SLVRC)	Mr. Andrew Houser (SLVRC)
Dr. Robert Davidson (SLVRC)	
Dr. Kushalappa AC (McGill University)	

Rationale

Diseases routinely cost growers high percentages of their crop value and can be issues at any stage of the cropping system. Management and control of these problems require the efforts of all facets of the potato industry beginning with certified seed production. Recent advances in seed production techniques to reduce bacterial and fungal diseases in the crop have been very effective in helping producers control these problems. However, the increase in virus issues, particularly potato virus Y, and the increasingly important component of soil borne pests and diseases have placed growers at a disadvantage for continued improved yields and quality. Additionally, many of the cultivars selected for advantageous nutrient content often have disease issues in the field (Colorado PCS certified seed directories: 2002 – 2007). A focused effort on these specific problems is required with emphasis being placed on breeding for resistance, developing techniques to reach an improved working base for managing certain soil borne pests, such as powdery scab, and developing appropriate outreach approaches to make certain that the new clones recognized through screening for diseases, nutrients, etc. are adopted to the average grower's operation to take full advantage of lower disease potentials and improved nutrient content.

IV. Improving production efficiency

CO-PD: Samuel Essah, (SLVRC) Dr. Harry Carlson (Univ. of California)

Rationale. Each potato cultivar has its own unique set of cultural management requirements to maximize tuber yield and premium size and grade tubers. When management guidelines are tailored for individual cultivars, it leads to the successful, sustainable and economic production of the cultivars, which results in the optimization of their genetic potential, while minimizing economic inputs and environmental impact. Value of new varieties comes in the form of improved quality and marketability, increased yield, and improved fertilizer and water use efficiency.

V. **Efforts to improve profitability**

CO-PDs: Jennifer Bond (CSU) & Tim Richard (Arizona State University)

Rationale

As consumer demand for fresh, quality, non-traditional foods continues to increase, the potato industry stands poised to take advantage of the changing market for fresh and specialty potato varieties. In the case of the more exotic potato varieties the ability of producers to capitalize on these trends and set their targets beyond "early adopter" consumers, depends partly on the efficacy of promotion and pricing programs. Participation in value-added markets may further serve to hedge against price volatility and reduce some forms of production risk. Further, research on consumer packaged goods indicates that consumers respond to innovation and "newness" of a product, regardless of its embodied attributes. To bridge the gap between evaluating retail success, estimating the practicality of on-farm adoption, and determining welfare implications for supply chain partners, we propose to conduct three distinct, though integrated, research studies.

VI. **Optimizing postharvest storage**

CO-PDs Sastry Jayanty, (SLVRC) and Ajjamada (McGill University)

Rationale

Early detection of diseases in potato storage gives a number of options to the storage manager. Tubers can be marketed early to limit the losses. Remedial measures such as reducing the humidity and running dry air through the storage can reduce disease spread. Additionally, isolating the infected area can be effective in reducing the disease spread if marketing conditions are not economically viable. Pressure bruise is a primary concern for all market classes of potato. Pressure bruise limits the storage duration of potato and reduces grade the longer potatoes are stored. Pressure bruise can result in quality losses of 20 to 30% in long term storage potatoes, yet little is known about factors influencing this condition.

STAKEHOLDER ENGAGEMENT

An advisory committee comprised of industry and research leaders from the fresh market and processing industries has been created to provide direction to the research and extension teams. Five Co-PDs have 50% extension responsibilities in the project to have significant partnership with stake holders.

SUB-PROJECTS

Sub-Project I. Screening for better nutritional value and overall quality to increase marketability

Need for the Proposed Activity:

Potato production encompasses a varied set of environmental conditions, pest problems and market niches. These diversities require the development of cultivars that are widely adapted or that are suited for specific production areas and/or markets. *Solanum tuberosum* Group Tuberosum (Tuberosum), the potato of commerce, lacks resistance to many pests and diseases that potato producers might confront during a growing season, and is lacking many quality characteristics that dynamic markets demand. Sustained development of new cultivars, embraced by growers and marketers in the US, is imperative.

Potato producers require specifically adapted cultivars with improved disease and pest resistance, in order to provide a healthy high quality product to consumers. Ensuring producer and industry profitability by providing cultivars with improved yield, quality, and pest resistance, while assuring environmental responsibility, is a major thrust of the proposed research. The potato crop is intensively managed and involves the use of numerous agricultural chemicals ; reducing their use is a high priority for producers. New cultivars with improved quality, plant architecture, pest resistance, and efficient fertilizer use, provide effective means for minimizing chemical use and enhancing economic and environmental benefits. The environment, growers, and consumers will all profit from reductions in inputs. Disease and insect pests increase the need for inputs if resistant cultivars are not available. During the past five years, the following diseases/pests have caused serious economic losses in one or more production areas: *Erwinia chrysanthemi* and *E. carotovora* (soft rots, blackleg, and Erwinia early dying), *Fusarium* and *Alternaria* dry rot, silver scurf *Helminthosporium solani*, white mold *Sclerotinia sclerotiorum*, PVY, PLRV, and other viruses, *Verticillium* wilt, the early dying complex, powdery scab *Spongospora subterranea*, nematodes, psyllids (and associated Zebra Chip), tuber moth, pink rot, and late blight (*Phytophthora infestans* (Mont.) de Bary). Ongoing identification of resistant germplasm and its incorporation into the hybridizations of breeding programs are critical in addressing these issues.

Consumer interest and awareness in the role of food, not only in nutrition, but also in health beyond nutrition, has increased dramatically. This project proposes to address this consumer awareness and interest. Vegetables, as a group, have been identified as possessing numerous compounds which act as preventatives against various diseases. Potatoes, in addition to being the most balanced vegetable food and contributor of essential minerals and nutrients, contain important antioxidants. The genetic potential of potato in this area is not yet fully determined, nor has there been significant effort in developing cultivars with higher phytochemical levels. Efforts have only begun to identify specific diseases which these pytochemicals help to overcome and their biochemical basis.

Funding of this work would accelerate the development of new potato cultivars for the United States. Consumers of fresh market and processed potato products will continue to benefit from the development of cultivars with improved qualities. Potato producers should continue to profit from the introduction of new cultivars with improved pest resistance in combination with superior marketing qualities, reduced need for inputs, and high yield. Producers will thus be able to continue to provide a consistent high quality, healthful product to consumers of fresh, processing, and seed potatoes.

Preliminary Data for the Proposed Work:

Currently, the Colorado and Texas programs have more than 25 advanced selections released for grower evaluation, with many undergoing final stages of grower evaluation prior to naming. These programs are in a good position to rapidly develop and make available new potato cultivars possessing improved characteristics that are important to the potato industry, including yield, quality, marketability, consumer acceptance, with a special emphasis on culinary quality(including flavor), and enhanced human health benefits.

Approach:

Cultivar development is a four-step process, encompassing first, the generation of segregating populations and evaluation for visual agronomic traits. Second, superior progeny are identified, and these selections undergo additional evaluation for economically important characteristics. Third, a profile of cultivar-specific management criteria (production and postharvest) are developed, which growers, shippers, processors, and/or marketers can fine tune for their operations. Finally, the new cultivar must be introduced to the intended market. These steps provide a base for a successful cultivar release. Without all components, fruition is difficult to attain. Potato breeding methodology has been extensively documented (Douches and Jastrzebski, 1991: Razdan and Matto, 2005: Sleper and Poehlman, 2006).

Goal 1: Develop russet, red, white, and specialty cultivars for both the fresh and processing markets. These cultivars will complement those developed by breeding programs in other areas of the United States.

Parents with desired characteristics will be hybridized at Colorado State University and Texas A&M University. Unselected seedling and early generation tubers will be received from and sent to several other breeding programs within the US. Approximately 200,000 seedlings will be grown for initial selection in Colorado and Texas. California will focus on advanced generation evaluations and cultivar specific management of advanced selections. Virus eradication and multiplication of selected clones is discussed below. It takes 14+ years to develop a new potato cultivar. Years 1 and 2 are the potato breeding phase of the development process. Parents are selected and crossed to produce true potato seed. Seedling tubers are then produced from the true seed in year 2. Subsequent years (3+) represent the selection phase of the development process. Each year represents another cycle of field selection. As each cycle is completed, fewer and fewer clones remain, and the amount of seed per selection is increased. Clones remaining after eight cycles of field selection are released to growers for evaluations prior to official release as a named cultivar.

Goal 2: Evaluate germplasm and/or advanced selections under diverse environmental, production, and postharvest conditions for traits important to the potato industry

including yield, quality, marketability, consumer acceptance, with a special emphasis on culinary quality (including flavor), and enhanced human health benefits.

Early and advanced generations of selected clones will be evaluated at a number of locations in Colorado (Center, San Luis Valley), Texas (Springlake, on the Southern High Plains and Dalhart, northwest tip of the Texas Panhandle), and California (Bakersfield, South Central Valley and Tulelake, north on the Oregon border), and ultimately in the uniform Southwestern Regional Trials (SWRT) and Western Regional Trials (WRT). These multiple sites represent diverse soil types, climates, and pest ecologies. The Springlake, Dalhart, and Bakersfield trials will be on stakeholder operations. The SWRT include russet, red, specialty, and chipping entries. Entries are evaluated in each state for numerous traits including chip quality, fry quality, etc. Clones are entered for evaluation in the SWRT for one to three years. Top entries are then graduated to the WRT for up to three years, and superior clones are released as new and improved cultivars. Seed for both of these trials is provided by the Colorado program.

Collaborative efforts will continue to expand on an "accelerated" breeding approach for high priority characteristics. This would employ both greenhouse and field evaluations, where appropriate, to identify breeding material earlier in the selection program.

In combination with these trials, field days will be conducted in each state for stakeholders, with all four project leaders in attendance whenever possible. Annual trial reports will be published and distributed locally and regionally, and will be posted on the web. Screening for beneficial human health and nutritional characteristics, such as antioxidants, will continue with increased emphasis. The effects of extracts and individual compounds from superior potato selections on proliferation of androgen-dependent and androgen-independent human prostate and breast cancer cells will continue, with animal feeding studies planned (if funding becomes available). Other studies will be initiated to investigate the effects of potato phytochemicals on colon cancer. Additional studies related to culinary quality (including taste) will be initiated. Postharvest quality assessments on selected clones will include blackspot susceptibility, storage weight loss, dormancy, enzymatic browning, specific gravity, French fry color, French fry texture, and chip quality.

Stakeholder Input and Program Review

A number of meetings with grower groups, research/extension advisory committees, and numerous individual stakeholders (near daily contact) are held to review research results and seek input into future activities. Project leader(s) participation in national forums, such as the National Potato Council Seed Seminar, provide another form of stakeholder interaction. Additionally, field days/open houses are held in all three states. A primary purpose of these events is to provide growers with a forum for feedback regarding potato breeding and cultivar development efforts. It also provides the project leaders with an opportunity to interact with growers and discuss their experiences with advanced selections undergoing commercial evaluation.

Sub-Project II. Enhancing Nutritive Attributes: Screening for better nutritional value and overall quality to increase marketability.

Need for the Proposed Activity

Consumers are increasingly aware of potential health benefits from diets rich in fruit and vegetables. While potato has not yet surfaced as a headline grabber in this respect, there is increasing evidence that some genotypes may possess health attributes that warrant more attention (Beals, 2007). Potato (*Solanum tuberosum L.*), a global staple food source provides high-quality protein and energy to millions world-wide. Less appreciated are several other positive nutritional attributes of potato as a food source, including a rich source of vitamins C and B6, phenolic antioxidants, potassium, magnesium, zinc and fiber. Convincing evidence for developing nutrient-rich potato cultivars was presented by several speakers at a recent symposium sponsored by the Potato Association of America at its 91st Annual Meeting, August 2007, Idaho Falls, ID (Anon., 2007). While potato has a long history as a critical food staple, in recent decades it has also been maligned for contributing to the overweight syndrome. Paradoxically, recent research has shown that certain genotypes are exceptionally good sources of phenolic antioxidants (Brown, 2007; Stushnoff et. al., 2008), carotenoids (Brown, 2007), vitamin C (Ducreux et. al., 2007; Love and Pavek, 2007) potassium and other nutrients. A few cultivars have shown intriguing inhibitory bioactive responses in cancer cell culture studies (Reddivari et al 2007 a, 2007b, 2007c, Stushnoff et. al., 2008; Thompson et. al., 2008). Considerably more research is required to develop nutritional profiles, especially for new cultivars and advanced selections. We propose to use recent advances in high throughput analytical screening and biochemical characterization of metabolites to explore and enhance selection for positive health attributes through the following approach.

Goal 1. Develop metabolomic profiles for bioactive compounds in germplasm to develop a better understanding of endogenous biochemicals and inhibitory activity.

Additional research that generates specific small molecule profiles from genomic and a metabolomic analysis appears necessary to enlighten our understanding of putative benefits. An opportunity to conduct advanced profiling research is in place through an existing collaborative research project with Dr. Mark Taylor, Scottish Crop Research Institute (SCRI), Invergowie, Dundee. The SCRI participates in a global effort to sequence the potato genome and is well-equipped for both genome and metabolome research. We view this as a potentially valuable collaboration that could benefit research/breeding programs in the US and the UK. Colorado State University has recently developed a fee for service central facility for genomic and metabolomic investigations. We currently participate in a potato research project with this laboratory.

***Experimental Design for Potato Metabolome Project*:**

Situation and Biological Question: Our previous research has identified several genotypes of potato that inhibited growth of breast cancer cells in culture. We are attempting to determine if there are metabolites in bioactive and control genotypes that: 1) increase, 2) decrease, 3) are present as unique new peaks, or 4) are absent, using the following experimental design.

Experiment #1			Biosource Response Class	
Treatments				
Flesh color	Index	Extract [%]	(-) Non-inhibitory	(+) Inhibitory
Purple	1	(0.18-0.4)		CO97216-1P/P
Red	1	(0.18-0.4)		CO97226-2R/R
Purple	3	(0.8-1.5)	Purple Majesty (P/P)	
Red	5	(3.0-6.0)	Mountain Rose (R/R)	
Non-pigmented				
White	1	(0.18-0.4)		Russet Nugget (RU/W)
White	2	(0.41-0.79)		CO95172-3RU/W
White	3	(0.8-1.5)	Rio Grande Russet (RU/W)	
White	4	(1.51-3.0)	Colorado Rose (R/W)	

Median sections of individual tubers were freeze dried, finely ground, screened to uniform particle size with a 100 mesh screen and stored at -20C in sealed vials, and extracted in 80% acetone by rotation in the dark at 4C, followed by centrifugation for 15 minutes at 6000 rpm. Clear supernatant 1.0 ml samples were concentrated to dryness in a rotary vacufuge and stored at -20 C immediately prior to solubilization in MEOH and injection for LC analyses.
Experiment 2 will utilize selections that produce variegated tubers, ie, tubers with both pigmented and non-pigmented sectors. Because these tubers are grown under identical environmental conditions and are genetically identical except for pigment expression, metabolic profiles from both sectors can be used to generate precise biochemical and inhibitory response profiles.

Experiment #2	Comparing pigmented to non-pigmented tissues from variegated tissues of the same tuber (genetically identical grown in the same environment)			
Flesh color	Total phenolics	Vitamin C	Radical scavenging activity	Inhibition response
White	lower	lower	lower	unknown
Purple	higher	higher	higher	unknown

Goal 2. Screen cultivars and breeding germplasm including species, for biosource inhibitory responses using cancer cell cultures.

Protocols for growing breast and colon cancer cell cultures are in place in our laboratories. Aqueous and organic extracts of raw and cooked potato cultivars will be tested for inhibitory response to growth and proliferation of cancer cell cultures. Preliminary tests with aqueous extracts from six genotypes of baked tubers revealed that 'Rio Grande Russet' most effectively inhibited growth of breast cancer cultures MCF and MDAMB-468. 'Purple Majesty' had some inhibitory activity, but 'Mountain Rose' and 'Yukon Gold' did not inhibit proliferation at the concentrations tested. A subsequent study completed in 2007 with 21 genotypes with estrogen independent MDAMB-468 cell cultures, revealed five genotypes including 'Russet Nugget' that inhibited with as low as 0.187 to 0.375% of the cell culture solution. To enable a categorized ranking of cell culture proliferation/inhibition, extract concentrations used were divided into five categories, 1 equal to the lowest concentration and 5 the highest. These index categories were then compared to TP, TEAC and vitamin C data in five categories. Examination of the top five in terms of 50% inhibition of breast cancer cells (IC_{50}) data "1" compared to the in vitro chemical assays showed only a slight relationship. While the antioxidant assays used generally agree and correlate with each other, and provide a reasonable assessment of antioxidant properties, none was an exclusive indicator of breast cancer cell inhibition properties (Stushnoff et. al., 2008). Further, the two different extraction approaches also generated slightly different results. It appears some factor other than antioxidant status alone may be involved in inhibition, and this deserves further investigation.

Goal 3. Develop an antioxidant index that incorporates antioxidant and vitamin content with radical scavenging capacity utilizing high throughput microplate assays and HPLC to characterize and develop standards for antioxidant attributes of potato cultivars and potato breeding germplasm.

Dietary intake of antioxidants from natural foods is fast becoming recognized as a positive contribution to a healthy lifestyle. From our recent research and that of several others (Brown et. al., 2007; Stushnoff et.al, 2008), evidence is mounting that certain potato genotypes are a good source of specific phenolic-based antioxidants. We have identified cultivars and advanced selections that are much higher in antioxidants than conventional cultivars. Some have also shown promising results in cancer cell culture inhibition studies. While growing-season environmental conditions, post harvest conditions, and cooking methods may alter antioxidant status, it seems clear that the best opportunity to maximize antioxidant health attributes is by identifying, selecting and breeding antioxidant-rich genotypes. Many published reports fail to specify cultivars, let alone storage history or environmental factors. While several different assays are considered desirable, comprehensive examination of those best suited to development of an index for potato to assist breeders in comparisons requires considerably more research.

Goal 4. Examine genotype x (abiotic & biotic) environment interactions that impact stability of antioxidant and vitamin phytochemicals in potato cultivars.

Phytochemical properties of key cultivars will be characterized for the following with collaborators as indicated

1. variables arising from testing production management practices, eg, N nutrition (Essah);
2. phytochemical differences arising from diseased and disease-free tubers (Davidson), evidence suggests pest predation may upregulate antioxidant content, but critically designed experiments to test this hypothesis in potato are lacking;
3. year to year stability of phytochemical trait expression (Holm);
4. alterations during storage duration (Jayanty);
5. relationship of taste and flavor among genotypes to phytochemical content (Bunning).

Goal 5. Provide compositional data to assist agro-economic and marketing studies (Bond) of new cultivars with health related value-added attributes.

Goal 6. Link data from metabolomic studies to other projects that employ animal feeding trials with a goal of connecting metabolites with genetics of mammalian diseases and dietary intervention.

This phase is projected as a future collaboration based upon data obtained from previous objectives, with Dr. Henry Thompson of The Cancer Prevention Laboratory (Thompson et. al., 2008) and Dr. Jairam Vanamala, Colorado State University, Dept. of Food Science and Nutrition.

Goal 7. Provide an assessment of sensory and quality differences among selected potato cultivars and to evaluate the effect of three different cooking methods (microwaving, boiling, and baking) on attributes such as flavor, texture, appearance, color, and overall acceptability. Quality assessments will include texture and color analysis and will complement sensory evaluations. Relationships between nutritional and sensory properties of selected potato cultivars will be examined.

Sensory analysis of food is the scientific discipline used to evoke, measure, analyze and interpret reactions to food characteristics as they are perceived by the senses of sight, smell, and taste for the purposes of evaluating consumer products (Stone et al., 1993). Favorable sensory attributes of vegetables are essential for consumer acceptance (Pollard, Kirk, & Cade, 2002). Organoleptic characteristics of potatoes commonly evaluated are skin and interior appearance, texture, flavor, aftertaste, and overall acceptability (Kleinhenz et al. 2003). Overall acceptability may be thought of as the sum total of physical characteristics embodied in the product (Fenwick, 1996). The amount of starch in various potato cultivars and effect of cooking method on starch breakdown impacts potato taste attributes. Many factors, including product characteristics and quality perception, influence the consumer's repeat purchase decisions (Waldron, Parker, & Smith, 2003), so it is important for sensory attributes of cooked potatoes to meet the standard expectations of the consumer.

Sensory Panel: Following the guidelines and approval of the Human Research Committee at Colorado State University, the selected potato cultivars will be cooked and prepared for tasting by trained consumer panels (n=25/panel). Preliminary tests will be used to determine optimal cooking times and temperatures and standard protocols will be established for each of the three cooking methods. Panelists will be recruited from university students, faculty and staff members and trained in various quality parameters using commonly available potato cultivars. Scoresheets using 9-point Hedonic scales will be used to evaluate and compare various organoleptic attributes, including flavor, texture, appearance and overall acceptability. The results from these assessments will be included in presentations and fact sheets provided to producers.

Quality Analysis: Texture will be analyzed using a TA-XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) using software Texture Expert Exceed for Windows version 2.64. Color will be assessed with a HunterLab ColorFlex Spectrocolorimeter (Hunter Associates Laboratory, Inc., Reston, VA).

Projected Timetable of Activities for Specific Objective: Enhancing Nutritive Attributes					
	Year 1	Year 2	Year 3	Year 4	Future
Objective 1	X	X	X	X	
Objective 2	X	X	X	X	
Objective 3		X	X	X	
Objective 4	X	X	X	X	
Objective 5		X	X	X	
Objective 6					X
Objective 7					X

Pitfalls and Limitations

Crop loss from severe weather events or disease infestations that impair collection of data are the most likely environmental limitations envisioned.

Proposed Concepts to Generate Research Funding Self-Sufficiency

Cultivars identified as nutrient-rich will be branded with a "healthy potato" identifier, or some other suitable label that will be made available to marketing and distribution agencies. The opportunity to brand and promote such cultivars will be made available for a fee that will be used to fund future potato research activities.

Because sales of "healthy" cultivars are expected to increase to health-awareness from consumers, funds from existing royalties used for research are expected to increase. Increased "in kind" support from growers can also bring more additional funding.

Sub-Project III. Efforts to identify and address threats from pests and diseases – PVY and Powdery Scab disease management.

Goal 1. Develop a comprehensive PVY resistance screening program.

Additional research that generates a more useful package of information on reaction to PVY for each new clone is necessary. It is especially important for understanding how each clone will react to PVY prior to release to the growers for field evaluation. It is proposed that a greenhouse will be utilized to grow clones that originate early in the breeding process and infect these clones with PVY. Infection will be accomplished by mechanical inoculation and use of aphid vectors. Foliage will be screened for presence of the virus, and resistance to infection will be identified. Tubers will be harvested and grown in the field to verify the absence of PVY. Additionally, each advanced clone will be screened for PVY in a similar manner in the field and tubers harvested and grown out during the certification post harvest testing to verify PVY status. Only those clones which have demonstrated resistance to PVY will be allowed to progress through additional screening for other clonal attributes. Additionally, these clones will be used as parents for future crosses. This information will be transmitted to the growers through a comprehensive extension program as described in section 7 and a series of cultivar management sheets.

Goal 2. Introduction of cultivars with less susceptibility to PVY to different potato growing regions.

Colorado will use its contacts within the Colorado Certified Potato Growers' Association (CCPGA) to further the introduction of new clones into the surrounding region. Currently, the CCPGA has an ongoing Memorandum of Understanding with Colorado State University to transfer ownership of new CSU cultivars to the CCPGA for commercialization. CCPGA has taken steps to protect these cultivars under Federal Plant Variety Protection. There has been a successful effort over the past decade to establish grower participants in several surrounding states to help commercialize these cultivars. One of the critical aspects of this program has been the communication to the various growers regarding all aspects of the protected cultivars. This network coupled with appropriate outreach has been instrumental in moving cultivars inter-state for successful production by regional growers. Currently, Colorado has five of the top 25 cultivars of 1000 acres+ raised for seed in the US (Russet Norkotah strains 3, and 8, Rio Grande Russet, Canela Russet, and Centennial Russet) (PAA Certification Section – Acreage summary for 2007). Of note is the fact that two of these cultivars, Rio Grande Russet and Canela Russet, have lower susceptibilities to PVY and have shown excellent results in the San Luis Valley, CO and in Bakersfield, CA under extreme pressure from infection by PVY. In Colorado, both cultivars have demonstrated low levels of PVY in the certified seed stocks, even though 40-50% of the Russet Norkotah acreage has been rejected from certification due to excess PVY. Additionally, both cultivars are gaining grower acceptance, with Rio Grande Russet accounting for almost 10% of the total acreage in the San Luis Valley, CO and Canela Russet almost 9% of the total acreage (National Ag Statistics, 2008)

Goal 3. Implementing disease management strategies to reduce and control diseases by intelligent cultivar rotation.

Cultivar rotation has long been practiced by potato growers as a way to reduce potential soil borne disease problems. It has been only recently that the benefits of cultivar rotation have been seen when dealing with disease issues such as pink rot and powdery scab. Growers have taken the approach of rotating susceptible cultivars with ones that are either less susceptible or resistant to reduce the disease on the susceptible cultivar during the next cropping cycle. Pink rot in Russet Norkotah is a prime example of how this strategy can work. When growing Russet Norkotah, it often develops pink rot during the season in fields containing the appropriate inoculum. Growers that rotate the next potato crop (2-3 years from the Russet Norkotah crop) with a less susceptible cultivar such as Rio Grande Russet have seen a marked decrease in pink rot in the next potato cropping cycle using Russet Norkotah, even though conditions are appropriate for disease development (Davidson, personal observation). There is evidence that this practice may also work with diseases such as powdery scab. During the life of this project, fields will be selected with known inoculum of powdery scab. Long term plots will be established in these fields to utilize cultivar rotations in-between the normal rotational crop cycle of potatoes, grain, green manure, potatoes. Soil will be sampled under these plants and spore levels determined using PCR to determine if levels are decreasing, staying the same or increasing

(Qu, et al, 2006). Additionally, a greenhouse will be utilized to conduct similar experiments where soil is screened after planting of susceptible to non-susceptible cultivars (Houser, 2008).

Goal 4. Developing methods for cultivar screening to soil borne diseases.

Screening cultivars for susceptibility to soil borne diseases has been a priority for several years. This is especially critical in comparing potential resistance within newer clones at an early stage of development. Typically, the field environment has been used to make these determinations (Haynes et al., 2004). However, recently, greenhouse methods are being developed to screen germplasm through the use of appropriate environmental controls and growth of the plants in inoculated soil. Greenhouse screening for resistance to diseases such as powdery scab has been utilized successfully for the past two years. We propose to further develop these methods utilizing current literature, experiences in the greenhouse, and field experiences to screen germplasm for pink rot/leak and powdery scab (Houser, 2008, Davidson, 2007).

Goal 5. Molecular analysis of powdery scab disease using smooth skin mutants.

Powdery scab disease caused by *Spongospora subterranea f. sp. subterranea* is one of the major concerns for potato producers in potato production regions of North America. This is a soil borne pathogen that infects root hairs, stolon epidermal cells, lenticels, eyes and wounds of developing tubers. Infected tubers and roots may have white gall-like growths, which in turn develop into brown powdery scab lesions on tubers as they mature (Harrison et al. 1997).

Powdery scab symptoms cause significant economic losses in both fresh and seed markets. Depending on the severity of symptoms, tubers could become non-marketable or grade may be lowered in fresh and seed markets. Seed lots infected with powdery scab may or may not pass inspection depending on the regulations of the certifying agency and the degree of infection. Infected tubers are also more susceptible to fusarium dry rot, bacterial soft rot and other pathogens during storage.

Christ (1993) observed that potato cultivars with smooth or light skin (i.e whites and reds) are more susceptible, whereas russet-skinned cultivars are less prone to powdery scab, although root galls are common. There are reports on partial russeting in some cultivars such as Rio Grande Russet. Partial russeting and irregular skin setting can lead to disease, loss of water and susceptibility to skin bruise, affecting tuber quality (Lulai EC, 2002). A better understanding of russeting mechanisms will aid in development of new cultural tools for better skin set in new cultivars to enhance the native capacity of tubers for skin set.

The important questions that can help us in understanding the powdery scab disease resistance mechanism in potato are:

What role do different types of tuber skin play in powdery scab resistance?

a. *Genomic studies*: *Studying the role of genes that are identified from microarray experiments.* Genes that are up regulated or down regulated in resistance and susceptible cultivars to powdery scab using RT-PCR will be studied. Candidate genes will be screened for their expression during skin development and russet skin setting. Our approach will generate markers that can identify genes or gene families that can be transferred from russets to smooth skin varieties through the traditional breeding programs.

b. *Metabolomic studies: Identifying different metabolites in smooth skin and russet skin cultivars*
Metabolites will be identified in russet cultivars using the campus Macro Molecular facilty and GC/MS located at SLVRC. Results from these experiments will help us identify the metabolic pathway and candidate genes responsible for resistance mechanism.

Methods:

Using smooth skin mutants of Centennial Russet and Russet Nugget identified by Dr. David Holm, we have shown increased susceptibility to powdery scab lesion development compared to the russet parent clone. This skin mutation offers opportunity to study the genetics of a specific russeting phenotype. We are approaching this issue with both genomic and metabolomic methods. Under genomic analysis last year, we analyzed 10,000 potato genes using a Potato microarray through funding from NSF (Solanaceae Gene Expression Profiling Service Information). Using microarray analysis we identified 1,200 genes down-regulated and 126 genes up-regulated in infected tubers. Our next approach is to understand the role of up regulated and down regulated genes in the resistance and susceptibility to powdery scab disease. In a second approach, we would like to evaluate smooth skin and russet skin using metabolomic analysis with GC/MS (Gas Chromatography/Mass Spectrometer).

In this proposed research plan, we would like to further investigate microarray data to identify a candidate gene or genes. We would like to determine individual gene transcript role in skin development and russeting by northern analysis or RT-PCR. Each candidate gene will be investigated in potato cultivars that are susceptible and resistant to powdery scab.

Metabolomic approaches will identify if there are any particular metabolites that are conferring resistance in russet cultivars. Then we can use candidate gene approach to identify source of resistance. This knowledge will help to develop markers for breeding durable resistant cultivars. We envision that these studies would increase our knowledge on how russeting plays a role in disease resistance.

Projected Timetable of activities for each specific goal

	Year 1	Year 2	Year 3	Year 4
Goal 1	X	X	X	X
Goal 2			X	X
Goal 3	X	X	X	X
Goal 4	X	X	X	X
Goal 5	X	X	X	X

Sub-Project IV. <u>Efforts to improve production efficiency, productivity, and profitability over the long term (including specialty crop policy and marketing); water and nitrogen management for sustainable potato production</u>

Irrigation and nitrogen (N) are two of the most important factors influencing potato tuber growth, development, yield, quality, storage properties, and environmental quality in potato production systems (Vos 1997). Nitrogen fertilization, irrigation, and cultivars also affect tuber characteristics such as tuber size, specific gravity, and nutrient concentration in the tuber (Harries 1992). Preliminary data collected by Essah (2007) in Colorado, indicate that irrigation requirements of cultivars differ for maximum tuber yield and quality. Rio Grande Russet, a new variety that is widely grown in Colorado and parts of the US, can produce similar tuber yield and quality with 33% less irrigation water, compared to the current irrigation water currently used by producers. Stark et al. (1993) in evaluating the effect of varying amounts of irrigation water on potato, concluded that different varieties needed different amounts of irrigation for optimum performance. Over irrigation of potato not only wastes scarce water resources, but it also decreases tuber quality by increasing tuber external and internal defects. The only way to apply optimum irrigation water for sustainable potato production is to develop cultivar specific irrigation management practices that will define the optimum irrigation water requirement for individual potato cultivars.

Nitrogen is the most essential nutrient for successful and sustainable potato production. However, excessive N application not only increases the cost of production, but it also leads to poor tuber quality, delayed crop maturity, and excessive nitrate leaching into surface and ground water. Studies conducted by Essah et al. (2007) indicate that different varieties differ in their N requirements for maximum production of quality tubers.

To take advantage of the water and N use efficiencies of new potato varieties that are grown in the US, and to reduce the use of the scarce irrigation water for potato production, and also reduce leaching of nitrate N into surface and ground waters, there is the need to develop variety specific irrigation and N management practices to improve nutrient and water use efficiency in potato production systems.

Drip irrigation in potato production has been practiced with success in the US and in other countries for many years. Singh and Sharma (2002) observed a 40% and 25% saving in water and NPK fertilizer, respectively, with the use of drip irrigation. A 25% increase in marketable tuber yield was observed under drip irrigation. Recent studies by Essah et al. (2007) showed a 13% increase in tuber yield and a 30% savings in water use. The major drawback of using drip irrigation in potato production is the initial cost of laying out the drip system. If potato yield and quality could be further improved to offset the initial cost of drip system installation, then it would be a perfect irrigation system that would reduce water and nutrient use, and disease reduction in potato production systems. The technique of injecting air to the root zone of potato plants through the drip irrigation system to improve soil microbial activity, increase root mass, with greater nutrient uptake, promises to increase tuber yield and quality. Injecting air into subsurface drip irrigation systems has been used with success in a variety of vegetables in California (Goorahoo et al. 2007). However, the use of this technology in potato production systems has not been documented. Ongoing preliminary studies by Essah and Dillon (2008) indicate increase root mass and vigorous plant growth when air is injected into the drip system.

Goal 1. Maximize the water use efficiency of potato cultivars by determining the optimum amount of irrigation water needed for maximum tuber yield and quality.

Goal 2. Maximize N uptake and N use efficiency by determining the optimum amount of N fertilizer needed for maximum tuber yield and quality.

Goal 3. Increase the productivity of potato under drip irrigation by injecting air into the drip system.

The study will be conducted at two contrasting sites for four years. One site will be in Tulelake , northern California, and the other site will be at the San Luis Valley Research Center, Colorado. Goals 1 and 2 will be tested at both sites, and Goal 3 will be included at the Colorado site. Goals1 and 2 will be tested in one field layout, in a Split Plot_design, and replicated four times. Irrigation treatment will be the main plot factor and N application rate will be the sub plot factor. Three irrigation levels equivalent to 1.00, 0.75, and 0.50 times estimated evapotranspiration (ET) will be applied to the main plots. Within each main plot there will be three N fertilizer application rates completely randomized within each irrigation rate treatment. Three potato varieties to be determined by the project's advisory committee will be used as test crops.

Data collection: Soil samples from 10 randomly selected locations in each experimental unit will be taken prior to planting, in 12 inch increments to the 36 inches depth to determine initial soil nitrate concentration.

Soon after tuber formation, plants will be sampled at 14 days interval from each experimental unit, and partitioned into leaves, stems, roots and tubers to evaluate the effect of the treatments on dry matter partitioning in the plants. Tuber bulking rate and mean tuber weight will also be evaluated. The effect of the treatments on leaf area index and leaf chlorophyll content will be determined.

After vine kill, but prior to harvest, soil cores will be taken from each plot at 12 inch increments to the 36 inches depth to determine treatment effects on the distribution of residual nitrate N in the soil. Temperature and moisture sensor will be installed in each plot to monitor treatment effects on soil temperature and volumetric soil water content. The crop will be harvested and tubers evaluated for total yield, size distribution, external and internal defects, and specific gravity.

Data will be analyzed as a split plot design in RCBD using SAS Procedure for Split Plot analysis.

Goal 3 will be addressed using a Split Plot design in RCBD with four replications. Drip management will be the main Plot factor with two treatments: drip with air injection and drip with no air injection. Nitrogen application rate will be the sub plot factor. All data collected for objectives 1 and 2 will be collected in this study. Water flow rate into drip tapes and the amount of air that is injected into the drip tape will be measured. Statistical analysis will be done as described for objective 1 and 2.

Project Action Plan and Timeline:

Schedule for conducting major activities of the project

ACTIVITY	Year 1			Year 2			Year 3			Year 4		
	1[a]	2	3	1	2	3	1	2	3	1	2	3
Meeting with advisory group and planning project.	✓	✓										
Project layout in the field, pre-plant data collection, and planting	✓	✓		✓	✓		✓	✓		✓	✓	
Data collection during crop growing season and after harvest.		✓	✓		✓	✓		✓	✓		✓	✓
Field day and workshop to demonstrate performance of crop to stakeholders					✓		✓	✓		✓	✓	
Data analysis and summary				✓		✓	✓	✓	✓	✓	✓	✓
Communication of project findings to stakeholders				✓			✓			✓		

[a] 1 = Winter/Spring; 2 = Summer; 3 = Fall

Results Expected and Transferability:

Significant irrigation water and nitrogen fertilizer savings are expected from this project. Maximum tuber yield and quality grade tubers are expected to be produced with minimum water and N input. The profit margin of producers is expected to increase because of less water and N input. Results of this study will be communicated to growers through grower field days, newsletters, and at potato workshops/conferences. The results will be presented at the Potato Association of America meetings, and at the annual meetings of the American Society of Agronomy.

Sub-Project V. Efforts to improve profitability of specialty crop policy and marketing

Approach:

Evaluate consumer preference and willingness to pay for various value-added attributes of new varieties through the use of consumer focus groups, sensory and survey analysis, and controlled experimentation. Scanner data analysis of supermarket sales data will provide baseline demand information for comparison against micro-level findings.

Consumer Preference Investigation:

Findings from a recent national survey (Bond, Thilmany, and Keeling Bond; Keeling Bond, Thilmany, and Bond; Keeling Bond, Lloyd, Thilmany, and Bond) indicated that consumers both valued nutritionally superior produce and were willing to pay a premium to obtain it. While this is a promising development for producers wishing to add-value to their fresh produce, the data consists only of stated, rather than revealed, preferences for these attributes and are generalized to a food category as opposed to individual product. Furthermore, past research has shown that stated and revealed preferences do not always correspond exactly, and farmer profitability will not be enhanced simply through consumer intent (Fox et.al, 2000.). With the above in mind and to create an accurate assessment of the marketability of new and existing potato varieties, we propose first to conduct a national survey of consumer demand for potatoes. This activity will facilitate the collection of preferences from the broadest possible spectrum of potato consumers, allowing for creation of marketing recommendations tailored to groups united by demographic and/or psycho-graphic similarities. We further propose validation of stated preference data through two revealed preference exercises: 1) lab-based experiments in a controlled, scientific environment using experimental economics methods and incentive-based payments to participants; and 2) analysis of scanner data.

Fox et. al, (2000). stated several advantages of using experimental valuation methods where participants are required to actually purchase the product they perceive value in: a) they are designed to reveal true preferences, and b) the use of real money, real food, and repeated participation ensures reliability of the data. Comparison of the stated and revealed datasets will illustrate the extent of hypothetical bias from the study's consumer survey results and generate more reliable information on consumers' tastes and preferences to integrate into marketing and outreach materials.

The revealed preference experiments will facilitate assessment of consumer preferences and tradeoffs between alternative nutrition information claims, appearance characteristics, and price. The first experiment is laboratory-based, allowing for strict control of attribute levels and revealed information. This exercise makes it possible to gather consumer preference information on new or enhanced potato varieties without having to source a large number of retail partners and product, while maintain data integrity. The second experiment compliments the first, by collecting historical data on consumer response to price and marketing stimulus with respect to existing potato varieties that are widely available in national grocery stores. Combining analyses from the two types of data will assist in making the most accurate predictions on the marketability of value-added potatoes, including the efficacy of alternative marketing claims and media, and consumer willingness to pay.

In particular, the proposed research will answer questions about whether marketing information can influence consumers to purchase more potatoes, whether it will result in preferences towards nutritionally enhanced varieties, increase consumer willingness to pay, or possibly have no effect on sales. Almost two-thirds of shoppers always or usually read food labels, but many are skeptical about health claims made on food labels (Gilbert 2000). Two-thirds of all shoppers agree that diet is "very important", indicating a strong potential demand for identified nutritionally-superior products (Gilbert 2000). For consumers to take full advantage, however, they require either information on the specific nutrient and chemical content of the product, if they are already knowledgeable about the link between these attributes and health, or a specific and verifiable health claim. Furthermore, consumers respond to both intrinsic sensory characteristic and revealed information, thus the methods by which this information is presented is a key concern in the marketing of fresh potatoes.

Knowledge of the consumer demand response to new varieties and marketing methods for a wide cross-section of the population will assist individual potato producers, processors, and industry organizations in entering and being successful in the value-added potato marketplace. Specifically, an expected outcome of this project is that our broad based marketing recommendations will reduce uncertainty and risk associated with producing and marketing new and value-added potato varieties. Through this risk-minimization, costs of entry into the marketplace are reduced and, in so much as value-added markets are able to serve as hedges against price volatility and reduce some forms of production risk, marketing margins and long-run prospects for profitability are increased.

The proposed consumer preference investigation will use numerous econometric analysis methods including contingent valuation and choice set creation. Findings from these activities will initially be targeted at academic audiences. However, it is most important to relate these findings to representatives of the potato industry who will be in the best position to widely disseminate and apply our results. As such, we envision writing a combination of outreach and fact sheet publications, as well as presenting the results to interested industry groups, such as the United States Potato Board, Idaho Potato Council, Colorado Potato Administrative Council, and others. We will also partner with the Colorado State University Specialty Crops Program which provides multiple opportunities to interact with and present to small and medium-sized producers and potential producers who are interested in growing specialty crops. Furthermore, we will be able to leverage our connection with San Luis Valley Experiment Station to reach audiences of potato growers in the state of Colorado.

Sub-Project VI. Optimizing postharvest storage.

Goal 1. Developing an early detection tool to monitor diseases in potato storage.

Huge losses are incurred by the potato industry due to disease spread in potato storages. These diseases are caused by both bacterial and fungal pathogens. Among the most devastating are soft rot (*Pectobacterium cartovora* ssp *cartovora* and *atroseptica*), dry rot (*Fusarium sambucinum*), ring rot (*Clavibacter michiganensis* ssp. *sepedonicus*), late blight (*Phytophthora infestans*), pink rot (*Phytophthora erythroseptica*), and leak (*Pythium ultimum*). Visual inspection, bad odors and temperature sensors are currently the only practical means of detection for diseases in potato storage. Devices that are sensitive to detect the presence of a pathogen or early rotting prior to the development of significant disease development would provide a powerful tool for reducing potato losses during storage.

Methods:

Potato tubers release volatile organic compounds (VOC) when they are under biotic stress (Lui et. al, 2005, and Costello et. al, 2000, Jelen et. al, 1995). Some of these VOCs have been characterized by using GC/MS (Gas chromatography- Mass spectrometry) and are identified as disease specific volatiles. Volatile collection traps can be used to capture these VOCs in potato storages and pathogen specific signature compounds can be identified. Our aim is to exploit this technique and develop a simple, cost effective tool for early detection of potato pathogens in commercial potato storages.

Sampling and analysis of airborne microorganisms has received attention in recent years owing to concerns with mold contamination in indoor environments and the threat of bioterrorism. Methods have been developed recently to identify a variety of microbial pathogens that are released in the circulating air (Tilsala-Timisjärvi and Alatossava, 2004). Molecular methods, such as quantitative polymerase chain reaction amplification, can enhance monitoring strategies by increasing sensitivity and specificity, while decreasing the time required for analysis.

By combining the sensitivity of GC-MS and PCR (polymerase chain reaction) detection technology, volatiles released from infected potatoes and DNA isolated from fungal spores will be used to monitor the conditions of potato storage. In this collaborative project, our aim is to develop a simple, sensitive and cost effective detection tool, useful for commercial operations to detect a variety of tuber-borne pathogens in potato storages prior to significant decay losses. In addition, the newly developed detection tools would be utilized in ongoing studies evaluating the efficacy of various management options (e.g., cover crops) to control soil-borne pathogens both in the field and in potato storages.

Approach:

Initially, a specific volatile signature will be collected from potato tubers infected with specific fungal and bacterial strains using GC/MS under laboratory conditions. This will be expanded to large potato storage rooms. VOCs will be trapped by using Super Q resin placed at ventilation systems or by passing air through traps by connecting to a vacuum pump in potato storage rooms. These traps can be collected and the volatile compounds can be desorbed by organic solvent and injected into GC/MS to analyze for disease specific volatile fingerprints.

Fungal spores that circulate in the ventilation system in potato storage can be trapped by using 0.2-μm pore polycarbonate track etch membranes (Poretics Corp, Livermore, CA). The filter holder will be directly connected to a battery-operated vacuum pump (Escort Sampling; Hazco Services Inc; Dayton, OH) and DNA of trapped airborne fungal spores will be isolated from the filters. A combination of quantitative PCR and length heterogeneity analysis using conserved rRNA primers will be used to identify and quantify the various spores collected by the filters. Sensitivity of these primers will be tested with DNA isolated from pure cultures of the common potato diseases listed above.

Disease detection probabilities based on fungal spore entrapment on a filter and VOCs captured on Super Q resin will be combined to increase the sensitivity of the detection technique to allow monitoring of diseases at very early stages of development in storage. A software program will be developed for automatic processing of mass spectral outputs and also to predict and detect disease. This will enable easy transfer of technology.

Preliminary results:
Several disease-specific, volatile organic metabolites have been detected based on headspace gas analysis of potato tubers infected with specific pathogens, using gas chromatography and mass spectrometry (GC/MS). However, in these studies, the specific metabolites detected were not consistent therefore, the previous studies require several samples to arrive at the final conclusion, and the technology transfer has been considered expensive. The GC/MS output analysis used in these programs lacked peak deconvolution, thus it was difficult to obtain a pure spectra of a compound in a mixture of 2-6 compounds in a peak. However, now using novel software to analyze GC/MS outputs it is possible to extract pure mass spectra for a peak with mixtures thus increasing the probability of correct identification of a compound (Roessner. 2001).
Metabolomics is a novel tool, where the disease specific volatile organic compounds produced by the pathogens in rotting tubers released to the storage headspace is identified and used as a fingerprint of specific disease. Disease specific biomarker metabolites will be identified under controlled conditions and tested under commercial conditions for their ability to detect diseases at an early stage of development.

Expected outcomes: Developing an early detection system would substantially benefit the storage operators in planning when to sell the tubers. It would also enable them to take remedial measures to avoid diseases.

Time line. First and the second year: Development of models and identification of biomarkers to detect five diseases of potato tubers under laboratory conditions.

Third year: Validation of the efficiency of models and biomarkers to detect diseases under commercial conditions in Colorado and under Montreal conditions as well as establishment of a facility to do this under Colorado conditions.

Forth year: Validation of the method under commercial conditions in Colorado and under Montreal conditions.

Goal 2. Understanding pressure bruise susceptibility in potato

We propose to determine why certain cultivars are more susceptible to pressure bruise, and develop better ways to study this complex phenomenon.

Approach:
Studying pressure bruise in commercial storage conditions is a challenging task because of the number of determining variables , and the difficulty in controlling them experimentally.
We are in the in the process of developing a technique to induce pressure bruise under lab conditions. Using this technique, we can apply ~300 pounds pressure per square inch (initial lab estimates) at precise locations on the tuber. With this technique a number of experiments can be designed to test the effectiveness of various chemical treatments on pressure bruise.

Expected outcomes:
Developing a laboratory technique to screen pressure bruise susceptibility in cultivars will help in screening the breeding material. This technique may also help in identifying chemical treatments to reduce pressure bruise, and in rapid screening and development of storage guidelines for new potato cultivars.

Time line: Year 1: Validation of the technique to replicate pressure bruise in laboratory conditions, and studying cultivar differences in their susceptibility.
Year 2: Testing the influence of cultural practices on pressure bruise susceptibility and chemical treatments to reduce pressure bruise susceptibility.

TECHNOLOGY TRANSFER AND EXTENSION (for all research results)
Outreach efforts are the key to the successful adoption of any new technology, cultivar, or production practice. Growers are profit driven and will adopt new cultivars, practices and technology only if there is sufficient evidence that they are cost effective. To help growers integrate findings from this research into their own operations several avenues will be utilized:

1. Research findings will be periodically reported to producers through the use of a quarterly newsletter, and the development of a comprehensive website. Findings will be communicated in such a way as to consistently facilitate integration of the information into a producer's own operation. Potential industry impacts will be discussed in each communication.
2. A series of workshops will be used (on cooperating grower's farms whenever possible) to illustrate to producers how each phase of this research can be integrated into their operations. Additional information will be provided to growers and industry personnel during the annual potato educational conferences around the region.
3. Existing positive relationships with the states' potato advisory groups will be utilized to help spread the word about nutrient benefits of given cultivars, disease resistance and cultivar performance, marketing opportunities, etc. Regional field days in Colorado, California and Texas will be used to help communicate the findings from this project. Additionally, funds will be solicited from the advisory committees to help producers move the new potato cultivars into the market place with all pertinent information about each cultivar's characteristics prioritized.
4. Cultivar management sheets will be provided to any interested grower detailing each cultivar's characteristics with emphasis on nutritional qualities, disease resistances, best production and storage practices, and marketing advantages. These sheets will be tailored to each individual state's production area and their common practices. For example, California and Texas industries are geared towards spring/summer markets with little long term storage. Colorado's industry, on the other hand, is focused on a fall crop, with long term storage a priority. Cultivars developed in this effort must be usable by both industries and potential problems for each type of production system must be detailed in the management sheets.
5. Original research results, as well as relevant current literature regarding each aspect of the project, will be distilled for growers to include an executive summary of each issue. This in turn will be placed into a scenario to assist the growers in moving the research information into action on their own operations.

Proposed concepts to generate research funding self-sufficiency:

Grower cooperators will be identified and utilized to speak at Extension/Outreach activities with fellow producers to help establish legitimacy of this research effort and provide growers with information related to disease resistance and cultivar performance. This will in turn promote the efforts of this research and provide added potential for grower research funds when the value is determined and grower support for additional monies from other research grant opportunities.