Research Report

2010-2011

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Research Areas

- Variety specific pressure bruise management guidelines and pressure bruise management
- Preventing netting loss in russet cultivars
- Enhanced nutritional/human health benefits for added market value
  - ❖ Antioxidant levels and effect of cooking on them in different cultivars.
  - ❖ Selenium and sulfur accumulation in Colorado cultivars

Executive summary

- Variety specific pressure bruise management guidelines and Pressure Bruise management
  Over last three years of our research concluded that the tuber hydration is one of the most important and manageable factors among other aspects such as pile height and duration of storage in reducing pressure bruise incidence. We developed a ventilated crib design to induce pressure bruise in potato tubers under laboratory conditions. We identified texture analysis is the accurate way of measuring tuber hydration status and developed a correlation between pressure bruise incidence and texture.
  (Journal article accepted for publication in American Journal of Potato Research)

- Preventing netting loss in russet cultivars
  Based on our current research there appear to be two varietal susceptibility and . timing of fertilizer treatments. In some cultivars if fertilized late in the season with boron, calcium, potassium, or nitrogen, netting was removed with less effort. It is unclear whether this is because of effects of the nutrients themselves or whether the effects result from delays in tuber harvest maturity. The differences may also be due to small changes in soil pH from treatment. The results of the "hand test" performed to samples from different fields and growers also provide strong evidence that grower practices or variability in soil conditions have an effect on netting loss.

- Enhanced nutritional/human health benefits for added market value

➢ Antioxidant levels and effect of cooking in different Colorado cultivars
(Published in LWT Food Science and Technology 2012 45:161-171)

➢ We identified Purple Majesty and Rio Grande Russet accumulates more Selenium than other Colorado cultivars tested.
(American Journal of Potato Research. (Accepted 2012) DOI:10.1007/s12230-011-9232-1)

Variety specific pressure bruise management guidelines and Pressure Bruise management

Introduction

Pressure bruise limits the duration of storage or reduces the grade of stored potatoes for all market classes of potato. Losses caused by pressure bruise are typically 20 to 30% for potatoes stored from September/October to June/July. Long-term storage is necessary to provide 12 months raw product and minimize shipping costs.

Pressure flattening is a result of the interaction of three factors; pressure within the pile, duration of storage, and moisture loss from the tubers (figure 1). Examining the three factors individually allows for an understanding of current strategies to limit pressure flattening and their economic and practical limitations.

Pressure flattening occurs as the tuber surface becomes depressed or flattened due to constant contact from a portion of an adjacent tuber. This contacted area also receives the force exerted by the adjacent tuber as a result of the weight of tubers above it in the pile. Tubers moisture loss is an important factor in increasing the susceptibility of tissue to forming depressions in response to this force. Assuming that large reductions in the height of piled potatoes or storing potatoes for only a few months are not practical alternatives to current methods, reducing moisture loss from tubers appears to be the most economical and practical approach for preventing or reducing pressure flattening.

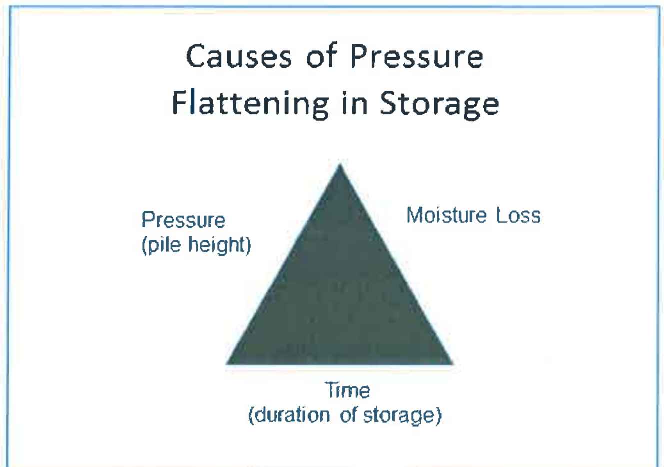


Figure 1

There are two ways to reduce the economic losses caused by pressure flattening. They are

1). Developing methods for predicting which fields or bins are more likely to pressure flatten early on and severely so that they can be shipped before pressure flattening damage becomes significant, and

2). Finding methods that can either delay or reduce pressure flattening.

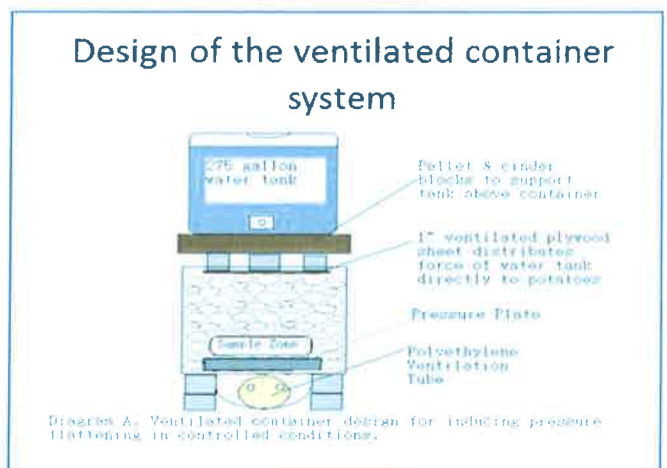


Figure 2

This report will focus on 2010-2011 year research to develop measurements at harvest that can be used to predict the development of pressure flattening in storage.

Results:

a. A system to create pressure flattening was developed in laboratory using ventilated containers (cribs) (figure 2). With this experimental setup it is much easier to evaluate samples from different fields, different fertilizer treatments and different pile heights. The cribs also allow for control over the date that the samples are removed and reduce the likelihood of samples being dumped or accidently damaged.

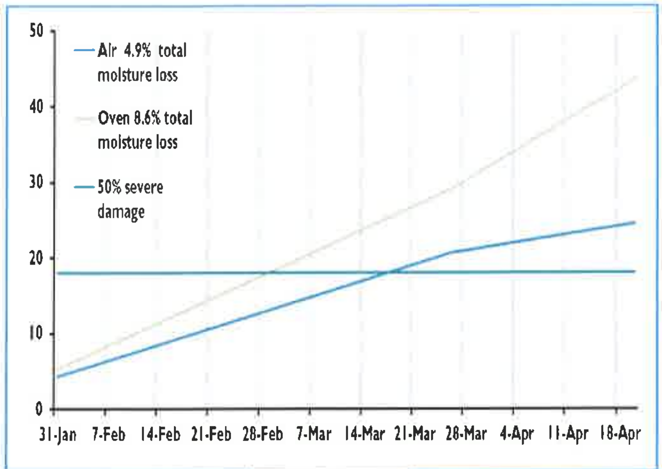


Figure 3

b. Canela Russet, Centennial Russet, Rio Grande Russet, and Russet Norkotah potatoes treated to induce moisture loss were evaluated after different durations of storage for pressure flattening using a ventilated container design. Differences in pressure flattening development occurred within a cultivar as a result of different moisture loss treatments as well as among the cultivars.

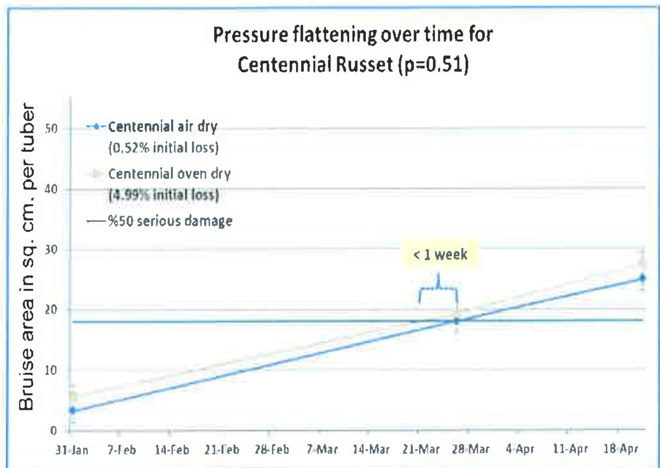


Figure 4

c. When all cultivars are grouped together by the initial moisture loss treatment, the higher moisture loss oven treatment develops pressure flattening faster (Figure 3). When compared against the line indicating 50% severe damage, the oven treatment develops severe pressure flattening 2-3 weeks earlier than the air treatment.

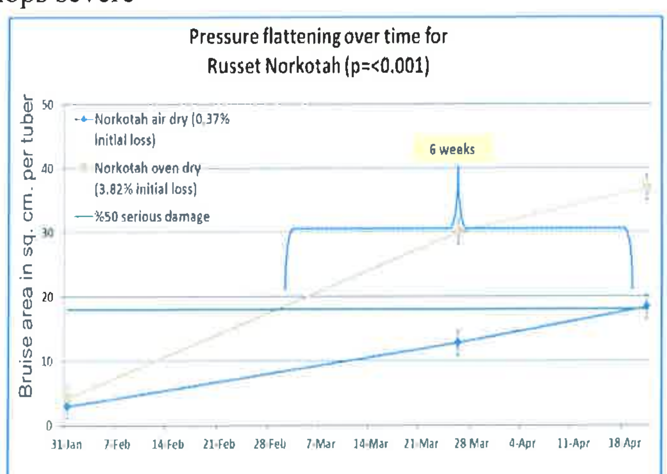


Figure 5

d. There was no difference in the storage time required for Centennial Russet to pressure flatten beyond USDA grade tolerances when the tubers had five percent or less than one percent moisture loss prior to storage. Russet Norkotah tubers that lost less than one percent moisture could be stored six additional weeks before the tubers were out-of-grade compared to those that lost three percent moisture (figure 5)

e. Preventing moisture loss during harvest and storage may not considerably decrease pressure flattening for some cultivars but may provide additional months of profitable shipping for other cultivars. 50% severe damage line indicates that at 18 sq. cm. of combined pressure flattened area, an 8-12 ounce tuber is severely damaged by USDA grade standards. As a result when the average pressure flattened area for a treatment crosses the severe damage line, approximately half of the tubers are severely damaged.

Conclusions

a. The data indicates that moisture loss, including susceptibility to at-harvest moisture loss significantly affects pressure flattening development. This is a very important finding since it shows that pressure flattening may be delayed or reduced by reducing moisture loss, at least for some cultivars. In other words, while the influence of time and pile pressure are still largely responsible for pressure flattening, the effect of moisture loss is not negligible. Current data indicates that feasible reductions in moisture loss may allow for an additional 2-3 weeks or more of storage without severe pressure flattening for some cultivars.

b. Susceptibility to moisture loss and pressure flattening can be measured at harvest. The relative amount of moisture loss observed from the at harvest measurements was able to predict some differences in pressure flattening. Results from some of the fields indicate that fields that lost more moisture during the at-harvest measurements developed more pressure flattening or to develop pressure flattening earlier.

c. At this point the ability to predict relative amounts of pressure flattening in storage is limited. Some cultivars are not as prone to pressure flattening as others. In addition, it may be that a difference in at harvest moisture loss of a few percentage points may increase pressure flattening in some cultivars but not in others.

Recommendations

1. Make sure field is not too dry after vine kill
2. Pre-wet bin floors prior to loading
3. Supply air and humidity to the potato pile while loading
4. Close the bin doors if there is any mechanical problem
5. Set the storage temperature to 1-2 degrees below the coolest pulp temperatures from that day
6. Humidity above 95% is preferred. Always humidify fresh air.
7. Watch closely pile height changes
8. Maintain adequate sprout control.

Understanding factors involved in netting Loss in Russet cultivars

Summary:

Russet netting loss causes quality problems from increased moisture loss and increased visual appearance of defects such as external bruises, small cracks, or minor harvest damage. Preliminary research in 2010 and the CCPGA royalty funded research in 2011 looked at the effects of late season fertility treatments and cultivar susceptibility to netting loss. Results indicated that some cultivars such as Norkotah Selection 3 and Classic Russet are more susceptible to netting loss than cultivars such as Canela and Centennial when grown under normal conditions. Furthermore, netting was removed somewhat easier for some cultivars if fertilized late in the season with Boron, Calcium, Potassium, or Nitrogen. It is unclear whether this is because of effects of the nutrients themselves or whether the effects result from delays in tuber harvest maturity. Other cultivars had not shown any susceptibility to netting loss regardless of treatment. Future research efforts may establish the role of soil moisture, at-harvest treatments, and soil pH in reducing the durability of russet netting for susceptible cultivars.

Methods

After examining the results of the 2010 preliminary research, it was decided that 2011 research would focus on late season fertilizer treatments and varietal susceptibility as sources of netting loss. Evaluation of soil moisture effects on netting loss was also planned for 2011, but was not successfully implemented. In 2011, replicated plot trials were established at the San Luis Valley Research Center. Classic and Norkotah CO3 were planted in separate plots, each with a randomized block experimental design and 4 replications. Ten russet varieties were planted in adjacent rows in a second field so that they would be grown under the same fertility and irrigation(CO99100-1RU, CO99053-3RU,Canela, Classic Russet, Centennial Russet, Mesa Russet, Premier, Norkotah CO3, Norkotah CO8,and Rio Grande). Fertility treatments were applied to the Norkotah and Classic plots during the first week of August, approximately 2-3 weeks before senescence. In 2011, the fertility treatments were 40lbs.nitrogen, 2 lbs. Boron, 10 lbs Potassium, and 20 lbs. Calcium, which are approximately twice the rates normally applied when applications are made late in the growing season. In general, the Norkotah, Classic, and variety testing plots all received approximately 110 lbs. per acre nitrogen, with half applied at planting. Irrigation and pesticide applications were made as required. No significant in-season disease was observed, although there was a high proportion (10%) of rot observed in the Norkotah CO3 plot at harvest.

Tubers were dug by hand approximately 4 weeks after vine kill and immediately placed in a humidified cold room. Subsamples of 40 tubers total were created for the fertility treatments to be tested for netting loss susceptibility. Twenty tubers per variety were tested from the plot that had the 10 different varieties.

Testing of russet netting was conducted 2 ways in 2010. Tubers from the Canela and Norkotah were cut in half lengthwise and placed, flat side down, in a container with holes in the bottom to allow for drainage. A high pressure spray nozzle was then placed 12 inches above the tuber surface and adjusted so that it sprayed a 1.5 inch diameter circular area. The spray was directed at the middle of the tuber and a timer was started. When approximately 50% of the netting had been removed by the spray, the timer was stopped and the seconds were recorded. Spraying was also stopped after two minutes if netting had not been removed and these tubers were recorded as 120 seconds. Care was taken so that the nozzle was at the same distance from each tuber tested.

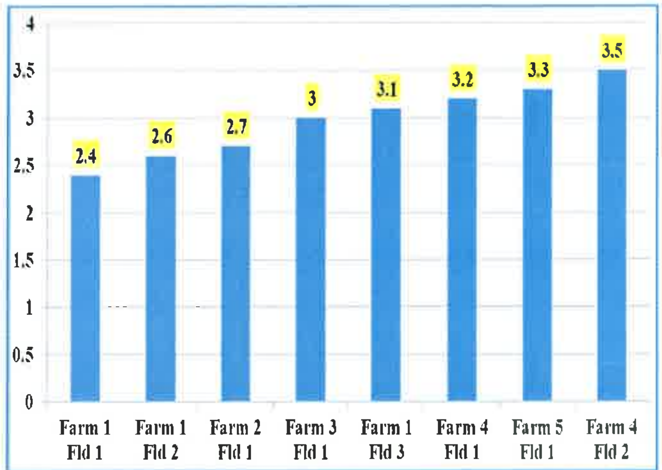


Figure 1.
Comparison of netting adherence of different late season fertilizer and chemical treatments (Norkotah 2010). Results are in seconds required for removal of netting under high pressure water spray

A separate "hand" test was conducted in 2010 to determine the susceptibility of Norkotah CO3 tubers from different fields, bins, and growers. Tubers were graded on a 1-5 scale based on the pressure and force required to remove netting both using pressure from the evaluators thumb and how much pressure was required to remove netting when tubers were rubbed against each other. Any skin damage or removal that occurred was not considered netting loss. A "1" indicated any light handling (any contact) will remove netting. A "2" indicated that normal handling (moderate pressure) will remove some netting. A "3" indicated that rough handling (moderate to high pressure) will result in loss of netting. A "4" would mean that only very rough handling (very high pressure) could remove netting. A tuber scored as a "5" would not lose netting from any amount of pressure or handling (although skin damage would occur). For the testing conducted in 2011, all evaluation was done using the water spray method

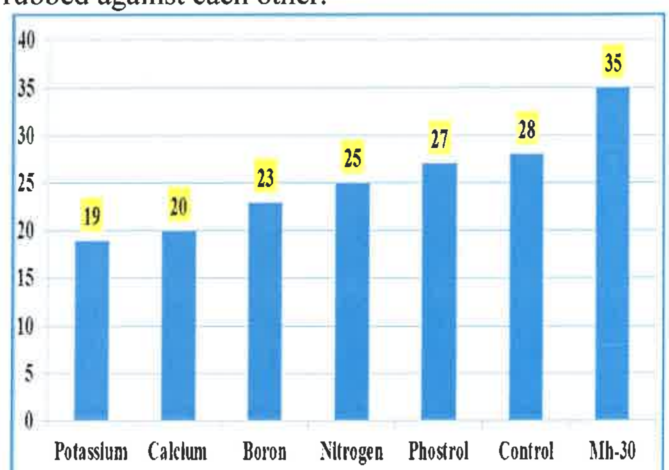


Figure 2.
Comparison of averaged netting adherence for different growers (Norkotah CO3 crops in 2010). Results are based on 1-5 scale as follows. A "1" indicates any light handling (any contact) will remove netting. A "2" indicates that normal handling (moderate pressure) will remove some netting. A "3" indicates that rough handling (moderate to high pressure) will result in loss of netting. A "4" would mean that only very rough handling (very high pressure) could remove netting.

Results:

In Figure 1, there was a trend toward faster netting loss for the Norkotah treatments of additional potassium, calcium, and boron (19, 20, and 23 seconds required for removal compared to 28 seconds for the control). Additional nitrogen, and application in the field of phostrol did not result in increased netting loss compared to the control tubers. Very few Canela Russet tubers (data not shown) lost netting during treatment with the water spray, so testing as stopped.

Norkotah CO3 tubers from different fields and growers showed large differences in the amount of pressure required to remove netting (Figure2). One field from a commercial grower indicated a score of 2.4 indicating that fairly routine handling or moderate pressure could remove the russet netting. Samples from a different local grower earned a score of 3.5 which corresponds to removal of netting only from rough or very rough handling. Tubers above a score of 3 would most likely be harvested and stored without significant netting loss.

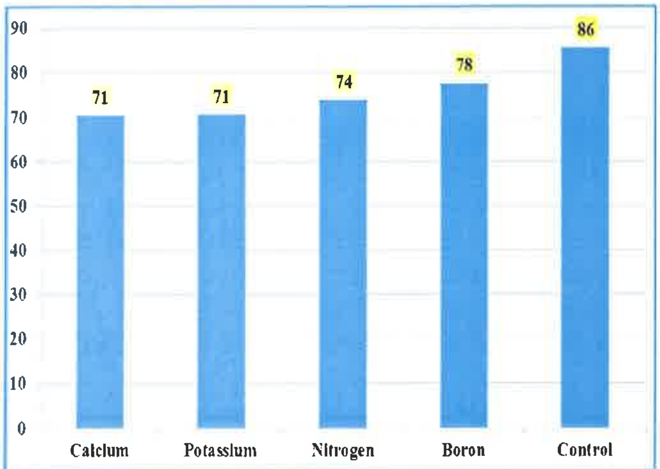


Figure 3.
Comparison of netting adherence of different late season fertilizer (Classic 2011). Results are in seconds required for removal of netting under high

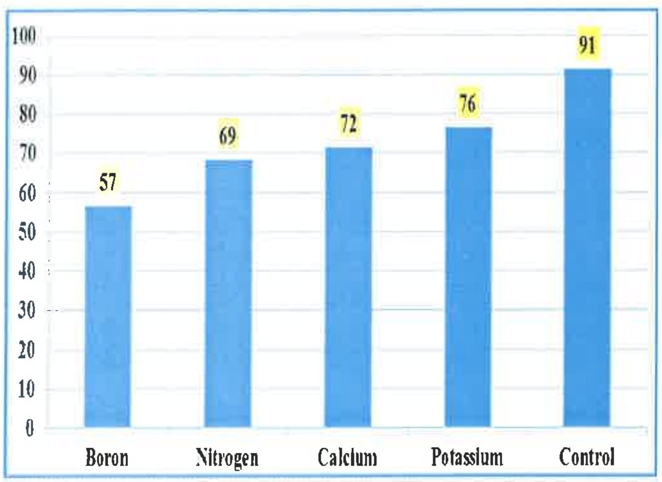
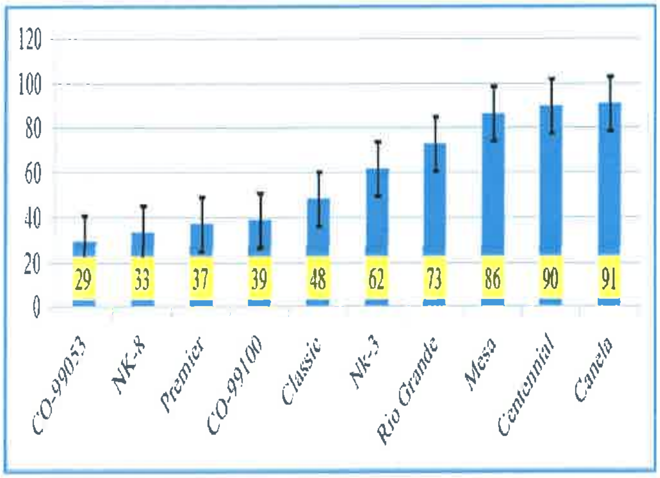


Figure 4.
Comparison of netting adherence of different late season fertilizer (Norkotah 2011). Results are in seconds required for removal of netting under high pressure water spray.

Figure 3 presents the results from 2011 testing of fertility treatments for the cultivar Classic Russet. Although the results were not statistically significant, there was a similar trend to the 2010 Norkotah results, which indicated easier removal of netting for tubers that had late applications of potassium, boron, calcium, or nitrogen. In Figure 4, Norkotah CO3 tubers from 2011 that were treated with potassium, boron, nitrogen, and calcium also show a trend for increased susceptibility to netting loss.

Results from some of the newer cultivars indicates that Mesa appears to be relatively resistant to netting loss, while Classic and CO-99100 were average cultivars with regard to netting loss (Figure 5). There was a statistically significant difference in the susceptibility of the cultivars to netting loss, with CO99053-3ru, Norkotah CO8, Premier, and CO99100-1ru being more susceptible to netting loss than Canela Russet, Centennial Russet, Rio Grande Russet, and Mesa Russet.

Conclusions and discussion:



Based on our current research there appear to be two factors most responsible for netting loss. The first may be varietal susceptibility. The past experience of a commercial potato grower who has dealt with netting loss has been that some russet varieties are more prone to netting loss than others. Other cultivars appear to have better or worse netting depending on the growing season. The 2010 and 2011 results support this observation. In 2010, late season chemical and fertility treatments were applied to two varieties, Norkotah and Canela. The data presented in Figure 1 is from Norkotah because the vast majority of Canela tubers would not lose significant netting under the water spray. The 2011 study looked at 10 russet cultivars and there were clear differences in susceptibility. Based on the 2010 results and previous grower experiments, it was expected that some cultivars such as Centennial and Canela would be more resistant to netting loss than Norkotah CO3 and Classic Russet.

Results from the fertilizer treatments were that netting was removed with less effort for some cultivars if fertilized late in the season with boron, calcium, potassium, or nitrogen. It is unclear whether this is because of effects of the nutrients themselves or whether the effects result from delays in tuber harvest maturity. The differences may also be due to small changes in soil pH from treatment. The results of the "hand test" performed to samples from different fields and growers also provide strong evidence that grower practices or variability in soil conditions have an effect on netting loss.

Direction of future research:

In order to make further progress in reducing netting loss, we need better understanding of the physiological effects that lead to poor adherence of the netting to the surface of the potato skin. Evaluation of harvest and biochemical maturity may help determine whether the fertilizer nutrients themselves are responsible for netting loss. It is also possible that these applications delay harvest maturity and it is this delay that increases susceptibility to netting loss. Evaluation of the effects of soil pH and soil moisture on netting loss as a greenhouse study may also help increase understanding of the factors responsible for netting loss.

Enhanced nutritional/human health benefits for added market value

B. Antioxidant levels and effect of cooking on in different cultivars.

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Potato tubers, which are one of the richest sources of antioxidants, are always cooked before human consumption. The objective of this study was to understand the effects of various domestic cooking methods, i.e., boiling, microwaving and baking on total phenolics, flavonoids, flavonols, lutein, anthocyanins and antioxidant activities in 5 cultivars and 9 advanced selections(Table 1) (with different skin and flesh colors after 6 months of storage. The three cooking methods reduced the levels of these compounds and the percentage of DPPH (2,2-Diphenyl-1-pikryl-hydrazyl) radical scavenging activity in all the cultivars and selections. Boiling minimized these losses. Red fleshed tubers contained more flavonoids, whereas purple tubers contained more flavonols. Despite severe loss of these compounds due to cooking, both the flesh types retained larger amounts of all these compounds due to higher initial levels. Decline in the radical scavenging activity is directly related to loss of these compounds due to cooking treatments in all white and colored flesh tubers.These findings also suggest that the nutritional value of potatoes was significantly reduced by the baking and microwave treatments (Table 2); however these losses were minimized by boiling. In general, baking is found to be more deleterious with respect to the retained nutritional value of potatoes. Overall, red and purple fleshed tubers contain the highest levels of antioxidant activity and boiling of these potatoes is an optimal cooking method to retain the largest amount of antioxidants.

Cultivar or selection	Tuber color	
	Skin	Flesh
Mesa Russet	Russet	White
CO99256-2R	Red	White
Silverton Russet	Russet	White
CO98012-5R	Red	White
CO95172-3RU	Russet	White
Colorado Rose	Red	White
Russet Nugget	Russet	White
VCO967-2R/Y	Red	Yellow
CO99045-1W/Y	White	Yellow
CO01399-10P/Y	Purple	Yellow
AC99329-7PW/Y	Purple and white	Yellow
Purple Majesty	Purple	Purple
CO97222-IR/R	Red	Red
CO97226-2R/R	Red	Red

Table 1

Nutritional value	Cooking method		
	Boiled	Microwaved	Baked
Total phenols	↓	↓↓	↓↓
Total flavonoids	↓	↓↓	↓↓
Total flavonols	↓	↓↓	↓↓↓
Lutein	↓	↓↓	↓↓
Pelargonidin	↓	↓↓	↓↓
Delphinidin	↓	↓↓	↓↓
Malvidin	↓	↓↓	↓↓
Antioxidant activity	↓	↓↓	↓↓↓

Table 2*

*Summary of nutritional value of potato cultivars and advanced selections affected by cooking methods. Numbers of inverted arrows indicate the degree of loss of nutritional value.

Conclusions

- Polyphenols and pigments in potato were reduced by boiling, microwaving and baking.
- Antioxidant activity of the tubers was decreased by cooking methods.
- Red and purple tubers retained higher antioxidant levels after cooking methods.
- Loss of polyphenols and pigments were low in boiling and severe in baking.
- Mesa Russet retained high total phenolic activity even after three cooking methods such as steaming, microwaving and boiling when compared with other russet cultivars.

B. Selenium and sulfur accumulation in Colorado cultivars

(American Journal of Potato Research 2012. (Accepted) DOI: 10.1007/s12230-011-9232-1)

Selenium (Se) is an essential trace element in the human body. Development and survival of animals and humans will be at risk without Se. Higher levels of Se in blood plasma have been correlated with reducing many cancers. Potato plants are being supplemented with selenium (Se) in several countries to enrich tubers with Se for obvious health benefits. Tubers of Rio Grande can supply more than the recommended dietary allowance (RDA) of Se to adult humans (Figure 1). **Se enriched potatoes like 'Selena' are being sold in the Irish marketplace, claiming to provide 50% of minimum RDA of Se (Anonymous** 2009). The presence of up to 561% RDA of Se in the tubers of Rio Grande Russet, Purple Majesty, and CO99053-3RU suggests these tubers are very rich source of Se in the human diet (Figure 1). Huge variations in the tuber Se levels among genotypes cultivated on the same field suggest that these differences were due to genotype rather than soil type. This genotypic variation may reflect differences in the expression of the sulfate transporter genes in the root. Apart from selenate, plants can also take up selenite without membrane transporters, and organic Se through the active mechanism. The form of Se absorbed influences the translocation of Se from the root to the shoot.

Along with selenium we estimated sulfur in same 8 genotypes. Selenium and sulfur uptake is mediated by same transporters. Due to their similarity in chemical form, transporters can't distinguish between sulfur and selenium. The percentage of S in the tubers ranged between 0.071 and 0.098, suggesting that the tubers of all the genotypes tested contain less S than the CNC. CNC is the concentration of a nutritional element just deficient for maximum plant growth. In other words, it is defined as the transition zone where it causes a 5 to 10% decrease in growth. The

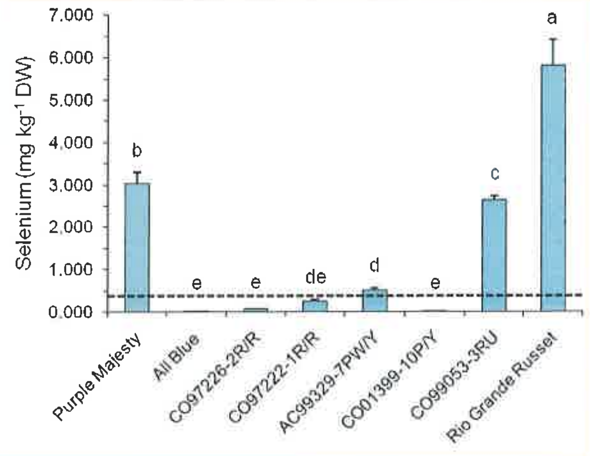

Figure 1

Total Se levels in the tubers of various potato genotypes. Bars are means ± SD of 6 to 9 determinations. The mean values that are not significantly different are represented by same letter ($p > 0.05$). Fifty percent RDA (------).

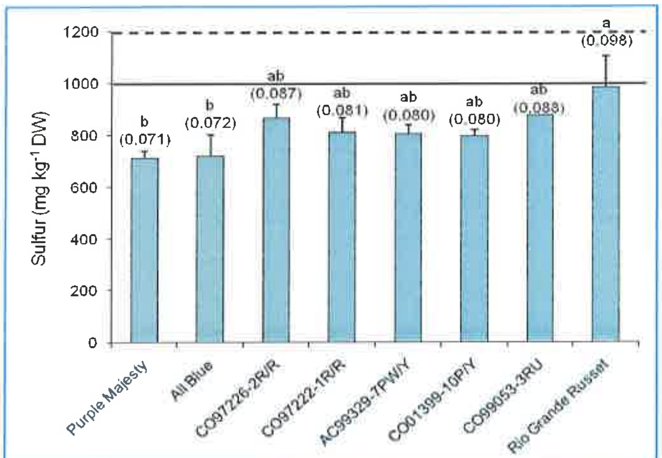

Figure 2 Total S levels in the tubers of various potato genotypes. Bars are means ± SD of 6 to 9 determinations. Values in parenthesis are percentage of S on dry weight (DW) basis. The mean values that are not significantly different are represented by same letter ($p > 0.05$). Critical S concentration in potato plant is 0.12% (------), and tuber is 0.10% (____)

lower limit of the sufficiency range is usually considered equivalent to the CNC. Tubers of these genotypes tested in the present study contained 18 to 41%, and 2 to 29% less S than the suggested CNC of S in potato plants and tubers grown at San Luis Valley Research Center, respectively.

Conclusions

- Selenium is very important dietary supplement
- Colorado cultivars and advanced selections differ in selenium content.
- Tubers of Rio Grande Russet, Purple Majesty, and CO99053-3RU can supply more than the recommended dietary allowance (RDA) of Se to adult humans