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Efficacy of Natural Compounds to Suppress Sprouting and Fusarium Dry Rot in Potatoes

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ABSTRACT Controlling sprouting and disease growth during storage of potatoes are critical to the maintenance of quality and profitability. CIPC (chlorpropham) is widely used as a sprout inhibitor for table and processing potatoes in North America but it cannot be used on or in the vicinity of seed potatoes. There are also some concerns regarding consumer safety of CIPC residues. At present, there are few products registered for control of Fusarium dry rot in stored potatoes and the available products have become less effective due to selection for resistant strains of the *Fusarium* fungus. There is a need for alternative methods for sprouting and disease control in stored potatoes.

A variety of 'natural' products including ground dill, ground cloves, clove oil, garlic powder, ground peppermint or peppermint oil were tested for their ability to suppress sprouting and the development of *Fusarium sambucinum* (dry rot) in non-dormant Norland potatoes. Two purified compounds extracted from plants were also tested (R- (-)-carvone and diallyl disulfide). Sprout suppression was examined on the basis of sprout mass at 14 and 28 days after treatments. Effectiveness against *F. sambucinum* was tested by measuring the size of dry rot lesions at 14 and 28 days after inoculation. A taste test was also conducted at 14 and 28 days after treatment.

Both purified plant extracts (diallyl disulphide and carvone) completely suppressed sprouting for 14 days of treatment and slowed sprouting over an additional 14 day observation period. Garlic powder, peppermint oil and ground cloves also suppress sprouting. None of the treatments suppressed the development of dry rot – and some treatments appeared to exacerbate this disease problem. Some treatments significantly altered the flavor of the potatoes. The altered flavor was preferred by some individuals and disliked by others.

BACKGROUND

Potato growers presently rely on low temperature storage to control disease development and sprouting of potato (*Solanum tuberosum* L.). However, carefully controlled cold temperature storage is not an option for typical small-scale or backyard growers. Commercial growers of table and processing potatoes have the option to use chemicals such as CIPC (chlorpropham) to control sprout growth during storage, but this option is again not available to seed or small scale growers. There are relatively few products registered for control of diseases such as dry rot (*Fusarium sambucinum)* in stored potatoes – and overuse of the limited array of available products has resulted in the proliferation of disease strains that are resistant to these products.

A number of alternative treatments have been identified with potential to control sprouting and disease in stored potatoes. Aromatic oils from caraway and dill seeds contain carvone (Bandara et al., 2003). Pure forms of carvone have significant sprout inhibition and disease suppressing properties (Beveridge et al., 1981; Sorce et al., 1997). Diallyl disulfide which is found in members of the onion family also has disease-suppressing properties (Bandara et al., 2003). Menthone and neomenthol, compounds found in spearmint and peppermint, have been shown to inhibit growth of *Fusarium sambucinum* (Frazier et al., 2002) and sprouting of potato (Coleman et al., 2001), without degrading the color or quality of potato products. Spencer and Vaughan (1991) found that cinnamaldehyde which can be extracted from cassia flowers or the bark of the cinnamon tree completely inhibited sprouting and reduced fungal growth on stored tubers. Clove oil is also being investigated as a potential sprout suppressant and disease control agent.

Most studies involving the use of natural products as sprout suppressant and disease control agents in stored potatoes have worked with highly concentrated and purified volatile extracts. However, these products can be toxic and expensive and may leave residues on the potato that result in poor taste (Coleman et al., 2001). Treating stored potatoes with more "natural" sources of these volatile oils (ie; seeds, leaves etc) may represent an alternative approach to managing sprouting and disease in storage. These unprocessed products are likely to be less potent that the concentrated and purified extracts but they are also cheaper and more readily accessible. The unprocessed forms may also contain a wider range of potentially useful bioactive volatile molecules.

The purpose of this study was to evaluate the potential to control sprouting and Fusarium dry rot in stored potatoes using 'natural' products available from local grocery and health food stores. Ideally these natural compounds would be inexpensive, easy and safe to use, and would have no negative impact on flavor or quality of the potato.

MATERIALS AND METHODS

All treatments were applied to Norland which had been in 4 °C storage for 5 months. Norland is a red-skinned table potato, with a short dormancy period. Norland is also quite susceptible to dry rot. The potatoes were just beginning to break dormancy at the start of the trial. For each treatment, six disease-free uniform-sized tubers were placed in an 18L plastic container that had been lined with moistened filter paper to increase the relative humidity. Two strategies were used to apply the disease and sprout control treatments. The essential oils were applied to a 10 cm filter paper disk which was attached to the lid of the container. This prevented the essential oil from coming into direct contact with the potatoes. The ground plant material was sprinkled over the potatoes. Ground peppermint leaves were also placed in a petri dish so that the leaves had no direct contact with the potatoes. A filter paper with water on it served as the control. The lids of all containers were sealed immmediatly after application of the treatments. The lids were removed for five minutes every 2-3 days to allow gas exchange with the respiring potatoes.

Every treatment included two potatoes which had been infected with *Fusarium sambucinum* just prior to the start of the trial. Each of these potatoes was wounded at various points using a toothpick. The potatoes were then immersed for 30 seconds in a suspension of *Fusarium sambucinum* spores (2.4 x 10^5 spores/ml).

The buckets were held at room temperature (20 °C) for 14 days. At that time, three potatoes were removed from each treatment, washed with distilled water and then left to dry for 24 hours. On two of these potatoes the sprouts were counted and weighed. These potatoes were then peeled and boiled according to the procedure outlined below. Taste testers at the University of Saskatchewan assessed the flavor of the boiled potatoes. The third potato was longitudinally sectioned at the *F. sambucinum* wound sites and the depth and width of the dry rot infections was measured.

The remaining three potatoes in each treatment were washed to free them from treatment residues. The filter paper disks with the aromatic oils were also removed from each container. The potatoes were then held for another 14 days under the previously described conditions to look for residual effects of the treatments. After the 14 day holding period, sprouting, disease development and flavor were again evaluated as previously described.

Taste testing

Two potatoes per treatment were cut into quarters and boiled for 20 minutes. The potatoes were strained and cooled to room temperature before taste evaluations were conducted. Taste testers were asked to rank the potatoes for flavor. Treatments were rated from 1-5: 1 being disliked extremely and 5 being like extremely. The testers also made additional comments regarding the flavor of the sample. There were 5 testers per trial

Treatments

The treatments involving ground plant materials were applied at a concentration of 1 g of product per six potatoes. The treatments involving aromatic oils were applied at 1 ml per six potatoes. These treatment rates were based on a previous study (Steven et al., 1993). The following treatments were used:

- Treatment 1: ground dill leaves mixed evenly with potatoes.
- Treatment 2: carvone on filter paper above potatoes.
- Treatment 3: ground cloves mixed evenly with potatoes.
- Treatment 4: clove oil on filter paper above potatoes.
- Treatment 5: garlic powder mixed evenly with potatoes.
- Treatment 6: diallyl disulfide saturated on filter paper above potatoes.
- Treatment 7: ground peppermint leaves mixed evenly with potatoes.
- Treatment 8: peppermint oil on filter paper above potatoes.
- Treatment 9: ground peppermint leaves placed in a petri dish set on top of the potatoes.
- Treatments 10 and 11 : Control = filter paper

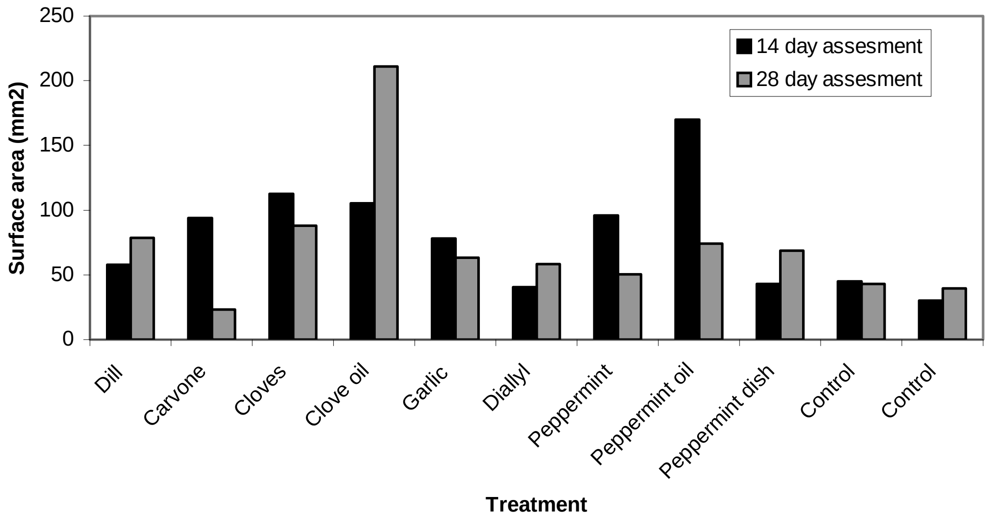
NB – none of the treatments are registered for use on potatoes in Canada at this time.

RESULTS AND DISCUSSION

Disease Suppression

After 14 days, all the treatments had larger dry rot lesions than the controls (Fig. 1). After 28 days, the carvone treated potatoes had the smallest dry rot lesions, with the controls again showing limited disease development. The potential to use carvone to suppress dry rot and other post-harvest pathogens has been noted in other studies (Bandara et al., 2003). All other treatments had larger dry rot lesions than the controls (Fig. 1). It was difficult to determine why the treatments did not suppress *Fusarium sambucinum* - and in fact seemed to worsen the problem. One possibility is that the products were interfering with the potatoes' ability to defend themselves against disease. Potatoes have the ability to heal wound sites – and this wound healing reduces the potatoes' susceptibility to wound invaders like *Fusarium sambucinum*. Many sprout suppressants work by interfering with the cell division processes that drive sprout growth. However, any treatments that inhibit cell division would also interfere with wound healing – potentially leaving the treated potatoes open to attack by *Fusarium* and other post-harvest pathogens. For this reason, sprout inhibitors like CIPC are not applied in commercial potato storages until well after wound healing has been completed. Future experiments should look at the potential to suppress dry rot independent of any treatment effects on wound healing.

Figure 1. **Size of *Fusarium sambucinum* lesions on stored potatoes as influenced by various aromatic oil and ground spice treatments at 14 and 28 days after treatment.**



Sprout Suppression

After 14 days, the control treatments had the greatest sprout development (Fig. 2). Carvone and diallyl disulfide completely inhibited sprout growth over 14 days (Fig. 2). The garlic powder, peppermint oil and ground cloves treatments produced sprouts that were 61%, 66% and 77% the size of the controls, respectively. Ground dill and peppermint leaves and the clove oil produced limited sprout-inhibition (Fig. 2).

At 28 days after treatment, the controls again had the greatest sprout growth (Fig. 2). Potatoes treated with carvone and diallyl disulfide had sprouts that were only 9% and 47% of the control, respectively. Ground peppermint leaves moderately suppressed sprouting (65% of control) – yet this treatment had not suppressed sprouting over the first 14 days of the trial. This may reflect differences in the vigor or physiological age of the peppermint-treated potatoes sampled between 14 and 28 days (Fig. 2). Garlic powder also suppressed sprouting (78% of control). All the other treatments had limited sprout suppression (Fig. 2).

None of the treatments significantly altered the shape or color of the developing sprouts; although sprouts on the diallyl and carvone treatments were very short with no side shoots. The number of sprouts was closely correlated with the sprout weight. This indicates that the products were controlling both sprout numbers and their subsequent development (data not shown).

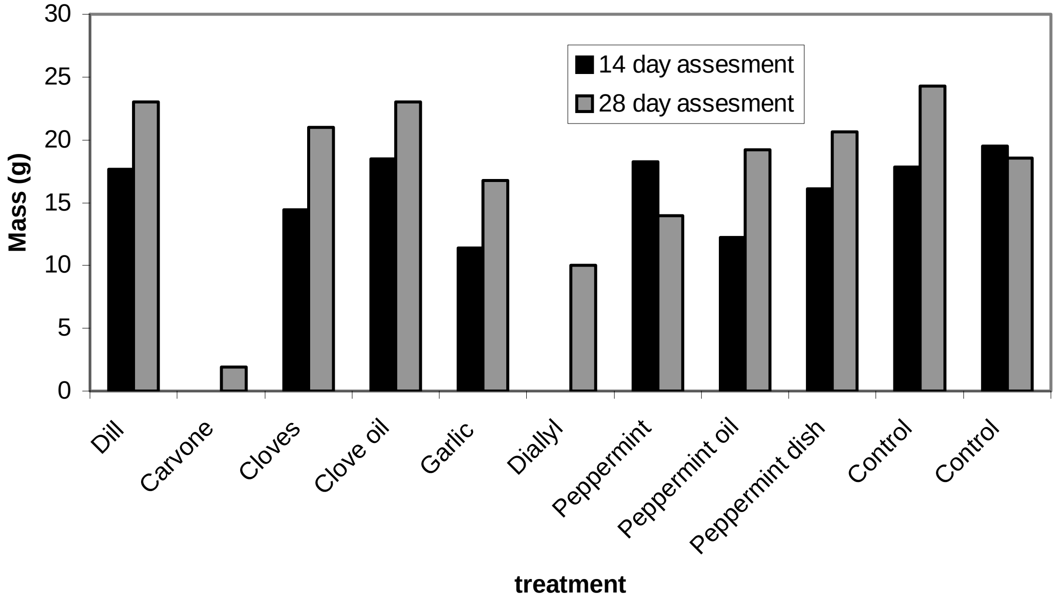


Figure 2. Sprout mass on stored potatoes as influenced by various aromatic oil and ground spice treatments at 14 and 28 days after treatment.

The relative efficacy of the ground unprocessed products versus the volatile essential oils extracted from these products as sprout inhibitors was variable. Ground cloves suppressed sprouting more than clove oil. Carvone and diallyl disulfide had greater sprout suppressing qualities than the ground products that contain these compounds (dill and garlic, respectively). However, both of the highly purified products have distinct limitations. Diallyl disulphide is very strong smelling and a skin and eye irritant. Similarly, R- (-)-carvone is a strong solvent and a skin irritant. Although garlic powder, peppermint oil and ground cloves have more limited ability to suppress sprouting, these products are inexpensive and safe to use and ingest; making them practical for the average small scale grower. None of the other treatments significantly suppressed sprouting at the treatment concentration used in this trial. It should be noted that the warm storage conditions used in this trial would have promoted sprouting – therefore a greater treatment effect on sprouting could be expected under more typical low temperature storage conditions.

Taste Test

At 14 days after initial treatment, potatoes treated with carvone received the lowest (poorest rating) (1.8) with a variation from 1-3 (Table1). These potatoes had an off flavor and most testers considered them to be bitter. R- (-)-carvone has been previously reported to leave a bitter taste on treated potatoes (Wikipedia, 2006). Potatoes treated with diallyl disulphide averaged 2.4 (dislike moderately), with a range of 1-5. Most testers found these potatoes to taste “garlicky”. Some samplers liked this taste, while others did not – this explains the wide range of scores. Potatoes treated with peppermint oil averaged 2.8 (neither liked nor disliked) with a variation from 1-4. Most testers found these to have no unusual flavor, however, one tester thought the potato tasted cool perhaps reflecting the presence of menthone. Another thought the peppermint treatments tasted bitter - peppermint oil also contains the bitter compound R-(-)-carvone. Potatoes treated with ground dill, ground cloves, clove oil, ground peppermint leaves and the controls were said to have no odd flavors. The highest rating was given to potatoes treated with garlic powder - averaging 4.6 (like extremely). This reflects certain peoples' appreciation of garlic (Table 1).

Table 1 **Assessment of Potato Flavor 14 Days after Treatment.**

Treatment	Tester 1	Tester 2	Tester 3	Tester 4	Tester 5	Range	Average
Dill	4	4	2	4	5	2 - 5	3.8
Carvone	1	2	1	2	3	1 - 3	1.8
Cloves	4	4	4	3	4	3 - 4	3.8
Clove oil	3	4	3	4	4	3 - 4	3.6
Garlic	5	4	4	5	5	4 - 5	4.6
Diallyl disiulfide	1	2	1	3	5	1 - 5	2.4
Peppermint	4	4	2	4	5	2 - 5	3.8
Peppermint oil	3	4	1	2	4	1 - 4	2.8
Peppermint dish	5	4	3	4	5	3 - 5	4.2
Control	2	4	4	4	4	2 - 4	3.6
Control	3	5	3	4	1	1 - 5	3.2

At 28 days after treatment, the carvone-treated potatoes again received the lowest taste scores (Table 2). All other treatments were rated on average as having a "neutral" taste. Potatoes treated with diallyl disulfide were thought by most to have a "garlicky" flavor; ground clove treatments were "bitter" or "musty", clove oil left a bad aftertaste and peppermint oil treatment was considered to be "moldy" or "musty". Overall taste ratings at 28 days were poorer than at 14 days. This was unexpected, as these potatoes had 14 days to dissipate any negative flavors caused by proximity to the sprout suppression agents. The decline in taste quality may be linked to the fact that after being stored for almost a month at warm temperatures many of the potatoes were sprouted and shrunken, with rotten spots. Sprouting and rots may explain some of the off-flavors noted in the 28 day sample.

CONCLUSION

Sprout and disease suppression during storage are ongoing concerns for potato growers. Although there are chemical control options for these problems, growers are seeking more effective and affordable options that are safe for the environment and the consumer. This project evaluated a number of "natural" products for their potential utility in protecting the quality of stored potatoes.

Table 2 **Assessment of Potato Flavor 28 Days after Treatment.**

Treatment	Tester 1	Tester 2	Tester 3	Tester 4	Tester 5	Range	Average
Dill	3	4	2	3	4	2 - 4	3.2
Carvone	1	4	3	1	2	1 - 4	2.2
Cloves	4	1	4	2	5	1 - 5	3.2
Clove oil	3	2	4	1	5	1 - 5	3
Garlic	3	5	4	3	2	2 - 5	3.4
Diallyl disulfide	3	2	5	1	2	1 - 5	2.6
Peppermint	4	1	1	3	5	1 - 5	2.8
Peppermint oil	4	2	2	2	4	2 - 4	2.8
Peppermint dish	3	3	4	3	2	2 - 4	3
Control	4	2	2	3	3	2 - 4	2.8
Control	4	3	4	3	4	3 - 4	3.6

Two highly concentrated and purified aromatic products (diallyl disulphide and carvone) produced a high level of sprout suppression even under conditions that encouraged sprouting. These treatments continued to retard sprout development well after the source chemicals were removed – but as the treatments wore off normal sprout development resumed. This suggests that these treatments could be used to suppress the sprouting of seed potatoes, without compromising the subsequent field performance of the seed. Both the carvone and diallyl disulfide had a lasting negative effect on flavor – this would be unacceptable in table potatoes, but would be of limited concern for seed. Garlic powder, peppermint oil and ground cloves showed more limited potential to suppress sprouting but they also had few negative effects on flavor. These products are readily available, and inexpensive, with a long history of safe use and consumption. These products would appear to have greater potential for use by small scale growers of table potatoes.

None of the treatments suppressed *F. sambucinum* growth – and some products actually appeared to increase this disease. Further analysis is needed to determine how, when and how much of these ‘natural’ products should be used in efforts to control dry rot. Longterm studies of these treatments under more typical storage temperatures are also needed.

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