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Changes in potato tuber sugar metabolism in response to natural sprout suppressive compounds

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ABSTRACT. The increased demand for potato by the Brazilian processing industry requires long term refrigerated storage, but after a few months, natural dormancy ends, and sprouts start to grow. Thus, sprout inhibitors are necessary to reduce the rate of growth and allow further storage. The purpose of research described here was to determine the effects clove and menthol essential oils have on the inhibition of sprout growth in non-dormant 'Asterix' tubers. Both eugenol and menthol treatments reduced the rate of sprout growth during storage at 8ºC for up to 50 days. Eugenol and menthol essential oils diminished the rate of accumulation of reducing sugar, which are responsible for browning of French fries. Color after frying was within acceptable levels when the tubers were treated with eugenol or menthol essential oils.

Keywords: *Solanum tuberosum* L.; clove oil; menthol; reducing sugars.

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Introduction

Potato is the fourth most consumed staple food in the world after rice, wheat and corn (*Associação Brasileira de Batata* [Abba], 2017). According to Food and Agriculture Organization of the United Nations (FAOSTAT, 2017), total area planted to potatoes in the world corresponds to 19.1 million hectares, with an overall production of 382 million tons. In Brazil, 3.7 million tons are produced in Brazil. Minas Gerais is the largest Brazilian potato producing state with an estimated annual production of over 1.9 million tons (*Instituto Brasileiro de Geografia e Estatística* [IBGE], 2017).

Although most potatoes are consumed by the fresh market, there is an increased demand by the food processing industry for a year-round supply of tubers. It is estimated that in 2017, the area devoted to potato growing for the industry increased by 11.8% compared to 2016, and equaled 20 thousand hectares (IBGE, 2017). The Brazilian market for frozen French fries and potato chips is growing at a rate of 15% per year. In order to maintain a constant flow of raw potatoes to meet this demand, it is necessary to store tubers for long periods.

After harvest, mature potato tubers enter a stage of deep dormancy for a certain period of time, which is defined as a developmental stage in which bud growth will not occur even under favorable growth conditions. The length of dormancy varies among cultivars and is affected by pre- and postharvest factors, but mainly by the temperature conditions during growth and storage (Muthoni, Kabira, Shimelis, & Melis, 2014). Control of sprouting is critical to potato storage because it leads to alterations in weight, increases in respiration, changes in texture, and nutritional value, softening, shrinkage, and the formation of toxic glycoalkaloids (Suttle, Campbell, & Olsen, 2016). Also, during sprouting there is a fast buildup of soluble sugars and increased activity of oxidative enzymes (Abbasi et al., 2015). These processes result in lower quality and intense browning of French fries and potato chips.

Potato dormancy is extended by lowering the temperature of storage. Additionally sprouting is controlled by applying maleic hydrazide or chlorpropham (CIPC, isopropyl 3-chlorocarbanilate). However, are increasing in the amount of CIPC that can be used due to the residue left on the tuber and environmental concerns (Kleinkopf, Oberg, & Olsen, 2003). Ethylene is a natural inhibitor of potato sprouting used in many countries where CIPC use is restricted or prohibited; however, ethylene induces darkening of fry products due to the accumulation of reducing sugars (Daniels-Lake, Pruski, & Prange, 2011).

Several natural compounds have been evaluated as potential suppressors of sprouting, including monoterpenes and aromatic compounds extracted from herbs and spices (Coleman, Lonergan, & Silk, 2001;

Elbashir, Ahmed, & Yousif, 2014; Abbasi et al., 2015). These volatile oils derived from plants, including peppermint and clove oils, are allowed by Federal organic standards, since their high volatility leaves little or no residue on the tubers (Frazier, Olsen, & Kleinkopf, 2004). Preliminary data show that vaporizing non-dormant potato tubers with essential oils is an alternative treatment for sprout inhibition to prolong the length that potatoes can be stored (Finger et al., 2018).

The efficacy of sprout suppressing volatile oils on long term cold stored potatoes of cultivar Asterix has not been evaluated before. The objectives of this work were to determine the efficacy of eugenol and menthol essential oils as sprout suppressants and their effects on tuber sugar metabolism.

Material and methods

Tubers of 'Asterix' from the Araxá region (19° 35' 34'' S 46° 56' 27'' O) were harvested after the plants had been killed with contact herbicide. Tubers weighing between 150-200 g were cured for ten days at 14ºC and 90% relative humidity for periderm maturation. Afterwards, the temperature was lowered 1 per day down to 8°C and 90-95% RH, and tubers were stored for three additional months. After dormancy was naturally broken, at early sprouting stage (from 1 to 2 mm long), the tubers were treated with eugenol and menthol at 50 solution in 95% ethanol. The essential oils were vaporized, according to the method described by Vaughn and Spencer (1991). A total of 35 tubers were placed in 65 L sealed containers containing a petri dish with 0.2 ml of solution, with final concentration of 100 mg kg^{-1} of potato. The oils were gradually released using a hot plate and after 2 hours, the tubers were removed and returned to the cold storage. Control tubers were treated with ethanol vapor for the same period.

All the analyses were performed on the day of treatment and after 10, 20, 30, 40, and 50 days. The number and length of sprouts were counted, considering the appearance of the 'eye' was evaluated, and the length sprouts were measured using a caliper. The values for the incidence of sprouting were calculated with the highest number of sprouts set to 100%.

Samples from tuber flesh were used for the quantification of soluble sugars. Total soluble sugars determination was carried out using the phenol-sulfuric acid method (Dubois Gilles, Hamilton, Rebers, & Smith, 1956). Reducing sugars were measured using dinitrosalicylic acid methodology (Gonçalves, Rodrigues-Jasso, Gomes, Teixeira, & Belo, 2010). Content of non-reducing sugars was determined as the difference between the total soluble sugars and the reducing sugars content.

To evaluate the color of French fries, samples were fried for 3 min. at 180°C. The final color of the fried product was determined based on the color standards defined by the United States Department of Agriculture (USDA, 1967) chart.

The experimental design was a completely randomized split-plot, with menthol and eugenol treatments as main plots and six sampling times as subplots. The experiment had four replicates per treatment with an experimental unit consisting of twenty potato tubers. The data were analyzed by variance and regression analysis using the Statistical Analysis System 9.1 (*Sistema para Análises Estatísticas e Genéticas* [Saeg], 2007). The choice of the regression model was based on the significance of the regression coefficients using the 5% probability level test in the coefficient of determination (R^2 = SQReg/SQtrat) and the biological behavior under study.

Results and discussion

Regardless of the treatment, the average number and length of sprouts per tuber increased in all treatments up to the 50th day of storage at 8ºC (Table 1). Eugenol and menthol had strong effects in reducing the sprout growth rate in non-dormant tubers of 'Asterix'. Tubers treated with menthol showed the least number and shortest sprouts, which were reduced by 25.3 and 61.8% respectively, compared to controls (Table 1). Eugenol, however, did not significantly reduce the number of sprouts; nevertheless, it was able to diminish sprout length by 43.9% compared to controls. The efficiency of clove oil (eugenol) or menthol (spearmint or peppermint) in burning the sprouts seems to be related to the source and tissue from which the essential oils were extracted, as well as the timing of application and potato cultivar (Kleinkopf et al., 2003; Gómez-Castillo, Cruz, Iguaz, Arroqui, & Vírsed, 2013; Abbasi et al., 2015).

Total soluble sugar increased throughout storage from an estimated average of 0.21% of the fresh weight at day zero (Figure 1). The content of sugars after 50 days of storage was 0.25% for the controls, 0.27% for the eugenol treated potatoes and 0.31% for the menthol treated potatoes (Figure 1). Thus, the highest

increase of sugars occurred with the menthol treated tubers (47.6%) and appears to be due to a lower consumption of soluble carbohydrates compared to control and eugenol treatments.

The changes in reducing sugars (RS) during storage followed different patterns over the 50 days of storage for each treatment (Figure 2). However, regardless of the treatment, there was a buildup of reducing sugars during storage. At the end of storage, tubers treated with menthol had the lowest content of reducing sugars (0.102%), while control tubers had 0.163% and the tubers treated with eugenol had 0.139% (Figure 2). The increase in reducing sugars occurs rapidly when the tubers are stored between 2 and 4ºC, but the amount of soluble sugar accumulated is also cultivar dependent (Sowokinos, 2001), which could explain the increase reducing sugars in the 'Asterix' tubers stored at 8ºC (Figure 2). Furthermore, other factors like aging, tuber maturity, and heat stress in the field contribute to the reducing sugar increase (Zommick, Knowles, Pavek, & Knowles, 2014).

The lowest content of reducing sugars at the end of storage occurred in tubers treated with menthol is related to the higher efficiency of menthol in controlling the growth of sprouts compared to eugenol treated and control tubers (Table 1 and Figure 2). Elbashir et al. (2014) determined that in the stored potato cultivars Diamant and Sinora, treatment with peppermint oil resulted in a lower content of reducing sugars compared to control tubers.

Table 1. Number (%) and length (mm) of potato sprouts from 'Asterix' treated with eugenol, menthol and control.

Treatments	Number of sprouts (%)	Sprout length (mm)
Control	80.28 A	3.14 A
Eugenol	76.26 A	1.76 B
Menthol	59.99 B	1.20 C

Means followed by the same letter in the column do not differ from each other by the Tukey test at the 5% probability level.

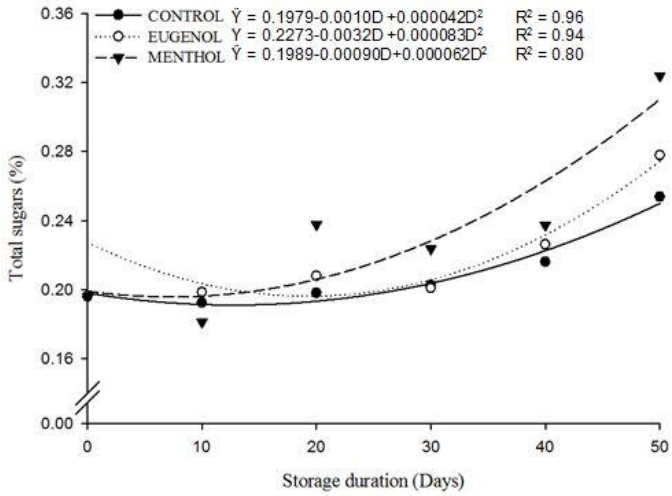

Figure 1. Total soluble sugars content (%) in 'Asterix' potato tubers as a function of storage duration (days) at 8°C.

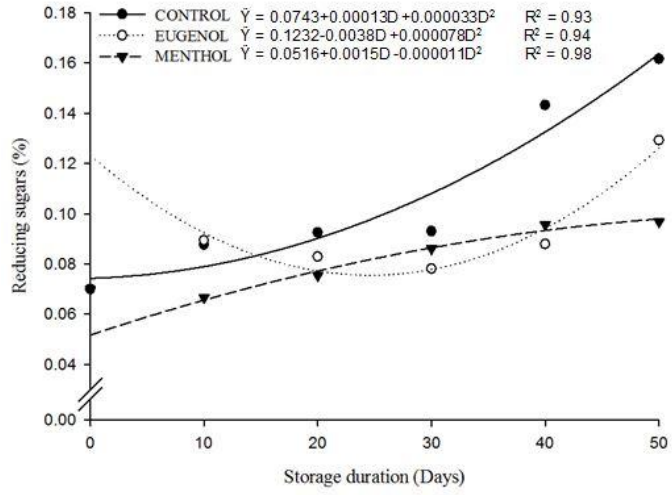

Figure 2. Reducing sugar content (%) in 'Asterix' potato tubers as a function of duration days (days) at 8°C.

Because of the reduced growth of sprouts observed on tubers treated with menthol, the demand for hexoses was less intense, resulting in higher accumulation of non-reducing sugars after 50 days of storage (Figure 3). Nevertheless, for the control tubers, which had a much higher rate of sprout growth (Table 1), the content of non-reducing sugar at the end of storage doubled compared to menthol treated tubers (Figure 3).

Throughout storage, the French fry color from control tubers was darker than that of tubers treated with eugenol or menthol (Figure 4). The lighter color ratings, 1 and 2, from eugenol and menthol treated tubers, is supported by the lower accumulation of reducing sugars over the fifty days of storage (Figure 2). The lower content of reducing sugars in the clove and menthol treated tubers, limited the Maillard reaction during frying, resulting in better quality of the final product (Figure 4).

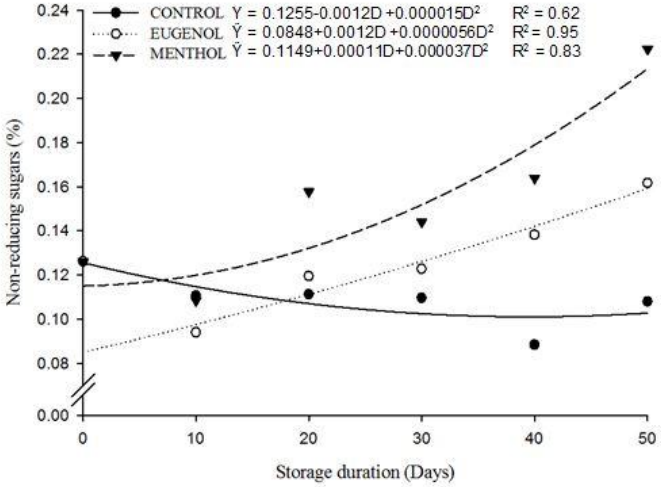

Figure 3. Non-reducing sugar content (%) in 'Asterix' potato tubers as a function of storage duration (days) at 8°C.

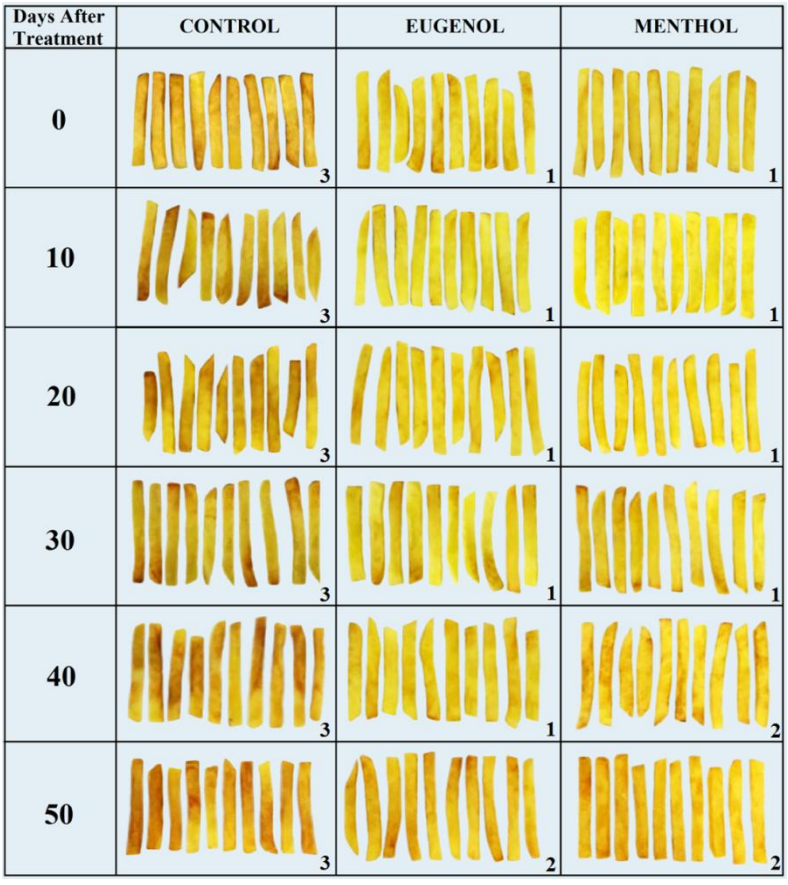

Figure 4. Appearance of French fries prepared from 'Asterix' potato treated with eugenol, menthol and control stored for 10, 20, 30, 40, and 50 days at 8ºC.

Conclusion

The essential oils, eugenol and menthol reduce the rate of sprout growth in non-dormant tubers, resulting in prolonged storage. Eugenol and menthol oils also decrease the rate of reducing sugar accumulation which is responsible for the browning of fried product.

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