



Inhibition of tuber sprouting in potato cultivars Asterix and Challenger by 1,4-dimethylnaphthalene

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ABSTRACT: *The aim of this study was to verify the efficiency of 1,4-dimethylnaphthalene in suppressing sprouting and the consequent maintenance of the quality of potato tubers of Asterix and Challenger cultivars, at different temperatures and storage regimes. Six treatments were tested, with and without 1,4-DNM, at temperatures of 8 °C and 20 °C. Assessments were made at 0, 45, 90, 135 and 180 days after application. The parameters evaluated were: number of sprouts, levels of total soluble sugars, levels of reducing and non-reducing sugars and coloration of potato strips after frying. The effects of 1,4-DNM on the quality control of potatoes resulted in sprout control and lower levels of total soluble sugars and reducing sugars, especially in the Challenger cultivar and at a temperature of 20 °C.*

Key words: stored potatoes, quality maintenance, sprout suppressor.

Inibição da brotação dos tubérculos das cultivares de batata Asterix e Challenger pelo 1,4-dimetilnaftaleno

RESUMO: *Objetivou-se com este estudo verificar a eficiência do 1,4-dimetilnaftaleno na supressão da brotação e a consequente manutenção da qualidade de tubérculos de batata das cultivares Asterix e Challenger, em diferentes temperaturas e tempos de armazenamento. Foram testados seis tratamentos, com e sem 1,4-DNM, nas temperaturas de 8 °C e 20 °C. As avaliações foram feitas aos 0, 45, 90, 135 e 180 dias após a aplicação. Os parâmetros avaliados foram: número de brotos, teores de açúcares solúveis totais, teores de açúcares redutores, e não redutores, e coloração dos palitos de batata após a fritura. Os efeitos do 1,4-DNM no controle da qualidade das batatas resultaram no controle da brotação e em menores teores de açúcares solúveis totais e de açúcares redutores, sobretudo na cultivar Challenger e à temperatura de 20 °C.*

Palavras-chave: batatas armazenadas, manutenção da qualidade, supressor da brotação.

INTRODUCTION

The potato is an important commodity in the world, being one of the most consumed foods, due to the diversity of forms of preparation and nutritional composition. The consumption of processed potatoes has been growing, due to changes in eating habits and the ease of semi-finished foods (FREITAS et al., 2006). Therefore, there was a need for cultivars with storage potential to supply the production chain throughout the year.

In order to prolong the storage period, the tubers are refrigerated. However, the temperature used in the refrigeration chambers should reduce sprouting, respiratory activity and the occurrence

of diseases, without promoting the accumulation of sugars in the tubers, which can lead to loss of quality in processing.

Sprouting despite refrigeration is not completely inhibited and remains a problem for industry, as it causes an increase in respiratory rate, loss of water through transpiration and an increase in the conversion of starch into reducing sugars, glucose and fructose (SINGH & KAUR, 2016). These physiological changes reduce the potential for storage and may promote the occurrence of the Maillard reaction during frying, which causes the fries to darken.

To avoid these problems, sprout suppressors such as chloropropane (CIPC) are

used (BLENKINSOP et al., 2002). This suppressor was widely used in the United States and in European countries, however, its use has suffered some limitations due to the possible accumulation of substances toxic to man and the environment (VIJAY et al., 2016). In Brazil, the use of CIPC is not registered. Therefore, several studies have been looking for alternatives to the use of CIPC. Among them we can mention 1,4-dimethylnaphthalene (1,4-DMN), which is a product of low environmental risk and human health, and can be used in stored potatoes (WEERD et al., 2010). Thus, the objective of this study was to determine the efficiency of the use of 1,4-DMN in suppressing sprouting and the consequent maintenance of the quality of potato tubers of Asterix and Challenger cultivars, at different temperatures and storage regimes.

MATERIALS AND METHODS

Experimental design and area characterization

The experiment was carried out in Split-plot, with the treatments in the plots (Ast/Control/8 °C; Ast/1,4-DMN/8 °C; Ast/Control/20 °C; Ast/1,4-DMN/20 °C; Cha/Control/8 °C; Cha/1,4-DMN/8 °C; Cha/Control/20 °C; Cha/1,4-DMN/20 °C) and in the subplots the evaluation times (0, 45, 90, 135 and 180 days), in the Fully Randomized Design with 4 repetitions. The potato tubers of the Asterix and Challenger cultivars came from the production area of Perdizes-MG (19° 21' 10" S and 47° 17' 34" W, altitude of 1000 m, Cwb classification according to Köppen and Geiger, characterized by rainy summer and winter dry). The tubers were planted in March and harvested in July 2017 and subsequently selected for the absence of mechanical damage, deformations and weight ranging from 90g and 250g.

Experimental procedure and analyses

The treatments were formed by 20 µL of 1,4-dimethylnaphthalene (1,4-DMN) (sigma) diluted in 15 ml of 95% alcohol (WEERD et al., 2010), applied on filter paper and placed in a petri dish heated for complete volatilization for 30 minutes inside hermetically sealed buckets containing 1 kilo of potato. The control consisted of 15 ml of 95% alcohol. After applying the treatments, the tubers were removed from the buckets and stored in incubators (BOD's), under temperatures of 8 °C and 20 °C and relative humidity of 85-90% in the absence of light. The analyzes were performed at 0, 45, 90, 135 and 180 days after application of the

treatments. The parameters evaluated were number of sprouts (determined by visual counting), total soluble sugar (TSS) content, reducing (RS) and non-reducing (N-RS) sugar content and color of the potato strips after frying.

Total soluble sugars

TSS quantification followed the Phenol-sulfuric method (DUBOIS et al., 1956), where the curve was calibrated, based on the standard 1% sucrose solution. Aliquots of 250 µL of the samples were pipetted into a glass tube, plus 250 µL of 5% phenol, and 1.25 mL of concentrated sulfuric acid. The material was in a thermostatic bath at 30 °C for 20 minutes. The reading was performed on a spectrophotometer, with a wavelength (λ) of 490 nm. The result was expressed in% TSS.

Reducing and non-reducing sugars

The determination of RS was performed according to the Somogy-Nelson methodology (NELSON, 1944), where the curve was calibrated, based on the standard 1% glucose solution. 200 µL aliquots of the sample were added to 200 µL of Nelson's reagent. The material was left for 15 minutes in boiling water followed by cooling in water. 200 µL of the arsenomolybdic solution and 600 µL of water were added. The readings were performed on a spectrophotometer, with a wavelength (λ) of 540 nm and the result was expressed in% RS. The quantification of N-RS was determined from the difference in TSS and RS content, expressed in% N-RS.

Coloring of potato strips after frying

The stored tubers were peeled, sliced into strips and fried in an electric fryer. The frying of the potatoes was carried out at 180 °C for 3 minutes. The color of the French fries was determined visually, by comparison, following the scale of notes determined by the United States Department of Agriculture (USDA, 1967) and the Brazilian potato industry whose color scale ranges from 1 (lighter) to 5 (darker).

Data analysis

The data obtained were analyzed using analysis of variance and regression using the System of Statistical and Genetic Analysis (SAEG, 2007), and the means compared by the Tukey test ($P \leq 0.05$). The regression model was chosen according to the significance of the regression coefficients, using the t test ($P \leq 0.05$) and the determination coefficient ($R^2 = \text{SQReg} / \text{SQtrat}$).

RESULTS AND DISCUSSION

The lowest storage temperature (8 °C) and the application of 1,4-DMN did not cause a reduction in the number of sprouts of the Asterix cultivar in any of the evaluation periods (Table 1). However, in the Challenger cultivar there was a reduction in the number of sprouts with the reduction of temperature and with the application of 1,4-DMN at 135 and 180 days of storage (Table 1). Indicating that the effect of temperature and sprout suppressor varies with the cultivar. The mode of action of 1,4-DMN is not yet clearly understood, but it has been suggested that the natural dormancy period is extended through the regulation of phytohormones (CAMPBELL et al., 2010).

The number of sprouts increased with the storage time in both cultivars (Figures 1A and 1B), which was expected for this characteristic. However, this increase was small compared to the extended storage period (180 days) (Figures 1A and 1B). In the Asterix cultivar, the average was 8 sprouts per tuber (Figure 1A). Whereas in the 'Challenger' the average was 5 sprouts per tuber, with the exception of the control at 20 °C, in which the average was around 25 sprouts (Figure 1B). The increase in the number of sprouts is accompanied by metabolic changes, including increased respiration, loss of mass, remobilization of starch and increase in the content of soluble sugars (FERREIRA et al., 2017).

In the Challenger cultivar, higher levels of TSS were observed in the tubers at 8 °C at 135 and 180 days (Table 2). This temperature

was sufficient to induce the accumulation of sugars in this cultivar. When potato tubers are exposed to low temperatures, there is a reduction in the starch pool, due to the inhibition of their synthesis enzymes, such as AGPase and GBSS and increased transcription of the α -amylase genes, promoting starch degradation in sucrose (N-RS) which is broken down into glucose and fructose (RS) by vacuolar acid invertase in potato tubers (WIBERLEY-BRADFORD et al., 2016). TSS being the sum of these sugars.

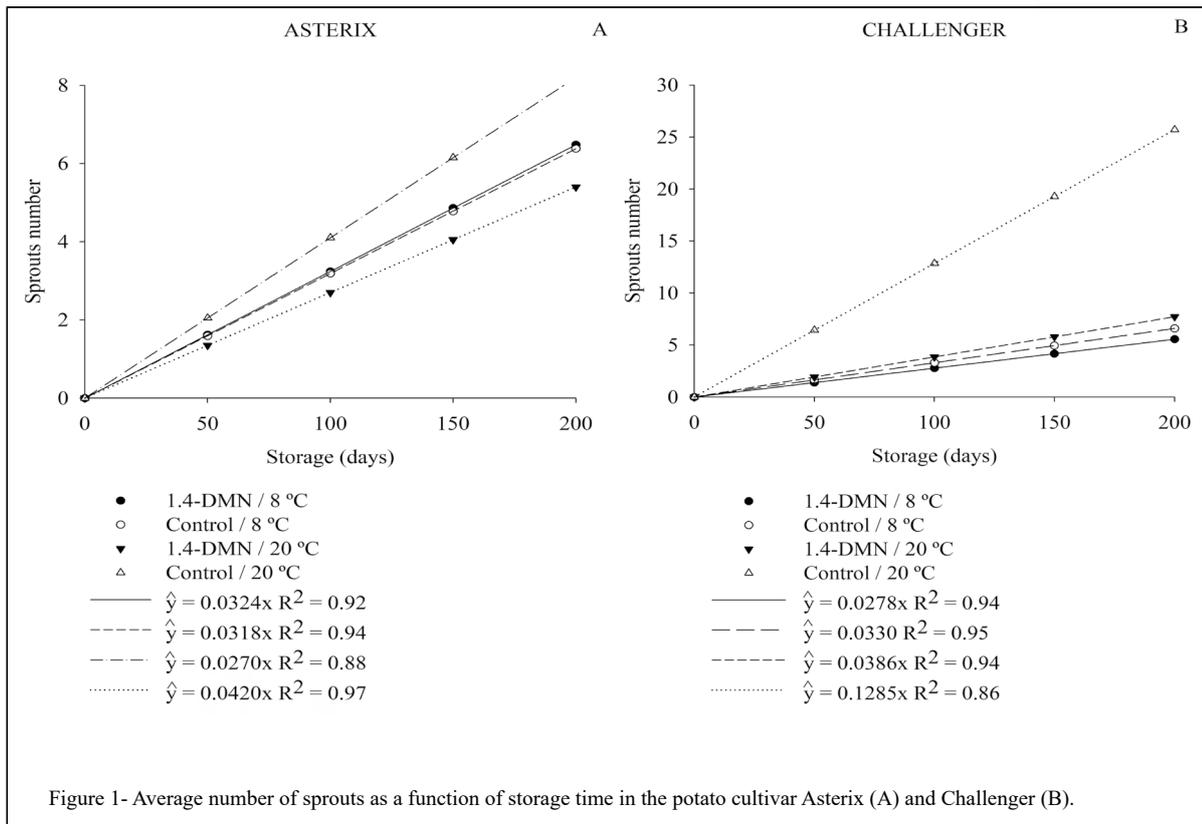
Lower TSS levels were found in the tubers of the Challenger cultivar treated with 1,4-DMN at 8 °C for 45 days and at 20 °C for 180 days (Table 2). While, in the Asterix cultivar, the tubers treated with the inhibitor had lower TSS content at 135 days at 8 °C and at 180 days at 20 °C, showing a beneficial effect of 1,4-DMN in reducing soluble sugar levels (Table 2).

For the Asterix cultivar, it was found that the lowest storage temperature (8 °C) resulted in higher levels of RS in most of the periods evaluated, in both conditions of use or not of 1,4-DMN (Table 2). For the Challenger cultivar, this effect was less evident, with a significant effect only observed in the absence of 1,4-DMN at 45 days (Table 2). There was no effect of the use of 1,4-DMN on the RS levels in the Asterix cultivar. For the Challenger cultivar, the only difference was at 45 days with storage at 8 °C, under these conditions the use of 1,4-DMN resulted in a lower mean of RS (Table 2).

Table 1 - Medium values for the sprouts number in Asterix (Ast) and Challenger (Cha) cultivars potato tubers.

Treatment	Sprouts number				
	0 day	45 days	90 days	135 days	180 days
1-Ast/Control/8 °C	0.00 A	0.00 A	3.37 A	4.94 B	5.56 BC
2-Ast/1,4-DMN/8 °C	0.00 A	0.00 A	3.44 A	4.62 B	6.25 BC
3-Ast/Control/20 °C	0.00 A	1.75 A	3.50 A	3.00 B	4.69 C
4-Ast/1,4-DMN/20 °C	0.00 A	0.87 A	4.12 A	5.69 B	7.31 BC
5-Cha/Control/8 °C	0.00 A	0.00 A	2.00 A	4.12 B	5.31 BC
6-Cha/1,4-DMN/8 °C	0.00 A	0.00 A	2.68 A	4.56 B	6.37 BC
7-Cha/Control/20 °C	0.00 A	0.00 A	3.19 A	4.69 B	7.94 B
8-Cha/1,4-DMN/20 °C	0.00 A	0.25 A	4.31 A	21.81 A	24.81 A

Means followed by the same letter, in the same column, do not differ at 5% probability by the Turkey test.



Significant effects of storage temperature on N-RS levels were only observed in the last evaluation period (180 days) for both cultivars. For the Asterix cultivar, higher averages were observed in the treatment with application of 1.4-DMN at 20 °C. While the Challenger cultivar showed higher averages for N-RS in the control treatment at 20 °C (Table 2). In the Asterix cultivar, a higher N-RS content was observed with the use of 1.4-DMN at 20 °C and at 180 days. In the 'Challenger', a higher N-RS content was obtained in the absence of 1.4-DMN (Table 2). Factors such as temperature, storage time, cultivar, degree of tuber maturation and sprout growth, can influence sugar levels due to the occurrence of carbohydrate catabolism and / or enzyme activities, which reduce the amounts of starch and increase in sugars (SINGH & KAUR., 2016).

Both cultivars showed, after frying on day zero, scale 2 (USDA) darkening. Coloring is an important quality aspect of potato chip

processing. During the hydrolysis of the starch, part of the sugar produced can be used to respiration the tuber before the frying process. Depending on storage conditions, such as at low temperatures, the phenomenon of sweetening occurs, which consists of the formation and accumulation of reducing sugars, glucose and fructose, which are undesirable (SINGH & KAUR, 2016).

During frying, a high temperature condition, the contact of reducing sugars with free amino acids and the undesirable Maillard reaction may occur. This reaction causes the formation of melanoidins, pigments that result in brownish brown fries. In addition to the depreciation of the visual aspect, there is the accumulation of acrylamide, a compound related to the development of cancer (WIBERLEY-BRADFORD et al., 2016).

For the Asterix cultivar, the presence of 1.4-DMN was efficient in maintaining the visual

Table 2 - Total soluble sugars (TSS), Reducing sugars (RS) and Non-reducing sugars (N-RS) in Asterix (Ast) and Challenger (Cha) cultivars potato tubers.

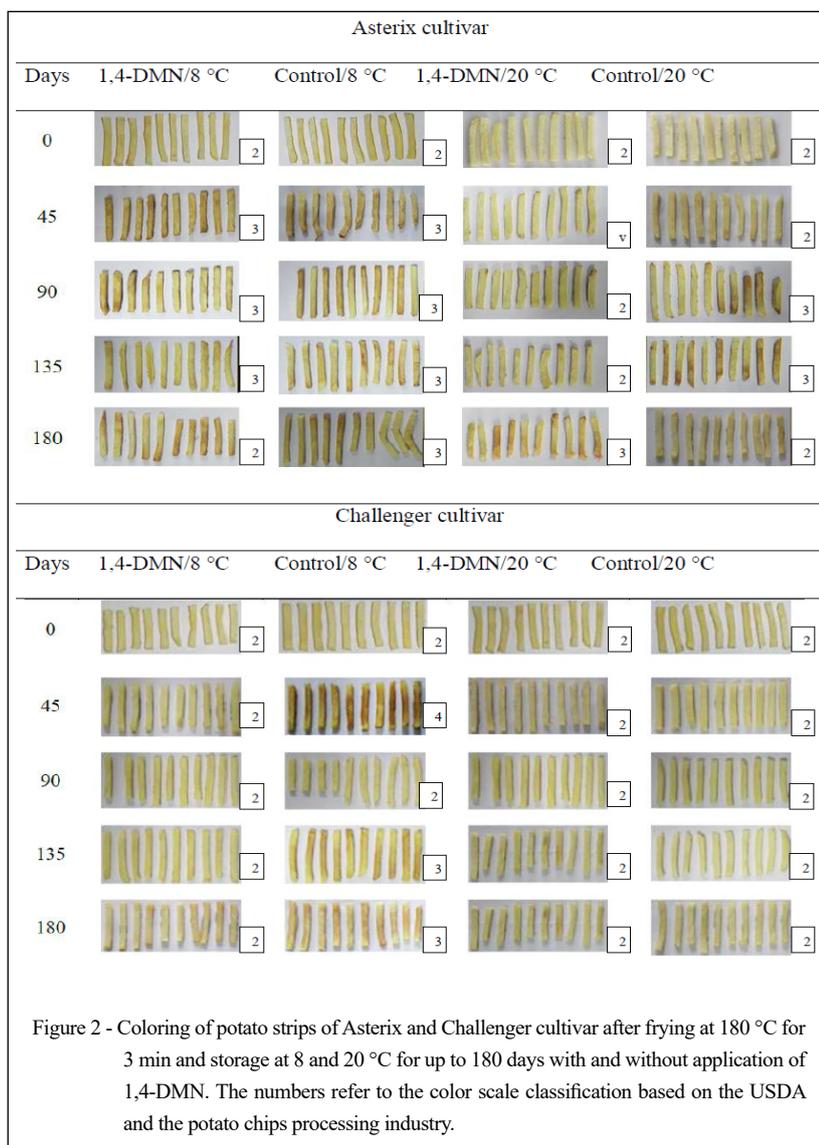
-----Total soluble sugars (TSS)-----					
Treatment	0 day	45 days	90 days	135 days	180 days
1-Ast/1,4-DMN /8 °C	0.102 A	0.301 ABC	0.518 A	0.372 BC	0.513 BC
2-Ast/Control/8 °C	0.088 A	0.376 AB	0.427 AB	0.636 A	0.533 BC
3-Ast/1,4-DMN/20 °C	0.099 A	0.137 BC	0.217 BC	0.202 BC	0.732 B
4-Ast/Control/20 °C	0.078 A	0.203 ABC	0.244 BC	0.338 BC	0.420 CD
5-Cha/1,4-DMN/8 °C	0.123 A	0.137 BC	0.233 BC	0.263 BC	0.179 DE
6-Cha/Control/8 °C	0.080 A	0.452 A	0.331 ABC	0.433 AB	0.159 E
7-Cha/1,4-DMN/20 °C	0.121 A	0.109 C	0.191 BC	0.169 C	0.519 BC
8-Cha/Control/20 °C	0.081 A	0.130 BC	0.170 C	0.174 C	1.007 A
-----Reducing sugars (RS)-----					
Treatment	0 day	45 days	90 days	135 days	180 days
1-Ast/1,4-DMN /8 °C	0.031A	0.253 A	0.385 A	0.275 AB	0.266 AB
2-Ast/Control/8 °C	0.032 A	0.324 A	0.248 AB	0.384 A	0.359 A
3-Ast/1,4-DMN/20 °C	0.030 A	0.077 B	0.111 BC	0.097 C	0.221 ABC
4-Ast/Control/20 °C	0.032 A	0.081 B	0.083 C	0.125 BC	0.177 BCD
5-Cha/1,4-DMN/8 °C	0.032 A	0.056 B	0.106 BC	0.058 C	0.083 CD
6-Cha/Control/8 °C	0.028 A	0.242 A	0.155 BC	0.155 BC	0.038 D
7-Cha/1,4-DMN/20 °C	0.032 A	0.041 B	0.027 C	0.042 C	0.062 D
8-Cha/Control/20 °C	0.029 A	0.027 B	0.030 C	0.063 C	0.112 BCD
-----Non-reducing sugars (N-RS)-----					
Treatment	0 day	45 days	90 days	135 days	180 days
1-Ast/1,4-DMN /8 °C	0.070A	0.047 A	0.133 A	0.108 A	0.247 C
2-Ast/Control/8 °C	0.055 A	0.052 A	0.179 A	0.251 A	0.173 C
3-Ast/1,4-DMN/20 °C	0.069 A	0.060 A	0.106 A	0.104 A	0.510 B
4-Ast/Control/20 °C	0.046 A	0.121 A	0.160 A	0.212 A	0.243 C
5-Cha/1,4-DMN/8 °C	0.090 A	0.081 A	0.127 A	0.204 A	0.096 C
6-Cha/Control/8 °C	0.051 A	0.209 A	0.175 A	0.278 A	0.121 C
7-Cha/1,4-DMN/20 °C	0.088 A	0.068 A	0.164 A	0.126 A	0.457 B
8-Cha/Control/20 °C	0.051 A	0.103 A	0.140 A	0.111 A	0.895 A

Means followed by the same letter, in the same column, do not differ at 5% probability by the Turkey test.

appearance of the fries, at 20 °C, in the periods of 45, 90 and 135 days (Figure 2). Whereas, for the cultivar Challenger, the presence of 1.4-DMN, 8 °C, was efficient in reducing the reducing sugar levels (Figure 2), for the period of 45 days, which gives better quality to the potatoes after frying, in relation to their respective control.

CONCLUSION

The application of 1.4-DMN does not control the sprouting of stored tubers of cultivar Asterix. In cultivar Challenger, the application of 1.4-DMN controls sprouting and reduces the levels of total soluble sugars and reducing sugars at a temperature of 20 °C.



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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the

writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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