*Original Research Article*

Influence of Potassium Fertilisation on the Induction of Phenolic Markers of Resistance to Internal Browning in Pineapple (*Ananas comosus* L. Merr.)

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ABSTRACT

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| The post-harvest quality of pineapple is often compromised by physiological disorders, including internal browning, which affects not only the appearance of the fruit but also its nutritional quality and consumer acceptability. Internal browning is a major limiting factor in the post-harvest quality of pineapple, negatively impacting its marketability. This study aims to evaluate the effect of potassium fertilisation on the induction of phenolic compounds associated with resistance to browning. The experimental field was established on sandy and low-fertility land at the Nangui Abrogoua University experimental farm (5º23'21''N; 4º11'09''W), Abidjan-Côte d'Ivoire. Four levels of potassium supply (20, 28, 34 and 40 g K₂O/plant) were tested on MD2 and smooth Cayenne varieties. After harvest, fruits were stored at a low temperature of 10°C for 14 days, then at 22°C for 5 days before browning symptoms were assessed. Phenolic metabolites were then characterised using ultra-high performance liquid chromatography (U-HPLC). After preservation, samples of the pulp from each fruit were taken in “dice” form and placed in a freeze-dryer (Alpha Christ 1-2 plus) for 2 days. Samples were analysed on two coupled U-HPLC chains. The results showed that an increasing amount of potassium fertiliser in pineapple cultivation significantly reduced the severity of fruit browning. Symptoms disappear from 34 g K₂O/plant. Analysis of phenolic profiles reveals increased biosynthesis of flavonoids such as rutin, myricetin, genistin, gallic acid, protocatechic acid, genistein, quercetin, kaempferol, taxifolin, epicatechin and quercitrin. These are identified as markers linked to resistance to internal rusting in pineapple. Furthermore, the MD2 variety proved more tolerant to browning than the smooth Cayenne, probably due to an initially richer phenolic composition. These results indicate that optimising potassium intake could be an effective strategy for limiting post-harvest losses and improving the quality of fruit intended for export. A better understanding of the interactions between mineral nutrition and phenol metabolism could lead to the development of optimised cultivation strategies for the pineapple industry. Further studies on the enzymatic mechanisms involved in internal browning will allow refining these recommendations and optimising post-harvest fruit management. |

*Keywords: post-harvest, storage, potassium amendment, phenolic markers, flavonoids, secondary metabolites*

1. INTRODUCTION

Pineapple (*Ananas comosus* (L) M.) is a monocotyledonous, herbaceous, of the Bromeliad family. It is the eleventh most cultivated fruit, with a global production of 25.8 million tonnes in 2016 (Fulgence et al.,2021; Marc et al.,2025). In Côte d'Ivoire, pineapple ranks third among export fruit crops, after banana and mango (Assocle, 2024). Pineapple is therefore an important source of foreign currency, providing a livelihood for many producers. Indeed, pineapple exports generate more than FCFA 45 billion a year for the Ivorian state and contribute 0.6% of national GDP and 1.6% of agricultural GDP (MINAGRI, 2018). However, the 1980s marked the start of a long crisis in the pineapple sector, which worsened after the political crisis of 2002 (Yapo, 2013). Côte d'Ivoire's exports to the European market fell drastically from 213,620 tons in 1999 to 18,516 tons in 2024 (Assocle, 2024). This decline is strongly linked to soil depletion due to monoculture, the high level of chemical residues, acidity and internal browning of the fruit, etc. (Marceline et al., 2020). Postharvest internal browning (PIB) in pineapple fruit is induced by low-temperature storage (Sangsoy et al.,2024; Lai et al.,2024)**.** However, internal browning is one of the most important causes of this crisis in the pineapple sector (Coulibaly et al., 2017; Kouadio et al., 2025). Indeed, the post-harvest quality of pineapple is often compromised by physiological disorders, including internal browning, which affects not only the appearance of the fruit but also its nutritional quality and consumer acceptability (Xinhua et al., 2011; Hong et al., 2013). Internal browning of pineapple fruit depends on several factors such as planting, cultivation techniques and, above all, post-harvest preservation procedures (low-temperature storage during export). Given the huge economic losses associated with internal browning when fresh pineapple is exported, work highlighting the influence of potassium amendment in controlling this phenomenon has been carried out (Coulibaly et al., 2019; Kouadio et al., 2025). Indeed, pineapple plants absorb the nutrients required for their various physiological functions (growth, development, reproduction) (PIP, 2009). Potassium, absorbed by plants in its ionic form K+, regulates osmotic pressure and the opening and closing of stomata (MAPM/DERD, 2007; Belfakih et al., 2013). Potassium (K) is an integral part of [plant nutrition](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/plant-nutrition), playing essential roles in plant [growth and development](https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/growth-development-and-aging). Despite its abundance in soils, the limitedly available form of K ion (K+) for plant uptake is a critical factor for agricultural production (Mostofa et al.,2022)**.**  In addition, it is used as a cofactor in enzymatic and biochemical reactions (Belfakih et al., 2013). Furthermore, the work of Gomes et al. (2004) reported that an appropriate concentration of potassium in the soil is necessary for good-quality pineapple production. Thus, according to Antonio et al. (2005), the application of a large quantity of potassium in pineapple inhibits the internal browning of the fruit at maturity. In view of the above, the study of the underlying mechanisms and the development of effective strategies to prevent internal browning are essential to improve fruit quality during storage. The aim of this study is to evaluate the impact of potassium fertilisation on the induction of phenolic markers linked to resistance to internal fruit browning during post-harvest storage in pineapple.

2. material and methods

**2.1 Plant material**

The plant material consisted of pineapple shoots of the MD2 and smooth Cayenne (*Ananas comosus* L. Merr.) varieties, from a farmers' plot in Bonoua (Côte d'Ivoire). Smooth Cayenne shows a high susceptibility to browning compared with the MD2 variety (Botondi et al., 2015; Zhou et al., 2020).

**2.2 Methods**

**2.2.1 Study site and culture establishment**

The experimental field was established on sandy and low-fertility land at the Nangui Abrogoua University experimental farm (5º23'21''N; 4º11'09''W), Abidjan-Côte d'Ivoire (Yéo, 2023). After chemical analysis and soil fumigation treatment, ridges measuring 6.5 m × 1 m were made over an area of 150 m2. Each ridge was amended with 1 kg of dolomite and 500 g of calcium triphosphate. For each pineapple variety, plants weighing around 400 g were transplanted onto the ridges in double rows in a block design. Each treatment of 12 plants was repeated three times. Plant spacing was 25 cm in the row and 40 cm between rows. Ridges were spaced 90 cm apart.

**2.2.2 Phytosanitary treatment**

Phytosanitary treatments were carried out using an insecticide based on chlorpyrifosetyl 480 g/L at 2 L/ha and a fungicide (fosetyl aluminium) at 7 kg/ha. A nematicide (Némacur® 40 EC, based on Fenamiphos 40% w/v) at a concentration of 25 mL/L was also applied at the foot of the plants at a rate of 6 mL of spray per plant. All these treatments were carried out from the second month of cultivation and/or the fifth month as required.

**2.2.3 Application of different potassium concentrations**

To evaluate the influence of potassium fertilisation on the resistance to browning of two pineapple varieties (MD2 and smooth Cayenne), four fertilisation modalities (T0, T1, T2 and T3) were applied in increasing doses of potash. All treatments received similar amounts of urea, complete fertiliser and trace elements. Only the quantities of potash varied between treatments. Each plant received 16 g of urea (46% nitrogen) and 10 g of a complete fertiliser composed of 11% nitrogen (N), 5% phosphorus (P2O5), 27% potassium oxide (K2O), 15% sulfur (S) and 5% magnesium oxide (MgO). This fertiliser was enriched with trace elements, including boron (0.51 g/L), EDTA chelated copper (0.25 g/L), EDTA chelated iron (0.16 g/L), molybdenum (0.05 g/L), zinc (0.47 g/L) and EDTA chelated manganese (0.51 g/L).

Potash application rates varied according to treatment modality. The T0 control treatment, corresponding to farmers' current practice, received 20 g K2O per plant in the form of standard potassium sulfate (50% potassium oxide and 17% sulfur) (Ouattara et al., 2014). Treatments T1, T2 and T3 received 28 g, 34 g and 40 g K2O per plant, respectively. Fertilisers were applied to plants during their vegetative phase according to a schedule of four applications, made in the 2nd, 4th, 6th and 7th months of cultivation. The first application was made in solid form, by granular deposition in the axils of the basilar leaves. The following three applications were made in liquid form, by fogging all the leaves.

**2.2.4 Harvesting and postharvest treatments of the fruits**

After nine months of cultivation, flower induction treatment (FIT) was carried out to homogenise plant flowering (PIP, 2009). FIT was carried out when the D leaf reached 70 g. The product used was calcium carbide prepared at a concentration of 2 kg in 200 L of water. A volume of 50 mL of the liquid obtained was immediately poured into the heart of each plant, using an adjustable-flow backpack sprayer. This operation was repeated 48 hours later to ensure successful flower induction. For each variety, a batch of 3 harvested fruits was made up for each treatment. The batches were marked T0, T1, T2, T3. A fungicidal solution (benomyl) was applied to the crown of the fruit before storage at 10°C for 14 days (time required for export). The fruit was then sampled and stored again at 22°C for 5 days (marketing time) before being used for the various analyses.

**2.2.5 Sample preparation**

After preservation, samples of the pulp from each fruit were taken in “dice” form and placed in a freeze-dryer (Alpha Christ 1-2 plus) for 2 days. The resulting lyophilizate, which is easily preserved over the long term, was used for the various analyses.

**2.2.6 Qualitative analysis of phenolic compounds by high-performance liquid chromatography**

**Conditions for U-HPLC analysis:** Ultra-high-performance liquid chromatography (U-HPLC) analysis was carried out using the method of Verdu (2013). Samples were analysed on two coupled U-HPLC chains. The first chain is an Agilent LC (1100 series, UV-Visible U-HPLC system, Germany), equipped with a degasser (G1322A), automatic injector, high-pressure binary pump and column compartment (G1316A). The second chain is an Agilent LC 1200 series and includes a quaternary pump (G1311A) linked to an iodine bar detector (G1315A). U-HPLC analysis is controlled by a computer running a workstation operating system and a chromatogram display managed by ORACLE VM VirtualBox chromatography software running under WinXPSP3. The entire U-HPLC system was coupled to a nuclear magnetic resonance spectrometer (Bruker Avance III) with an operating frequency of 600 MHz for one proton. Separation of phenolic compounds was carried out on a reverse-phase C18 silica column (Zorbax Eclipse XDB-C18, 150 x 4.6 mm, 5 μm, Agilent). Elution was performed with a binary gradient composed of:

- solvent A: ultrapure water / 0.25% (99/1, v/v) trifluoroacetic acid

- solvent B: acetonitrile / 0.25% trifluoroacetic acid (99/1, v/v)

The elution gradient profile is shown in Table 1.

**Table 1: Elution gradient profile for phenolic compounds.**

|  |  |  |
| --- | --- | --- |
| Time (min)  | Solvent A (%)  | Solvent B (%) |
| 0-5 | 95 | 5 |
| 5-10 | 80 | 20 |
| 10-15 | 70 | 30 |
| 15-20 | 60 | 40 |
| 20-22 | 90 | 10 |
| 22-25 | 95 | 5 |

*TFA: trifluoroacetic acid; solvent A (0.25% TFA in ultrapure water); solvent B (0.25% TFA in acetonitrile)*

**Separation and identification of phenolic compounds by analytical U-HPLC:** Separation of phenolic compounds was carried out in a computer-controlled U-HPLC under a pressure of 550 to 1500 bar. An aliquot of 10 μL of purified phenolic compound extract was injected into the U-HPLC at a flow rate of 1.3 mL/min. Separated compounds (peaks) were revealed at 280 nm. The detection limit of the compounds was set at an absorbance of 30 mA. Below this value, the compound was considered undetected. The various peaks were obtained and then identified using a reference library of phenolic compounds. This library contains retention times and nuclear magnetic resonance (NMR) spectra of phenolic compounds. It was previously developed from commercially available phenolic compounds likely to be present in pineapple (Belhadj et al., 2008; Faurie et al., 2009; Wei et al., 2016; Guerrero et al., 2020)

3. results

**3.1 Impact of potassium fertilisation on the appearance of pineapple pulp**

Pulp appearance shows that the severity of browning symptoms is inversely proportional to the amount of potassium applied to the plants. Internal pulp browning is more intense in smooth Cayenne pineapple than in MD2. No translucency symptoms were observed in MD2 pineapple. On the other hand, in smooth Cayenne, this symptom was observed in treatments T1 and T2. Analysis of the results suggests that pulp translucency precedes browning (Fig. 1).



**Fig. 1. Evolution of internal browning symptoms in MD2 and smooth Cayenne pineapples as a function of the potassium concentration applied to the soil.**

*MT0 (MD2 control fruits from 20 g K2O/plant treatment); MT1 (MD2 fruits from 28 g K2O/plant treatment); MT2 (MD2 fruits from 34 g K2O/plant treatment); MT3 (MD2 fruits from 40 g K2O/plant treatment); CT0 (smooth Cayenne control fruits from 20 g K2O/plant treatment); CT1 (fruits of the smooth Cayenne variety from the 28 g K2O/plant treatment); CT2 (fruits of the smooth Cayenne variety from the 34 g K2O/plant treatment); CT3 (fruits of the smooth Cayenne variety from the 40 g K2O/plant treatment); a (Browning symptom); b (Translucency symptom).*

**3.2 Qualitative analysis of phenolic compounds**

Analysis of the samples by ultra-high-performance chromatography (U-HPLC) was used to identify the phenolic compounds present in pineapple pulp as a function of the different potassium treatments. Before sample analysis, 16 phenolic standards were chromatographed under the same conditions as the samples to determine their different retention times (Table 2).

Thus, by comparing the retention time of each chromatogram with those of the standards, the various phenolic compounds could be identified. This was made possible by a reference library of commercially available or purified phenolic compounds. This contains retention times and NMR spectra of phenolic standards.

**Table 2: Retention times of phenolic compounds isolated by U-HPLC at 284 nm**

|  |  |  |
| --- | --- | --- |
| Numbers | Phenolic compounds  | Retention times (min) |
| 1 | Arbutin | 04,036 |
| 2 | Gentisic acid | 11,500 |
| 3 | Quercitrin | 11,832 |
| 4 | Chlorogenic acid | 12,167 |
| 5 | Syringic acid | 13,664 |
| 6 | Epicatechin | 14,168 |
| 7 | Isoferulic acid | 18,333 |
| 8 | O-coumaric acid | 21,167 |
| 9 | Rutin | 23,834 |
| 10 | Myricetin | 32294 |
| 11 | Genistin | 32,621 |
| 12 | Gallic acid | 07,412 |
| 13 | Protocatechic acid | 08,277 |
| 14 | Genistein | 09,963 |
| 15 | Quercetin | 28,645 |
| 16 | Kaempferol | 29,768 |

**3.3 Identification of phenolic compounds extracted from fruits from different potassium treatments after preservation in the smooth Cayenne variety**

Chromatographic analysis showed the presence of eight phenolic compounds in the control fruit (T0), nine in the fruit from treatment T1, 14 in the fruit from treatment T2 and 16 in the fruit from treatment T3. Compounds (1) to (8) were revealed in the fruit from all treatments. However, a decrease in the peak of compounds (7) and (8) was observed as the amount of potassium applied increased. After treatment T1, there was de novo synthesis of compound (9), followed by treatment T2, which induced synthesis of compounds (10 to 14). In addition to these 14 compounds, T3 treatment induced compounds (15) and (16) (Fig. 2).

The compounds were identified as: arbutin (1), gentisic acid (2), quercitrin acid (3), chlorogenic acid (4), syringic acid (5), epicatechin (6), isoferulic acid (7), o-coumaric acid (8), rutin (9), myricetin (10), genistin (11), gallic acid (12), protocatechic acid (13), genistein (14), quercetin (15) and kaempferol (16).

**Comparison of the phenolic content of fruits from different potassium treatments of the smooth Cayenne variety:** Compound (9) was synthesised in fruit from treatment T1 (28 g K2O/plant). Compounds (10), (11), (12), (13) and (14) were synthesised in fruit from treatments T2 (34 g K2O/plant) and T3 (40 g K2O/plant). However, only fruits from treatment T3 were able to induce the synthesis of compounds (15) and (16).



**Fig. 2. Chromatographic profile of phenolic compounds extracted from pulps of the smooth Cayenne pineapple variety revealed at 284 nm as a function of potassium treatments**

*1: arbutin (4.036 min); 2: gentisic acid (11.500 min); 3: quercitrin (11.832 min); 4: chlorogenic acid (12.167 min); 5: syringic acid (13.664 min); 6: epicatechin (14.168 min); 7: isoferulic acid (18.333 min); 8: o-coumaric acid (21.167 min); 9: rutin (23.834 min); 10: myricetin (32.294 min); 11: genistin (32.621 min); 12: gallic acid (7.412 min); 13: protocatechic acid (8.277 min); 14: genistein (9.963 min); 15: quercetin (28.645 min); 16: kaempferol (29.768 min); Treatment 1 (28 g K2O/plant); Treatment 2 (34 g K2O/plant); Treatment 3 (40 g K2O/plant).*

**3.4 Identification of phenolic compounds extracted from fruits from different potassium treatments after conservation in the MD2 variety**

The chromatographic profile shows the presence of 11 phenolic compounds in fruits from treatments T0 and T1, 14 in fruits from treatment T2 and 16 in fruits from treatment T3. Compounds (1 to 8), as well as compounds (13) and (14), were revealed in fruits from all treatments. After treatment T2, there was de novo synthesis of compounds (10), (11) and (12). In addition to these 14 compounds, T3 treatment induced compounds (15) and (16). The synthesis of compounds (7) and (8) was inhibited by treatment T2. The compounds were identified as: arbutin (1), gentisic acid (2), quercitrin acid (3), chlorogenic acid (4), syringic acid (5), epicatechin (6), isoferulic acid (7), o-coumaric acid (8), myricetin (9), genistin (10), gallic acid (11), protocatechic acid (12), genistein (13), taxifolin (14), quercetin (15) and kaempferol (16) (Fig. 3).



**Fig. 3. Chromatographic profiles of phenolic compounds in MD2 pineapple pulp were revealed at 284 as a function of potassium treatments**

*1: arbutin (4.036 min); 2: gentisic acid (11.500 min); 3: quercitrin (11.832 min); 4: chlorogenic acid (12.167 min); 5: syringic acid (13.664 min); 6: epicatechin (14.168 min); 7: isoferulic acid (18.333 min); 8: o-coumaric acid (21,167 min); 9: rutin (23,834 min); 10: myricetin (32,294 min); 11: genistin (32,621 min); 12: gallic acid (7,412 min); 13: protocatechic acid (8,277 min); 14: genistein (9,963 min); 15: quercetin (28,645 min); 16: kaempferol (29,768 min); Treatment 1 (28 g K2O/plant); Treatment 2 (34 g K2O/plant); Treatment 3 (40 g K2O/plant)*

**Comparison of phenolic content of MD2 fruits from different treatments:** Comparison of chromatographic profiles shows that de novo synthesis of compounds in pineapple fruits was only induced from treatment T2 onwards. However, only compounds (10), (11) and (12) could be synthesised at this applied potassium dose. Compounds (15) and (16) could be synthesised after the application of 40 g K2O/plant (treatment T3) in the MD2 pineapple variety. On the other hand, high potassium levels (T2 and T3) inhibited the biosynthesis of compounds (7) and (8).

**3.5 Comparison of phenolic content of smooth Cayenne and MD2 pineapple fruits from different treatments**

Chromatographic analyses show the presence of 16 phenolic compounds in each of the smooth Cayenne and MD2 pineapple varieties. However, compound synthesis differed according to potassium treatment for each of the pineapple varieties studied.

In addition to the phenolic compounds arbutin (1), gentisic acid (2), quercitrin acid (3), chlorogenic acid (4), syringic acid (5), epicatechin (6), isoferulic acid (7), o-coumaric acid (8) present in the fruits of the control treatment (20 g K2O/plant) of smooth Cayenne pineapple, the fruits of the control treatment of MD2 pineapple also contains myricetin (9), genistein (13) and taxifolin (14).

In the smooth Cayenne variety, rutin (9) is synthesised in fruits of treatment T1 (28 g K2O/plant), while genistein (13) and taxifolin (14) only appear in treatment T2 (34 g K2O/plant) fruits. Genistein (10), gallic acid (11) and protocatechic acid (12) were all revealed in fruits from treatment T2 (34 g K2O/plant) in both pineapple varieties studied.

Quercetin (15) and Kaempferol (16) were only synthesised in fruits from treatment T3 (40 g K2O/plant) in both pineapple varieties. Overall, increasing the amount of potassium applied in culture led to a decrease in the peaks of certain compounds, while inducing the synthesis of new phenolic compounds (Fig. 4).



**Fig. 4. Chromatographic profiles comparison of phenolic compounds in pulps of smooth Cayenne and MD2 pineapple cultivars revealed at 284 nm**

*1: arbutin (4.036 min); 2: gentisic acid (11.500 min); 3: quercitrin (11.832 min); 4: chlorogenic acid (12.167 min); 5: syringic acid (13.664 min); 6: epicatechin (14.168 min); 7: isoferulic acid (18.333 min); 8: o-coumaric acid (21,167 min); 9: rutin (23,834 min); 10: myricetin (32,294 min); 11: genistin (32,621 min); 12: gallic acid (7,412 min); 13: protocatechic acid (8,277 min); 14: genistein (9,963 min); 15: quercetin (28,645 min); 16: kaempferol (29,768 min); Treatment 1 (28 g K2O/plant); Treatment 2 (34 g K2O/plant); Treatment 3 (40 g K2O/plant).*

4. discussion

Analysis of the physico-chemical data shows that the severity of browning symptoms observed on the pulps is inversely proportional to the amount of potassium applied to the plants. However, browning was more intense in the smooth Cayenne variety than in the MD2 variety. This result shows that the smooth Cayenne variety is more susceptible to browning than MD2 variety (Stewart et al., 2002; Botondi et al., 2015; Coulibaly et al., 2019). Furthermore, symptoms of translucency and browning of the flesh are observed on the pulp of pineapple fruits from treatments T0 (20 g K2O/plant) and T1 (28 g K2O/plant). This seems to suggest that low concentrations of potassium cause damage to pineapple fruit, leading to physiological disorders, as reported by Teisson and Combres (1979) and Smith (1983). The dose of 28 g K2O/plant, usually used in pineapple cultivation in Côte d'Ivoire, remains insufficient to completely reduce pineapple browning. In contrast, pineapples treated with 34 g K2O/plant showed almost no symptoms of internal browning or translucency. This dose would therefore be ideal for reducing internal browning in pineapple. Indeed, at this dose, phenolic degradation enzymes polyphenoloxidase (PPO) and peroxidase (POD) have low activity, that is to say, appear to be inhibited (Raimbault, 2011; Coulibaly et al., 2019). According to the work of Kouakou et al. (2009), since phenolic acids are the preferred substrates for PPO and POD, the phenol-degrading enzymes responsible for internal browning, the reduction in these phenolic compounds seems to deprive these enzymes of the substrate and thus redouble browning. Thus, increasing potassium intake, which seems to suppress total phenol synthesis, would be a means of preventing fruit browning (Gomes et al., 2004). Furthermore, according to Raimbault (2011), the activity of PPO, a key browning enzyme, is higher in the smooth Cayenne variety than in MD2 pineapple. In addition, Stewart et al. (2001 and 2002) and Zhou et al. (2003) reported that PPO enzyme activity is spatially and temporally correlated with the development of internal browning symptoms in the smooth Cayenne variety, justifying the susceptibility of this variety compared with MD2.

The results of this study also showed that translucency symptoms were only observed in the pulp of pineapples of the smooth Cayenne variety that had received 28 g K2O/plant and 34 g K2O/plant. These results suggest that pulp translucency precedes browning. Indeed, Soler's (1994 a, b) work showed that abiotic stresses such as exposure to cold, in the case of our study, would provoke vacuolar remodelling involving lysis or fusion of the vacuoles. These changes lead to an invasion of the intercellular spaces, resulting in translucent flesh. Then, contact between vacuolar phenols and PPOs or PODs as a result of the action of galactolipases, which hydrolyse monogalactosyl-diacylglycerol (a major thylakoid lipid), leads to browning of the affected areas (Matos et al., 2001).

In contrast, our study showed a progressive decrease in browning symptoms as the applied concentration of potassium increased. This reduction in browning symptoms would indicate that potassium plays an important role in membrane resistance, making the fruit flesh firmer (PIP, 2009). In fact, the high concentration of potassium leads to an increase in intracellular potassium levels, which in turn may result in a decrease in vacuolar pH (Gomes et al., 2004). This intracellular condition complicates the pumping of protons, thus lowering membrane permeability and limiting vacuolar lysis and invasion of intercellular spaces.

Regarding the study of phenolic markers of resistance to internal browning in pineapple, U-HPLC analysis of the fruit pulp from pineapples subjected to different potassium treatments in the field revealed the presence of many phenolic compounds in both varieties. The phenolic compounds identified in pineapple pulp belong to the phenolic acids and flavonoids groups (Yao et al., 2023). For both pineapple varieties, the results showed that fruits from the four types of treatment T0, T1, T2 and T3 all contained arbutin, gentisic acid, quercitrin acid, chlorogenic acid, syringic acid, epicatechin, isoferulic acid and o-coumaric acid. The presence of these compounds, therefore, appears to have no direct relationship with browning resistance in pineapple fruit. However, the synthesis of rutin, myricetin, genistin, gallic acid, protocatechic acid, genistein, quercetin and kaempferol induced by treatments T2 and T3 would appear to be linked to the control of fruit browning in pineapple. Indeed, these phenolic compounds seems to be inversely correlated with the development of internal browning symptoms observed on the fruit pulp. These results indicate that these phenolic compounds in pineapple fruit has a positive significance in the acquisition of pineapple fruit resistance to internal browning. The synthesis of these compounds would therefore be stimulated by an increase in the amount of potassium applied. Indeed, according to the work of Coulibaly et al. (2019), pineapple pulp browning decreases as the amount of potassium applied to the plants increases. The synthesis of myricetin, genistein and taxifolin observed in the MD2 pineapple control fruit, in contrast to the smooth Cayenne variety, would justify this variety's greater resistance to internal browning as reported by Raimbault (2011) and Kouadio et al. (2025). The synthesis of these compounds, which are all flavonoids, seems to show that this group is not directly linked to the internal browning of pineapple fruit (Kouakou et al., 2009). Indeed, unlike phenolic acids, flavonoids are not the preferred substrates for PPOs. Thus, their biosynthesis and increased levels in the fruit pulp promote resistance to internal browning, as reported by Kouakou et al., (2009). The presence of flavonoids (genistin, taxifolin, epicatechin, quercitrin, kaempferol and myricetin) in fruit from the T3 treatment (40 g K2O/plant) in each variety, and their total absence in the more sensitive smooth Cayenne control fruit, shows that resistance to internal browning in pineapple pulp is also reflected in the acceleration of phenolic biosynthesis. Indeed, flavonoids being considered as end compounds in the polyphenol synthesis chain, their presence shows that the polyphenol biosynthesis mechanism in T3-treated fruits has come to an end (Yapo, 2013). It has also been shown that metabolizable sugars such as sucrose are necessary for polyphenol biosynthesis (Larronde et al., 1998). This could also explain the rapid synthesis of phenolic compounds in fruits of the MD2 variety, which is richer in sugar than smooth Cayenne pineapple (Yapo, 2013). On the other hand, the absence of isoferulic acid and o-coumaric acid in fruits from treatments T2 and T3 in MD2 pineapple would indicate that these compounds are the preferred substrates for oxidation enzymes (PPO and POD).

Furthermore, the decrease in peak amplitude observed in chromatographic profiles with increasing potassium levels is positively correlated with the decrease in phenolic compound content (mainly phenolic acids). Potassium, therefore, seems to repress the synthesis of phenolic acids, which are directly linked to browning. Indeed, according to Naoumkina et al. (2010), the initial products of phenolic biosynthesis, such as erythrose-4-phosphate and phosphoenolpyruvate, derived from glucose degradation, could be inhibited by potassium.

5. Conclusion

This study highlighted the positive impact of potassium fertilisation on reducing internal browning in pineapple fruit, particularly in the smooth Cayenne variety, which is more sensitive to this physiological disorder. The application of 34 g K₂O/plant proved optimal for mitigating this phenomenon by promoting the accumulation of specific phenolic compounds (rutin, myricetin, genistin, gallic acid, protocatechic acid, genistein, quercetin and kaempferol), identified as potential markers of resistance to browning. These results suggest that optimising potassium intake is a promising agronomic strategy for improving post-harvest pineapple quality and reducing economic losses associated with internal browning. Further studies on the enzymatic mechanisms involved in internal browning will allow us to refine these recommendations and optimise post-harvest fruit management.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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