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Study of Potassium Fertilization on Some Antinutritional Factors in Two Pineapple Varieties Cultivated in Côte D'ivoire during Postharvest Storage

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluated the effect of potassium fertilization on the physical characteristics and certain antinutritional factors (oxalates, phytates, and tannins) of two pineapple varieties (*Ananas comosus* L. Merr.), MD2 and smooth cayenne, cultivated in Côte d'Ivoire and stored under conditions

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simulating export. A randomized block experimental design was established with four increasing doses of K_2O (20, 28, 34, and 40 g/plant). The parameters measured included fruit diameter, pulp core diameter, average weight, percentage of exportable fruits, as well as oxalate, phytate, and tannin contents. Results showed that an application of 34 g K_2O/plant optimized weight, size, and percentage of exportable fruits while reducing concentrations of antinutritional compounds, particularly tannins. The MD2 variety exhibited better physical performance and lower oxalate and phytate contents compared to smooth cayenne. Beyond the optimal dose, a slight decline in performance was observed, suggesting that excess potassium may induce nutritional imbalances. These findings confirm the importance of a rational management of potassium fertilization to reconcile yield, market quality, and nutritional value, thereby strengthening the competitiveness of the Ivorian pineapple sector in export markets.

Keywords: *Postharvest quality; MD2; smooth cayenne; postharvest storage; tannins; phytates; oxalates.*

1. INTRODUCTION

Pineapple (*Ananas comosus* L. Merr.), a herbaceous monocotyledon of the Bromeliaceae family, occupies a strategic place in the Ivorian economy, where it represents the third largest fruit crop for export after banana and mango. During the 1990s, the sector generated more than 45 billion CFA francs per year, contributing 0.6% to the national Gross Domestic Product (GDP) and 1.6% to the agricultural GDP. At that time, Côte d'Ivoire ranked among the leading suppliers of fresh pineapple to the European market, with a production of 213,620 tons in 1999 (FAO, 2023). However, a structural crisis that began in the 1980s and was exacerbated by the sociopolitical crisis of 2002 led to a progressive collapse in production, which fell to 18,516 tons in 2024 (Assocle, 2024). In addition to soil depletion caused by monocropping, fruit acidity, and the high level of chemical residues, postharvest internal browning (IB) has emerged as the main factor responsible for the deterioration of the commercial and nutritional quality of pineapples (Coulibaly et al., 2017; Kouadio et al., 2025).

IB, often induced by the low storage temperatures required for export, first manifests as translucency and then as browned areas, altering the appearance and organoleptic acceptability of pineapples (Hong et al., 2013; Lasekan & Hussein, 2018; Lai et al., 2024; Sangsoy et al., 2024). The intensity of this phenomenon varies by variety: smooth cayenne is considerably more susceptible to browning than MD2 (Chandra et al., 2023). In this context, mineral nutrition, and particularly potassium supply, appears to be an agronomic lever capable of limiting IB. As an essential nutrient, potassium is absorbed in ionic form (K^+) and plays roles in osmotic regulation, stomatal function, membrane stability, and numerous enzymatic reactions (MAPM/DERD, 2007; Belfakih et al., 2013; Mostofa et al., 2022). Experimental trials have shown that progressively increasing doses of K_2O, up to 34 g/plant, significantly reduce the severity of internal browning (Gomes et al., 2004; Antonio et al., 2005; Coulibaly et al., 2019; Coulibaly et al., 2025).

Moreover, potassium fertilization influences the metabolism of phenolic compounds, some of which (such as flavonoids (rutin, myricetin, genistin, quercetin, kaempferol, taxifolin) and phenolic acids (gallic acid, protocatechuic acid)) seem to function as markers of resistance to browning, whereas other phenols serve as preferred substrates for polyphenol oxidase, the key enzyme involved in IB (Kouakou et al., 2009; Yao et al., 2023).

Nevertheless, the specific effect of potassium fertilization on the dynamics of antinutritional compounds during postharvest storage remains largely unexplored in the Ivorian context.

The present study aims to evaluate the impact of potassium fertilization on the physical characteristics and certain antinutritional factors of two pineapple varieties cultivated in Côte d'Ivoire during postharvest storage. The objective is to provide optimized agronomic recommendations to reduce economic losses related to internal browning and enhance the competitiveness of the Ivorian pineapple sector in export markets. These plants were randomly sampled from a smallholder plot in Bonoua, Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material consisted of pineapple suckers of the MD2 and smooth cayenne varieties (*Ananas comosus* L. Merr.), cultivated on a large scale in Côte d'Ivoire. These plants were randomly sampled from a smallholder plot in Bonoua, Côte d'Ivoire.

2.2 Methods

2.2.1 Establishment of the crop and experimental design

The experimental field was established in July 2024 on sandy, low-fertility soil at the experimental farm of Nangui Abrogoua University in Abidjan (5º23'N; 4º11'W), Côte d'Ivoire. After chemical analysis and soil fumigation, ridges measuring 6.5 m × 1 m were constructed on a surface area of 150 m². Each ridge was amended with 1 kg of dolomite and 500 g of triple superphosphate. For each pineapple variety, plants weighing about 400 g were transplanted on the ridges in double rows following a block design. Each treatment, composed of 12 plants, was replicated three times. The spacing was 25 cm between plants within a row and 40 cm between rows. Ridges were spaced 90 cm apart (Coulibaly et al., 2025).

2.2.2 Application of different potassium doses

To evaluate the influence of potassium fertilization on the antinutritional factors of MD2 and Smooth Cayenne pineapples, four treatment modalities (T0, T1, T2, and T3) were established based on increasing doses of K_2O (Coulibaly et al., 2025). Each plant received a uniform supply of 16 g of urea (46% nitrogen) and 10 g of a complete fertilizer formulated with 11% nitrogen (N), 5% phosphorus (P_2O_5), 27% potassium (K_2O), 15% sulfur, and 5% magnesium oxide (MgO). This fertilizer was further enriched with micronutrients, 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). Only the quantities of potash varied among treatments, applied as potassium sulfate (50% K_2O, 17% sulfur).

The control treatment (T0), corresponding to the practice commonly adopted by producers, received 20 g of K_2O per plant, supplied as standard potassium sulfate (50% K_2O and 17% sulfur) (Ouattara et al., 2014). Treatments T1, T2, and T3 received 28 g, 34 g, and 40 g of K_2O per plant, respectively. Fertilizers were applied during the vegetative phase, following a schedule of four applications at the 2nd, 4th, 6th, and 7th months of cultivation. The first application was carried out in solid form, by depositing granules at the base of the leaves, while the remaining three applications were performed in liquid form, as a fine spray over the foliage (Coulibaly et al., 2025).

2.2.3 Phytosanitary treatment and flower induction

Phytosanitary treatments were conducted using an insecticide based on chlorpyrifos-ethyl (480 g/L) applied at 2 L/ha and a fungicide based on fosetyl-aluminum applied at 7 kg/ha. A nematicide (Nemacur® 40 EC) was also applied at the base of plants at a dose of 25 mL/L, corresponding to 6 mL of solution per plant. These treatments were performed starting from the second month of cultivation and/or during the fifth month depending on phytosanitary needs (Coulibaly et al., 2025). After nine months of cultivation, a floral induction treatment (FIT) was applied to homogenize flowering (PIP, 2009). This was carried out when the D-leaf reached a weight of 70 g. The product used was calcium carbide, prepared at a concentration of 2 kg in 200 L of water; 50 mL of the resulting solution was immediately poured into the center of each plant using a backpack sprayer with adjustable flow. The operation was repeated 48 hours later to ensure effective induction.

2.2.4 Harvesting and storage of fruits

For each variety, a batch of three harvested fruits was collected for each treatment (T0, T1, T2, and T3). Before storage, the crown of each fruit was treated with a fungicidal solution containing benomyl. Fruits were then stored at 10 °C for fourteen days, corresponding to the export transport period. After this period, they were transferred to 22 °C and maintained for five days, simulating marketing conditions, before being used for analyses.

2.2.5 Grading of harvested fruits

Before storage, the total number of harvested fruits was counted for each treatment. Fruits were individually weighed using a precision balance (Mettler Toledo, B154®). Fruits weighing

≥800 g were considered to be of commercial size, and their proportion was expressed as a percentage. The average gross weight was calculated by dividing the total weight of fruits by the number of harvested fruits per treatment. The average exportable weight, corresponding to fruits meeting export standards, was calculated after excluding malformed fruits or those not meeting weight criteria. According to Kobenan et al. (2005), export grades are defined as follows: A6 (1.8–2.1 kg), A8 (1.5–1.8 kg), B9 (1.3–1.5 kg), B10 (1.1–1.3 kg), and C12 (0.9–1.1 kg), thus setting the acceptable range for exportable fruits between 0.9 and 2.1 kg.

2.2.6 Analysis of antinutritional factors

2.2.6.1 Extraction and quantification of tannins

Tannins, phenolic compounds, were extracted following the method of Kouakou et al. (2007; 2009). Fifty mg of lyophilized pineapple pulp were introduced into a hemolysis tube, then 10 mL of 96% methanol were added. The mixture was kept in the dark for 10 h at 4 °C. After centrifugation at 5000 rpm for 10 min, the supernatant was collected and filtered through a 0.45 µm Millipore membrane. This filtrate constituted the crude phenolic extract.

Tannin content was determined following Bainbridge et al. (1978). One mL of phenolic extract was mixed with 5 mL of vanillin reagent (0.1 mg/mL vanillin in 70% sulfuric acid). After 20 min in the dark, absorbance was measured at 500 nm against a blank. Tannin content was expressed in milligrams of tannic acid per gram of lyophilized pineapple pulp (mg/g DM), calculated from a calibration curve ($y = 3.11x$; $R^2 = 0.996$).

2.2.6.2 Extraction and quantification of phytates

Phytates were extracted and quantified according to Latta and Eskin (1980). Ten mg of lyophilized pulp were homogenized in 20 mL of 0.65 N HCl for 12 h at room temperature. The mixture was centrifuged at 12,000 rpm for 10 min, and the supernatant was filtered through a 0.45 µm Millipore membrane. For quantification, 0.5 mL of filtrate was mixed with 3 mL of Wade reagent. After 20 min in the dark, absorbance was measured at 490 nm. Phytate content, expressed as mg of sodium phytate per g of lyophilized pulp (mg/g DM), was calculated from a calibration curve ($y = 0.033x$; $R^2 = 0.996$).

2.2.6.3 Extraction and quantification of oxalates

Oxalates were determined according to Day and Underwood (1986), using potassium permanganate titration. Ten mg of oven-dried, ground sample were homogenized in 75 mL of sulfuric acid. The mixture was stirred for 1 h, then filtered. A 25 mL aliquot was titrated hot with 0.05 M potassium permanganate until a persistent pink color appeared. Oxalate content (mg/g) was calculated using:

$$\text{Oxalate (mg/g)} = (2{,}2 \times V_{eq})/me$$

Veq: is the titration equivalence volume (mL of $KMnO_4$) and me: is the sample mass (g).

2.2.7 Statistical analyses

Statistical analyses were performed using Statistica 7.1 software. One-way analysis of variance (ANOVA) was used to test for significant differences among means. When significant differences were found, means were separated using Newman–Keuls test at a 5% significance level. For percentage data considered non-parametric, comparisons were performed using the Kruskal–Wallis test at a 5% risk level.

3. RESULTS AND DISCUSSION

3.1 Evaluation of Physical Characteristics of Fruits

The physical characteristics of the fruits varied according to the potassium treatments (Table 1). A significant increase in the pulp core diameter and the average fruit weight was observed in both varieties. The average fruit weight ranged from 1.22 to 1.83 kg for MD2 and from 1.00 to 1.58 kg for Smooth Cayenne. However, fruit diameter showed little variation with the applied potassium concentration. The percentage of marketable fruits ranged from 79.67 to 88.77% for MD2 and from 74.67 to 88.74% for Smooth Cayenne. Results revealed that MD2 pineapples exhibited superior physical characteristics compared to Smooth Cayenne.

3.2 Evaluation of Physical Characteristics of Fruits

3.2.1 Oxalate content

The results presented in Fig. 1 indicate that, for a given variety, the oxalate content of fruits from different treatments did not differ significantly ($p < 0.05$). The values remained similar to those of the control fruits: 39.67 mg/100 g DM for MD2 and 47.48 mg/100 g DM for Smooth Cayenne. However, Smooth Cayenne consistently recorded higher oxalate contents across all treatments.

3.2.2 Phytate content

Fig. 2 presents the phytate content of fruits according to treatments. Results show that for both pineapple varieties, phytate content did not vary with increasing potassium application. Thus, phytate content remained statistically equivalent to the control: 11.93 mg/100 g DM for MD2 and 15.22 mg/100 g DM for Smooth Cayenne. Nevertheless, Smooth Cayenne consistently accumulated higher phytate levels than MD2 across all treatments.

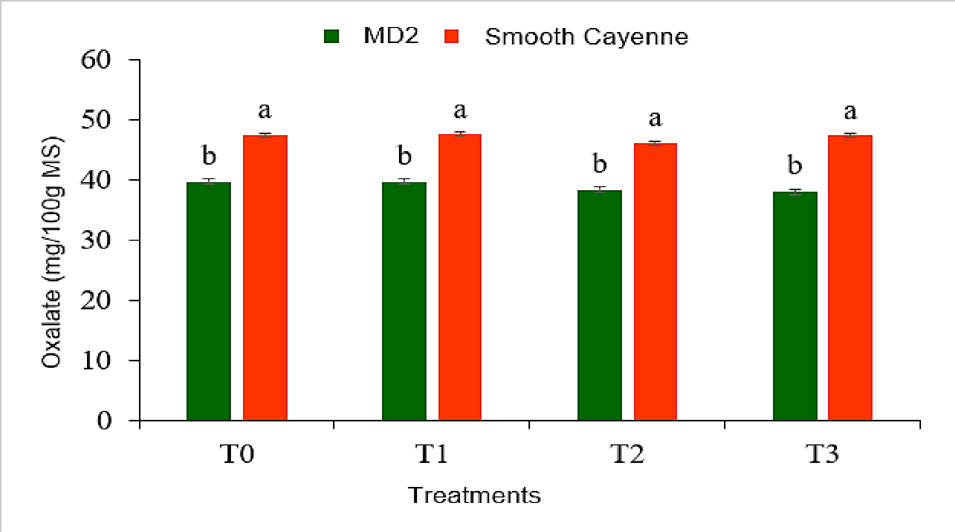

Fig. 1. Variation in oxalate content of two pineapple varieties as a function of potassium application after postharvest storage

T0 = control fruits (20 g K_2O/plant); T1 = 28 g K_2O/plant; T2 = 34 g K_2O/plant; T3 = 40 g K_2O/plant. Histograms with different letters differ significantly (Newman–Keuls test at 5%)

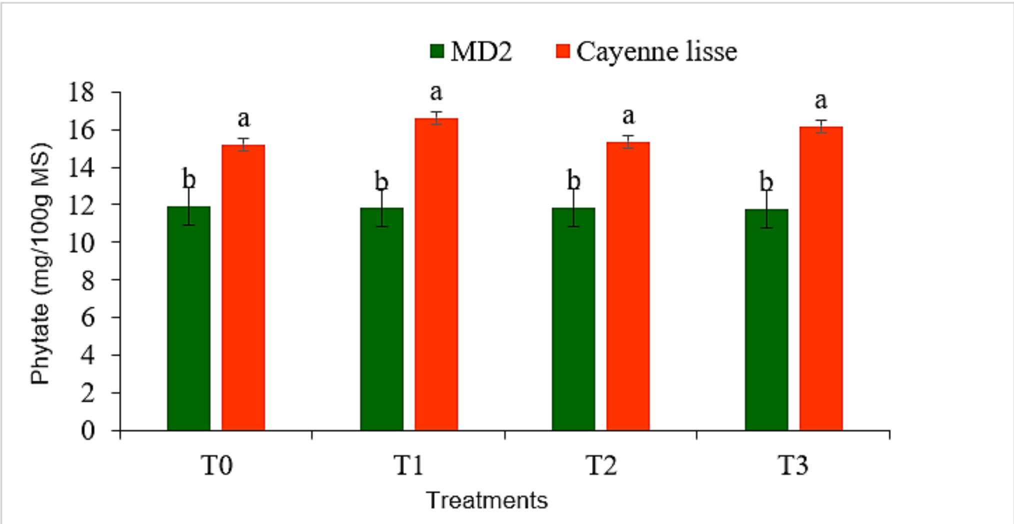

Fig. 2. Variation in phytate content of two pineapple varieties as a function of potassium application after postharvest storage

T0 = control fruits (20 g K_2O/plant); T1 = 28 g K_2O/plant; T2 = 34 g K_2O/plant; T3 = 40 g K_2O/plant. Histograms with different letters differ significantly (Newman–Keuls test at 5%)

Table 1. Physical characteristics of the pineapple varieties studied according to the potassium treatments applied

		Fruit physical characteristics			
Varietes	**Treatments**	**Diameter (cm)**	**Pulp Core Diameter (cm)**	**Weight (kg)**	**TFE (%)**
MD2	T0	10.54 ± 0.02 c	2.81 ± 0006 c	1.22 ± 0.03 c	79.67 ± 0.03 c
	T1	10.94 ± 0.04 b	3.32 ± 0.11 b	1.25 ± 0.09 c	82.77 ± 0.02 b
	T2	11.93 ± 0.04 a	3.64 ± 0.05 a	1.83 ± 0.06 a	88.77 ± 0.01 a
	T3	11.81 ± 0.00 a	3.83 ± 0.03 a	1.61 ± 0.02 b	84.74 ± 0.06 b
Smooth Cayenne	T0	9.24 ± 0.07 d	2.65 ± 0.08 c	1.02 ± 0.04 d	74.67 ± 0.08 d
	T1	10.20 ± 0.15 c	2.80 ± 0.05 c	1.00 ± 0.03 d	80.98 ± 0.06 c
	T2	10.88 ± 0.02 b	3.01 ± 0.05 bc	1.58 ± 0.05 b	88.74 ± 0.03 a
	T3	10.41 ± 0.1 c	3.31 ± 0.11 b	1.28 ± 0.05 c	83.40 ± 0.05 b

T0 = control fruits (20 g K_2O/plant); T1 = 28 g K_2O/plant; T2 = 34 g K_2O/plant; T3 = 40 g K_2O/plant. In the same column, values followed by the same letter are not significantly different (Newman–Keuls test at 5%). Pulp Core Diameter = DiaCP; Exportable Fruit Rate = TFE

3.2.3 Tannin content

The results in Fig. 3 show that Smooth Cayenne generally contained higher tannin concentrations than MD2, except for treatment T2 (34 g K_2O/plant), where both varieties recorded identical values. At treatments T0 (20 g K_2O/plant) and T1 (28 g K_2O/plant), Smooth Cayenne exhibited 1.63 mg/100 g DM and 1.73 mg/100 g DM, respectively, compared to 1.26 mg/100 g DM for MD2 in both cases, with the difference more pronounced at T1. At treatment T3 (40 g K_2O/plant), the difference between the two varieties became marginal, with 1.69 mg/100 g DM for Smooth Cayenne and 1.63 mg/100 g DM for MD2. The trends showed that, for MD2, tannin content remained stable between T0 and T1, increased notably at T2, then decreased slightly at T3. For Smooth Cayenne, the increase was more regular: a moderate rise from T0 to T1, stability between T1 and T2, followed by a slight decline at T3. These results suggest that increasing K_2O doses promotes tannin synthesis up to an optimal threshold (observed at T2), beyond which levels decline.

The analysis of results demonstrated that potassium fertilization had a determining effect on the physical characteristics and nutritional quality of pineapples. The dose of 34 g K_2O/plant represented the optimal level, improving size, weight, and exportable yield while reducing antinutritional factors such as oxalates, phytates, and tannins. Conversely, excessive doses resulted in a relative decline in performance, confirming the importance of balanced potassium management.

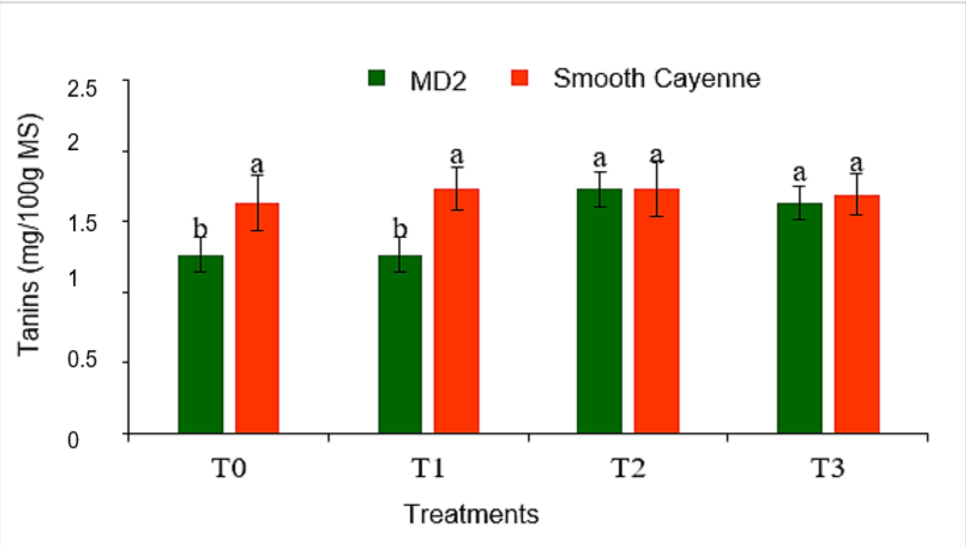

Fig. 3. Variation in tannin content of two pineapple varieties as a function of potassium application after postharvest storage

T0 = control fruits (20 g K_2O/plant); T1 = 28 g K_2O/plant; T2 = 34 g K_2O/plant; T3 = 40 g K_2O/plant. Histograms with different letters differ significantly (Newman–Keuls test at 5%)

4. DISCUSSION

The present study showed that potassium fertilization exerts a decisive influence on the physical characteristics and certain biochemical parameters of pineapple fruits, particularly in the MD2 and Smooth Cayenne varieties. Progressive increases in potassium doses up to 34 g K_2O per plant resulted in significant improvements in fruit diameter, average weight, and exportable fruit rate, confirming the central role of this element in osmotic regulation, assimilate translocation, and photosynthesis stimulation (Coulibaly et al., 2025). As the main osmotic cation in the cytoplasm, potassium promotes cell expansion and enhances tissue filling with water and sugars, thus leading to larger fruits of higher commercial quality. These findings are consistent with those reported by Bartholomew et al. (2017), Zörb et al. (2014), and Cunha et al. (2021), who highlighted the importance of balanced potassium supply for optimizing fruit size, density, and firmness in tropical crops. Similarly, Hu et al. (2021) demonstrated that potassium enhances the translocation of photosynthates to storage organs, which explains the improved performance observed at the optimal dose in this study. However, an excessive application of 40 g K_2O/plant led to a slight decline in performance, indicating a nutritional imbalance that may reduce the uptake of elements such as calcium and magnesium, which are essential for growth and storage organ quality (Cakmak, 2005; Zörb et al., 2014).

The analysis of antinutritional factors revealed clear varietal differences. Oxalate, phytate, and tannin contents were generally higher in Smooth Cayenne than in MD2, reflecting genetic specificities in secondary metabolism regulation. Although these compounds contribute to defense mechanisms against certain biotic and abiotic stresses, they are known to reduce mineral bioavailability and compromise fruit nutritional quality (Gemede & Ratta, 2014). The relative stability of oxalates and phytates with respect to potassium supply suggests that their biosynthesis is little influenced by potassium and is more strongly determined by genotype, as also noted by Noonan and Savage (1999) and Reddy et al. (2017). Smooth Cayenne, with a more active metabolism of organic acids and phytates, consistently showed higher levels, while MD2 tended to limit the accumulation of these compounds, consistent with its recognized advantages for organoleptic quality and exportability (Lobo & Paull, 2017; Sanewski et al., 2018).

Tannin levels showed greater modulation depending on potassium dose. A significant increase was observed up to 34 g K_2O/plant, followed by a slight decline at higher doses. This bell-shaped pattern reflects the existence of a physiological threshold beyond which potassium overload no longer stimulates phenolic biosynthesis but instead leads to metabolic redistribution or dilution effects in larger fruits. This phenomenon is consistent with the observations of Ahmad et al. (2018), Taiz et al. (2018), and Cunha et al. (2021), who demonstrated that potassium can stimulate the phenylpropanoid pathway (responsible for phenolic compound production) up to an optimal threshold, beyond which metabolic balance is disrupted. Similar trends have been observed in other fruit crops such as grapevine (Silva et al., 2023) and mango (Sivakumar et al., 2011), confirming the nonlinear effect of potassium on secondary metabolism.

Thus, the results of this study highlight the importance of rational potassium management in pineapple production. The optimal dose of 34 g K_2O/plant achieved a balance between improved physical performance and reduced antinutritional factors, representing a compromise between yield, market quality, and nutritional value. Conversely, excessive potassium application undermines these benefits, emphasizing the need for balanced fertilization to avoid ionic imbalances and quality losses. These findings also corroborate the work of Sossa et al. (2017) on pineapple in Cameroon and Dagnew & Shah (2024) on papaya, which showed that moderate potassium fertilization improves postharvest quality and reduces losses due to physiological disorders. Finally, the observed varietal differences underscore the necessity of tailoring fertilization recommendations to the physiological and genetic characteristics of each cultivar in order to strengthen the competitiveness of the Ivorian pineapple sector in export markets.

5. CONCLUSION

This study highlighted the central role of potassium fertilization in improving the agronomic and nutritional performance of pineapple in Côte d’Ivoire. Progressive potassium application significantly increased fruit diameter, average weight, pulp core diameter, and exportable fruit rate. The optimal dose of 34 g K_2O/plant reconciled high yield, uniform fruit size, and reduced antinutritional factors. In contrast, an excess of 40 g/plant resulted in a partial decline in performance, indicating the presence of a critical threshold. The MD2 variety showed better responses than Smooth Cayenne, confirming its potential for export, although both varieties benefited from potassium fertilization. Antinutritional compound levels remained low, without compromising fruit nutritional value. This study therefore demonstrated that rational management of potassium fertilization is essential to enhance the competitiveness of the Ivorian pineapple sector while ensuring high-quality and sustainable production. Looking ahead, it would be relevant to further investigate integrated fertilization strategies by studying interactions between potassium, other essential nutrients, and cultural practices, as well as their effects on postharvest quality parameters such as firmness, sugar content, and shelf life. Such studies could support the development of more sustainable production strategies adapted to local conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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