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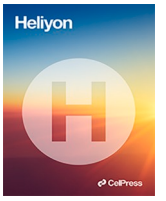

Research article

Investigation of the impact of cold plasma pretreatments, long term storage and drying on physicochemical properties, bioactive contents and microbial quality of 'Keitt' mango

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ABSTRACT

There is heightened demand for dried mango fruits with desired nutritional and physicochemical qualities, microbiologically stable and chemical residue free. This has led to the exploration of innovative preservation technologies for the extension of storability prior to processing. This study investigated the impact of cold plasma (CP) treatment on physicochemical properties and microbial stability in fresh and dried 'Keitt' mango during long term storage. Freshly harvested 'Keitt' mangoes were subjected to: CP treatment (for 5 min (CP5) and 10 min, CP10), dipping in "Chronos Prochloraz" for 30 s (industry practice), and untreated group (control). All samples were stored at 11 °C for 30 days, prior to minimal processing and hot air drying at 60 °C. Results after 30 days of storage demonstrated that untreated samples (control) had the highest TSS (15.06 ± 0.32 °Brix), while CP10 pretreated samples had the lowest TSS (13.80 ± 0.06 °Brix) value ($p \leq 0.05$). In comparison to the fresh samples post storage, all pretreated dried mango slices retained lower total flavanols with CP5 (13.49 ± 1.64 mg GAE 100/g), CP10 (20.12 ± 1.42 mg GAE 100/g) and SMB (23.89 ± 3.35 mg GAE 100/g), but higher than the dried untreated samples (6.68 ± 0.53 mg GAE 100/g). Yellowness (b^*) of the fresh pulp (38.53 ± 1.73) increased significantly ($p \leq 0.05$) with the long-term storage (39.88–46.74) and drying (55.01–64.90). CP pre-treatment combined with drying resulted in ≥2 Log reduction in microbial count. This study shows the potential of cold plasma as a pretreatment for extending storability and maintaining the quality of 'Keitt' mangoes.

1. Introduction

The high demand of mango by consumers due to its taste and nutritional importance, has led to an increase in its worldwide

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production [1,2]. The nutritional aspects of this delicious fruit include different micronutrients, essential minerals, phenolics, β-carotene, dietary fibre, and other bioactives [3]. It has a strong marketability in its fresh form thanks to its excellent sensory characteristics and can be eaten either raw or processed as a snack such as dried slices [4]. During postharvest storage, various factors such as the degradation of green pigments, the production of beta-carotene and the fast-ripening process of fruit occur suggesting therefore the use of pretreatment for a prolonged shelf-life [5].

Cold plasma technology is one of the innovations that has caught the interest of food industry experts recently, particularly in fruits and vegetables [6]. Plasma is produced by applying either alternative or direct current electric field to atmospheric gas, which generates electrons, ions, UV radiation, reactive species, free radicals, atoms, and excited molecules with the ability to render microorganisms inactive [2,6]. Due to its dry, non-thermal nature, continuous operation at atmospheric pressure, and lack of chemical requirements, cold plasma has recently been investigated as a food disinfection [2,7]. In comparison to others alternative approaches, this is a low temperature process and can operate at a shorter working period with a low level of food damage [2]. Low temperature plasma has been suggested to be highly effective in maintaining the nutritional quality attributes of fruit [8]. Ashtiani et al. [7] demonstrated that CP pre-treatment before osmotic dehydration lowered the drying duration for mushrooms. However, there are drawbacks for plasma treatment depending on the discharge method used. There is limited application for large fruit as plasma discharge could be uneven across the surface, efficacy is treatment duration and distance from source the plasma jets or flames discharged dependent, and this could increase the surface temperature of sensitive fresh produce, and where feed gas is required the high cost of carrier/process gas is a drawback [2,9].

Recent publications by Yi et al. [10] reported 0.61 log reduction in the microbial growth of fresh cut mango (cv. Hongyu) after 3 min exposure to dielectric barrier discharge (DBD) plasma at 75 kV followed by 4 days of storage at 20 °C. Similarly, combined DBD treatment at 50 V and a 1.0×10^4 Hz with plasma activated water applied to small Tai mango lessened anthracnose and extended the shelf life by 8 d [11]. After being exposed to gliding arc discharge for 7 min, the growth of *Colletotrichum gloeosporioides* mould was significantly inhibited in Nam Dok Mai mango fruit [12]. However, no research has been done to compare the effects of low-pressure cold plasma pre-treatment with dipping in "Chronos Prochloraz" (as the standard industry practice) combined with long-term storage on the quality attributes of mango fruit and prior to hot air drying.

Furthermore, extending the storability of fresh mango fruit beyond the short production period for the whole mango fruit would ensure added value, increasing farmers earnings (alleviating poverty). In addition, improved storability combined with drying would significantly reduce postharvest losses, and alternative phytosanitary measure would reduce dependence on fungicides. Therefore, the main goal of this study is to establish a postharvest handling strategy for mango fruit post-production for value addition (drying) using 'Keitt' as a case study. The set objectives were (i) to investigate the impact of cold plasma treatment duration on long-term storability of freshly harvested 'Keitt' mango, and (ii) to evaluate the impact of cold plasma treatments, long-term storage duration and drying on physicochemical properties, bioactive contents and microbial stability of 'Keitt' mango.

2. Material and methods

2.1. Plant materials, pre-treatments and storage

The 'Keitt' mangoes were harvested at stage 3 maturity, ≈126 days after fruit set with average fruit mass (467.67 ± 12.99 g), and total soluble solids (TSS, ≈14.00 °Brix). Freshly harvested 'Keitt' mango from the foothills of the Cederberg mountains (−32°24'85.03"S, 18°94'07.71"E) at the Tamarak Mango Estate, Western Cape Province, South Africa, were transported under cool conditions to the Agro-Processing Pilot Plant of the ARC Infruitec-Nietvoorbij, Stellenbosch, South Africa. Fruits were sorted, inspected and only intact fruits that were homogeneous in size, shape, colour and without bruising or decay were selected.

The bulk mangoes were divided into four batches based on the pre-treatments, which were administered as follows: (i) fresh mango fruit were treated with cold plasma for 5 min, (ii) fresh mango fruit were treated with cold plasma for 10 min, (iii) the third group of fruit was dipped in Chronos Prochloraz for 30 s in order to replicate industrial practices, and (iv) the control group which were untreated. Each treatment was replicated in triplicate with ten boxes of fruit per treatment and nine mangoes per box. After treatments all fruit samples were stored at 11 °C for 30 days, and afterwards five boxes were taken for analyses and others were processed.

2.2. Minimal processing and hot air drying

Fruit samples per treatment batch underwent minimal processing and were peeled and sliced using a sharp knife. The slices had a thickness of approximately 8 mm and were arranged on a steel tray with a parallel airflow arrangement. Immediately after processing and prior to hot air drying, only the fruit sample which served as control during long-term were dipped for 2 min in 1 % sodium metabisulphite (SMB, 10 g/kg) to replicate industrial practices. Previous study from Yanclo et al. [2] demonstrated that pre-treatment with CP could be an effective alternative to SMB dipping of fresh cut mangoes. In-house designed dehydrator tunnel was turned on an hour before drying of samples to equilibrate the chamber. The dehydrator was set to 60 °C, 35 % relative humidity and 2.50 L/min airflow rate to guarantee a steady-state temperature. The temperature inside the dehydrator was measured using a HI935005 K-Type Thermocouple Thermometer (Hanna instruments, South Africa). The weight loss of mango slices was monitored during drying using a Labotech Top-loader analytical electronic balance (accuracy 0.01 g) at 3-h intervals until the samples reached a stable weight. Six runs of each experiment were conducted. After completion of drying experiment with final moisture content 9.92 ± 1.84 % on a dry basis, dried mango slices were allowed to cool before being packaged and kept for two days in a dark cupboard.

2.3. Colour change

Using pre-calibrated Chroma meter (Minolta CR-400, Minolta Corp., Osaka, Japan), redness-green (a^*), yellowness-blueness (b^*), and lightness (L^*) of whole fresh mango fruit pulp and dried slices were measured. The following formulas were used by Pathare et al. [9] to calculate the chroma (C^*), *hue* angle (h°), and total color difference (ΔE) of the fresh mango pulp and dried slices:

$$C^* = \left(a^{*2} + b^{*2}\right)^{1/2} \tag{1}$$

$$h^\circ = arctan\left(b^* / a^*\right) \tag{2}$$

$$\Delta E = \sqrt{\left(L_0^* - L^*\right)^2 + \left(a_0^* - a^*\right)^2 + \left(b_0^* - b^*\right)^2} \tag{3}$$

L^*_0, a^*_0 and b^*_0 indicate the initial (raw mango slices) measured value, while L^*, a^* and b^* indicate the dried mango slices.

2.4. Measured quality attributes

2.4.1. Biochemical attributes

To measure the total soluble solids (TSS) of mango juice a digital refractometer (Atago N1, Tokyo, Japan) was used. Using a blender (Model RSH – 080475, China). For dried samples, 6 g of dried slices was ground into a powder and combined with 60 mL of distilled water. The mixture was used to determine the TSS using a drop of the mixture, and results were expressed as °Brix based on dry weight [13]. Furthermore, the sample was vortexed to obtain a homogenous mixture which was later used to measure the titratable acidity (TA). For this experiment, 60 mL of mixture was titrated against 0.33 N of NaOH, which was then reported as a percentage of citric acid (%, CA). Automated titrosampler (Crison Instruments, S.A. E−08328 ALELLA-Barcelona) was used to quantify TA when the pH reached 8.20 endpoint [14]. The pH was determined with the aid of a digital pH meter (Crison Model 00924 basic 20+, South Africa) as reported by Yanclo et al. [15].

2.4.2. Bioactive compounds

Distilled water (2000 μL) was added to 10 mg of powdered mango pulp, then homogenized by vortex for 30 s. Before assessing the bioactive compounds, the solution was centrifuged at 2951 ×*g* for 5 min in a Hermle Z206A compact centrifuge (Wehingen, Germany). For the assessment of Ferric Reducing Antioxidant Power (FRAP), distilled water (6.60 mL), acetate buffer (30 mL), ferric 2,4,6-tripyridyl-s-triazine (3 mL), and $FeCl_3$ (3 mL) were combined as a reagent. Ascorbic acid (10 μL) that served as standard was dispensed into wells pre-marked in the well plate. After that, 300 μL of the FRAP reagent was pipetted (using a multichannel) and added to each well. Plate was incubated for 30 min at 37 °C. Concentrations ranging from 360 to 440 μM was used for FRAP and the concentration curve Y = 0.0072X + 0.001 with R^2 value of 0.9998 was used. The results were reported as μM vitamin C/mg dry weight basis.

A modified extraction method from Duda-Chodak et al. [16] for Trolox equivalent antioxidant capacity (TEAC) was used. As standard, 25 μL of Trolox was carefully dispensed into plate wells containing previously added supernatant (25 μL). A solution of EtOH (20 mL) with ABTS (1 mL) was prepared, and 300 μL of ABTS was pipetted into each well. Subsequently, the plate was incubated at room temperature for 30 min before measurements were taken. TEAC extrapolations were done using Trolox concentrations with a range from 190 to 210 μM, and a standard curve equation of Y = 0.0043X + 0.0065 and an R^2 value of 0.9983. The values were expressed as μM Trolox/mg dry weight basis.

Approximately 180 μL 0.10 mM 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution combined with 95 % ethanol was mixed with 20 μL of mango juice extract. The mixture was incubated at room temperature and shielded from light for half an hour. In each microplate well, DPPH reagent (275 μL) was poured, while the wells containing Trolox standard, and the control were filled with 25 μL of the standard solution. After incubation at room temperature for 30 min, the mixture was assessed at an absorbance of 593 nm using a spectrophotometer with 190–210 M of concentrations. The curve equation Y = 0.0125X + 0.2312 with R^2 of 0.9829 was used to express DPPH activity and reported as μM Trolox/mg dry weight basis.

Using quercetin as the standard, an updated version of the methodology outlined by Pavun [17] was utilized for the determination of total flavanol content. The process involved placing mango juice (5 mL) in a polytron and homogenizing it for 30 s. The resulting supernatant from homogenization underwent extraction by rotation on a tube rotator for 15 min, followed by 3 min centrifugation for at 4000 rpm, covered to keep out light, and stored at room temperature in darkness. Each well plate was filled with the following: quercetin (12.50 mL), 0.1 % hydrochloric acid in 95 % ethanol (12.50 μL) and 2 % HCl (225 μL), then incubated for 30 min at room temperature. Subsequently, readings were taken, and the results were analysed using values ranging between 27 and 33 mg/L, a calibration curve equation (Y = 0.0024X + 0.0089 with an R^2 value of 0.9933) was used. The findings were expressed as mg quercetin equivalent (QE)/g dry weight basis.

Technique outlined by Wang et al. [18] underwent modifications to quantify the total flavonol content. After extracting a volume of 25 μL of supernatant, mango juice was subjected to sonication followed by centrifugation at 4000 rpm for 5 min. The reaction was initiated by adding 1 mL of p-DMACA solution (0.10 % in 1 M HCl in MeOH) to the supernatant and incubated for 10 min at room temperature. A blank was used to measure the absorbance at 640 nm. As the reference Catechin was used ranging from 5.94 to 4.86 mg/L, and the total flavonol content was calculated using the calibration curve equation (Y = 0.0372X + 0.0036 with R^2 value of 0.9996). Total flavonol was expressed in mg catechin equivalents (CE)/g dry weight basis.

Total phenol was evaluated using the Folin-Ciocalteu method in compliance with the procedures described by Phan et al. [19]. Initially, a transparent plate well was filled with 50 μL of a blend consisting of: mango extract (200 μL) and distilled water (1800 μL). In the second stage, 1 mL of saturated 7.50 % Na_2CO_3, Folin-Ciocalteu's reagent (0.5 mL), and distilled water (1 mL) was mixed into the vials. After plating (50 μL) of the mixture, the reaction plate was incubated in the dark for 2 h at 20 °C. The standard curve equation used was expressed using concentrations varying from 180 to 220 mg of the gallic acid as $Y = 0.0093X + 0.0529$ with $R^2 = 0.9995$. The absorbance was determined at 750 nm using a spectrophotometer (Fluostar Omega, BMG Labtech, Offenburg, Germany). Results were reported in mg gallic acid equivalents (GAE)/L dry weight basis.

2.5. Microbial analysis

The quantification of total aerobic mesophilic bacteria, and yeasts and molds total plate count technique outlined by Yanclo et al. [2] was used. Each dried sample (10 g) was obtained aseptically and homogenized with 90 mL of sterile physiological solution (PS). Further threefold dilutions were prepared using 1 mL of diluents into 9 mL of PS. To quantify the microbes, 1.0 mL of each dilution was pour plated onto plate count agar and potato dextrose agar. Plates were incubated for 48 h at 37 °C and for 3–5 days at 25 °C, for aerobic mesophilic bacteria and yeast and mould, respectively. The colony forming units (CFU) were counted within the range of 25–250 and transformed to Log CFU/g. The experimental procedure was replicated in triplicate per dilution, resulting in of 9 replicates ($n = 9$).

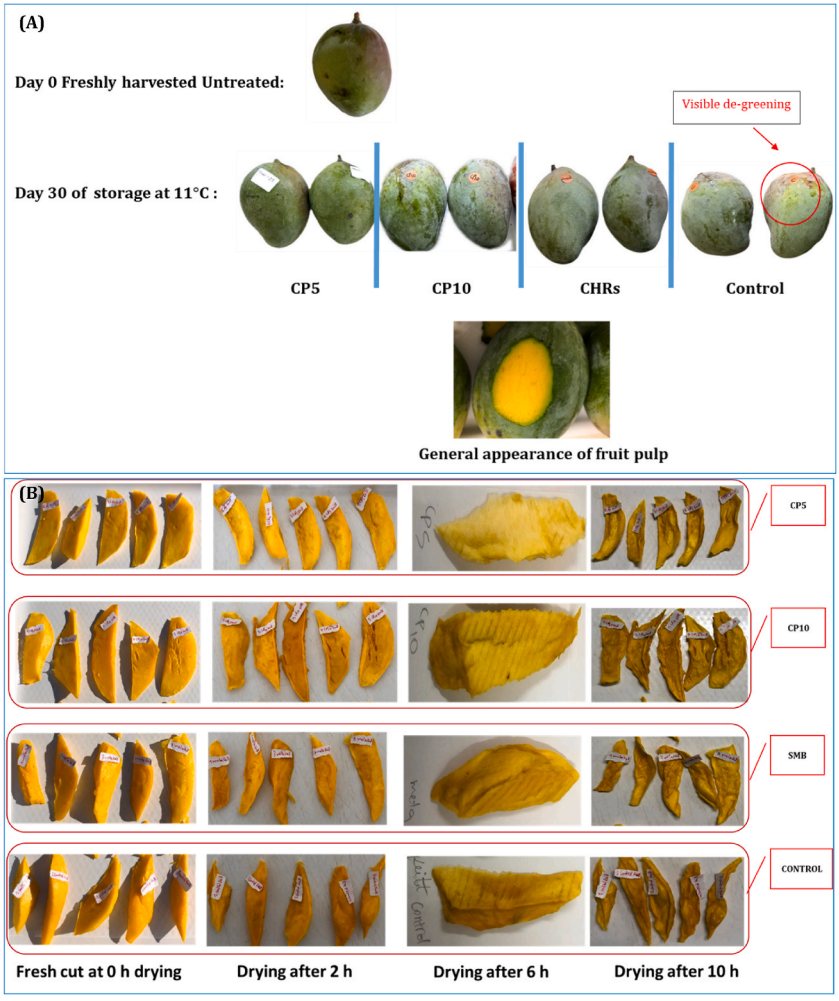

Fig. 1. **(A)** Visual changes in pre-treated whole mango fruit during 30 days of storage at 11 °C, and **(B)** pretreatments combined with hot air drying at 60 °C, on colour attributes of 'Keitt' sliced mango fruit. CHRs = Chronos treated whole fruit, CP5 = Cold plasma treatment for 5 min, CP10 = Cold plasma treatment for 10 min. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

2.6. Statistical analysis

Data analysis was conducted with SAS software (Version 9.4; SAS Institute Inc, Cary, USA) using the General Linear Models Procedure (PROC GLM). Effects experimental factors were examined via analysis of variance (ANOVA). To separate mean values of the measured variables, the Fisher's least significant difference (LSD) test was employed $p \leq 0.05$. All the results were presented as mean ($n = 6$) ± standard error.

3. Results and discussion

3.1. Visual colour change

Visual observation showed that after 30 days of storage at 11 °C, the whole mango fruit mesocarp changed slightly for the CP-treated samples, however, the control samples increased more in de-greening (Fig. 1A). Whole fresh mango pretreated with "Chronos" showed an increase in de-greening at the end of cool storage compared to the untreated (control), which showed gradual yellowing of the mesocarp as annotated in Fig. 1A. According to Hu et al. [20], "Chronos Prochloraz" pretreatment prior to storage could reduce pigment degrading enzyme activity, therefore helping to maintain the natural color of the mango fruit. According to Amorim et al. [21] CP treatment may promote the degradation of chlorophyll resulting in a lighter appearance of the fruit. This was consistent with the observation in this study.

3.1.1. Lightness of fresh pulp and dried 'Keitt' mango

Lightness, a key color and first quality attribute is crucial for consumer perception and acceptance. L^* values signify lightness ranging from black (0) to white (100). After 30 days of storage, the fresh-cut mangoes pretreated with CP5 and CP10 exhibited a significant ($p \leq 0.05$) increase in L^* values compared to the baseline prior to storage (56.51 ± 1.23) and the control (58.49 ± 2.17) (Table 1). Previous studies on the application of CP for 3 min at 75 kV on 'Hongyu' mango indicate a higher retention in L^* values [10]. Likewise, Lacombe [22] reported that L^* values increased significantly for blueberries fruit pretreated for 120s with cold plasma at 47 kHz, 549 W. These results suggest that cold plasma could play a potential role in preserving the natural lightness of the fruit. This phenomenon can be attributed to the interaction between the reactive species generated by cold plasma [23] and the biochemical components of the mango tissue, influencing pigments and cellular structures responsible for light reflection [24].

After drying the mango slices the colour attributes revealed significant increase in the lightness of the dried slices compared to fresh cut baseline and CP5, but the L^* value obtained in samples dipped in SMB, CP-treated and control were relatively similar (Table 1). Sulfite-based treatments, due to their anti-browning properties, positively impact the L^* value of dried mango slices [25], but it was comparable to CP-treated samples in this study. A similar increase in L^* values was noted in hot air-dried chili pepper pretreated with cold plasma with a frequency of 20 kHz and 750 W [26]. Cold plasma can induce structural modifications in the cellular components of fresh mango tissue due to etching of the reactive species generated. These modifications may include changes in cell wall integrity, cell membrane permeability, and intercellular organization [27]. Furthermore, hot air drying reduces the presence of surface moisture that can facilitate biochemical reactions, hence, the possibilities for the inhibition of enzymatic and non-enzymatic browning, contributing to increased color lightness.

3.1.2. Yellowness of fresh and dried 'Keitt' mango

The b^* values are denoted as blue to yellow color range with the $-b^*$ values representing blue colors and $+b^*$ values yellow colors [28]. Thus, the yellowness of fresh mango pulp increased significantly ($p \leq 0.05$) at end of storage for samples pretreated with CP10 (46.74 ± 1.92) and Chronos (46.93 ± 2.43) compared to CP5 and control, which not statistically different from the baseline freshly harvested samples (Table 1). Similar response was noted for 'Hongyu' mango pretreated with dielectric barrier discharge for 3 min at 75 kV, exhibited higher retentions of b^* value as reported by Yi et al. [10]. A further increase in b^* values was recorded across all the dried slices ($p \leq 0.05$), with sample pretreated with SMB retaining the highest b^* value (64.90 ± 1.65) in comparison to CP5 (55.01 ± 3.34) with the lowest value ($p \leq 0.05$) as shown in Table 1. The $+ b^*$ value is also indicative of the typically yellowish color of the mango pulp as highlighted by Nyangena et al. [29] and as shown with Fig. 1B.

Table 1
Effect of pre-treatments and storage duration on colour attributes of fresh pulp after 30 days at 11 °C and dried mango 'Keitt' slices.

'Keitt' mangoes	Duration	Redness (a^*)	Yellowness (b^*)	Lightness (L^*)	Chroma (C^*)	Hue angle (h°)	TCD
Harvest (Day 0)	Baseline	0.65 ± 0.32^{e}	38.53 ± 1.73^{e}	56.51 ± 1.23^{d}	38.27 ± 1.04^{e}	81.95 ± 2.84^{c}	0^{c}
Post storage (Day 30)	CP10 min	1.83 ± 0.48^{cd}	46.74 ± 1.92^{d}	63.33 ± 2.02^{ab}	46.80 ± 1.89^{d}	87.55 ± 2.19^{ab}	9.77 ± 1.50^{b}
	CP5 min	3.18 ± 0.61^{bc}	40.16 ± 1.57^{e}	57.16 ± 1.40^{cd}	40.32 ± 1.52^{e}	86.22 ± 1.82^{ab}	5.24 ± 1.09^{c}
	Chronos	0.90 ± 0.53^{de}	46.93 ± 2.43^{d}	64.16 ± 1.38^{a}	46.99 ± 1.71^{d}	89.68 ± 2.13^{a}	13.58 ± 1.97^{a}
	Control	3.70 ± 0.82^{b}	39.88 ± 2.59^{e}	58.49 ± 2.17^{cd}	40.15 ± 2.51^{e}	84.11 ± 1.24^{bc}	4.64 ± 1.30^{c}
Dried samples	CP10 min	5.68 ± 0.61^{a}	58.66 ± 2.67^{bc}	62.17 ± 1.43^{abc}	60.52 ± 2.10^{b}	83.68 ± 0.83^{c}	8.08 ± 4.24^{abc}
	CP5 min	3.40 ± 0.70^{b}	55.01 ± 3.24^{c}	63.63 ± 1.87^{ab}	55.01 ± 2.94^{c}	86.05 ± 1.03^{b}	8.11 ± 1.11^{ab}
	SMB	6.12 ± 0.66^{a}	64.90 ± 1.65^{a}	64.05 ± 1.06^{a}	66.93 ± 2.60^{a}	83.89 ± 1.69^{bc}	12.56 ± 4.26^{ab}
	Control	6.86 ± 0.40^{a}	62.61 ± 0.56^{ab}	61.66 ± 1.11^{bc}	62.91 ± 1.06^{b}	84.81 ± 2.43^{abc}	11.09 ± 4.18^{ab}

Mean ± S.E. presented. Mean values in the same row followed by different letter (s) indicate significant difference ($p \leq 0.05$) according to LSD test.

Notably, SMB acts as an antioxidant and inhibits the activity of enzymes like polyphenol oxidase (PPO), which catalyse the oxidation of phenolic compounds in fruits. By inhibiting enzymatic browning, SMB prevents the formation of dark-colored compounds, allowing the natural yellow pigments in mangoes, such as carotenoids, to be more prominent [30]. In addition, CP treatment can prevent oxidative reactions that lead to colour changes in mango fruit [31]. Particularly ROS, can scavenge and neutralize free radicals and reactive intermediates responsible for oxidation. By reducing oxidative stress, CP helps to maintain the natural yellow colour of the fruit. In addition, CP can modify the surface properties of mango fruit and dried slices, leading to improved yellowness attributes [2, 13], and alter the surface hydrophilicity of the fresh fruit, which can influence moisture absorption [29]. During hot air drying, moisture is removed from the mango slices, leading to a concentration of pigments present in the fruit [2]. As water is evaporated, these pigments become more concentrated, resulting in a more intense yellow color in the dried mango slices. Overall, sodium metabisulphite and CP treatment influenced the color lightness of dried mango slices by inhibiting enzymatic browning through PPO inhibition, scavenging free radicals, and protecting against non-enzymatic browning reactions. These mechanisms collectively help preserve the natural color and visual appeal of the dried mango slices.

3.1.3. Red-green value of fresh and dried 'Keitt' mango

The a^* scale describes colour change from ($+a^*$, red) to ($-a^*$, green) [28], and notably the redness values for fresh-cut mango (pulp) were significantly lower in comparison to the dried slices ($p \leq 0.05$). At the end of storage, the lowest a value was recorded for samples pretreated with Chronos (0.90 ± 0.53), followed by CP10 (1.83 ± 0.48) compared to CP5, and control samples (Table 1). Consistent with previously reported studies a^* value increased in hot-air-dried 'Heidi' mango [2], and fresh-cut mango cubes [10]. Yanclo et al. [2] observed higher a^* value across all the surface of hot-air-dried 'Heidi' mango slices compared to the fresh baseline samples (-2.92 ± 0.86). The authors suggested that increase in a^* value after drying could be due to non-enzymatic browning consequences that lead to redder surface or slightly darkened samples. Thus, the increase in $+a^*$ value could be considered as an indicator of browning at the end of drying for fresh-cut fruits.

3.1.4. Chroma and hue angle of fresh and dried 'Keitt' mango

Higher C^* values suggest more intense colors, and in this study the pulp of pretreated fresh 'Keitt' mango exhibited higher C^* values for CP5 (40.32 ± 1.52) and CP10 (46.80 ± 1.89) compared to the untreated control after 30 days of storage at 11 °C as well as the untreated baseline prior cold storage (38.27 ± 1.04) (Table 1). The results suggest that CP could enhance chroma by promoting pigment synthesis or inhibiting color degradation processes [32,33]. Fresh mango pretreated with Chronos prochloraz showed the highest chroma values (46.99 ± 1.71) compared to the baseline and CP treated fruit. These results suggest that Chronos Prochloraz treatment extends the shelf-life of fresh 'Keitt' mangoes by inhibiting fungal growth and delaying senescence processes therefore maintaining the color of the fruit (Fig. 1B). Fresher fruit tends to have higher chroma values due to the preservation of color compounds [34]. Furthermore, higher C^* values were observed for dried mango slices pretreated CP5 (55.01 ± 2.94), CP10 (60.52 ± 2.10) and with SMB (66.93 ± 2.60) compared to the fresh cut values prior drying (Table 1). Highest C^* value observed for SMB pretreatment dried slices suggests that the was effective in maintaining chroma intensity during the drying process. Sulphite compounds, such as sulphurous acid and sulphur dioxide, have antioxidant properties [35]. These compounds delay oxidative reactions, which can lead to color degradation in fruits during drying by inhibiting enzymatic browning, which occurs when enzymes such as polyphenol oxidase (PPO) catalyse the oxidation of phenolic compounds in fruits [36]. Therefore, by inhibiting oxidation, SMB helps preserve the natural color of the mango slices as shown with Fig. 1B.

Additionally, h° values showed an increase in pretreated fresh samples compared to the baseline before cold storage, the highest value being Chronos treatment (Table 1). With a hue angle of 0° corresponding to red, 90° to pure yellow and 120° representing green, the observed changes in this study indicate an intensification of orange color and an increase in the browning [37]. All measured fresh pulp and dried 'Keitt' mango slices were closer to the 90° compared to the untreated fresh cut baseline (81.95 ± 2.84). Overall, based on h° yellowness was better preserved in dried 'Keitt' mango slices pretreated with CP5 followed by CP10 and SMB. Changes in hue angle can serve as a quality indicator for mangoes [38]. Monitoring hue angle variations over time can help assess the effectiveness of the treatment in preserving fruit color and identify any potential issues related to color stability or degradation during storage.

3.1.5. Total color difference (ΔE) of fresh and dried 'Keitt' mango

Highest total color difference (ΔE) for fresh mango fruit pulp was found in mango pretreated with Chronos (13.58 ± 1.97) followed by CP10 (9.77 ± 1.50) and CP5 (5.24 ± 1.09) which showed lower ΔE values compared to the control (4.64 ± 1.30) (Table 1). In the dried slices, SMB had the highest value (12.56 ± 4.26) followed by CP5-pretreated slice (8.11 ± 1.11) and CP10 (8.08 ± 4.24). A higher ΔE indicates a more pronounced shift or alteration in color attributes from fresh to dried fruit samples [39]. Likewise, the decline in ΔE observed in 'Keitt' dried mango slices in our study could be attributed to the inactivation of enzymes responsible for browning in fruit samples that underwent pretreatment. Enzymatic browning occurs when enzymes like polyphenol oxidase (PPO) catalyse the oxidation of phenolic compounds, resulting in the formation of brown pigments [40]. By inhibiting enzymatic browning, these pretreatment methods can help preserve the original color of the mangoes, leading to a decrease in ΔE as shown with Fig. 1B. This decrease in ΔE may be linked to the breakdown of polyphenols and other bioactive compounds in the CP-pretreated samples with shorter drying times, as proposed by Cao [41].

Studies by Zhou [42] indicate a decline in the total color difference by 18–27 % of dried wolfberry pretreated with atmospheric pressure plasma, at 20 kHz and 750 W. Furthermore, the results observed in this study emphasize the effectiveness of Chronos and SMB used in industry as pretreatment in retaining color attributes of fresh and dried fruits respectively compared to cold plasma pretreatment. However, it is worth noting that CP treatment also achieved improved color retention after long cold storage period

compared to the untreated control. Further research is needed to elucidate the specific mechanisms involved and optimize cold plasma treatment parameters for enhancing the color quality of fresh and dried 'Keitt' mango fruit.

3.2. Biochemical quality attributes

3.2.1. Total soluble solids

After 30 days of storage the total soluble solids in fresh mango fruit increased slightly but statistically significant across all treated and control compared to the initial TSS prior cold storage (Table 2). Control samples had the highest TSS (15.06 ± 0.32), while CP10 pretreated fresh 'Keitt' fruit had the lowest value of TSS (13.80 ± 0.06°Brix) at the end of cold storage after 30 days, indicating a decline which could be attributed to stress due to the longer duration of CP treatment. Similarly, Wu et al. [43] observed a decline in TSS of mango fruit pretreated with dielectric barrier discharge at 50 V of input voltage and a 10 kHz of frequency.

For the dried mango slices TSS was significantly higher with compared to the fresh cut control after the 30 days. Dried CP10 samples had the highest value (Table 2). These results suggest that CP and drying improved the TSS contents of dried mango slices. CP is a highly reactive mixture of ions, electrons, radicals, and UV photons [44]. Oxygen radicals (such as O, OH, O_3) generated during cold plasma can react with sugars present in the mango slices leading to the formation of carbonyl compounds, carboxylic acids, and other oxidation products [45]. The results of the work on jujube slices pretreated with CP prior hot air drying also showed an increase in TSS of CP pretreated samples [13]. They suggested that this increase might be linked to the formation of a protective layer on the surface of the fruit slices. This layer may help in retaining moisture and nutrients within the fruit, leading to an increase in TSS. Indeed, during the drying process of fruits, moisture content is significantly reduced and as a result, an environment that is less favourable for microbial growth and enzymatic activity is created, thus contributing to the preservation of the fruit [46]. These results show that CP could impact biochemical components in mango fruit (whole and dried slices) via various mechanisms, including surface modification, activation of metabolic pathways, enzyme inactivation.

3.2.2. Titratable acidity and pH

Titratable acidity of fresh mango increased significantly from baseline (0.10 ± 0.01 %) ($p \leq 0.05$) for pretreated and control samples (Table 2). The same pattern of increase was observed in the dried mango slices pretreated with CP10, CP5, and SMB compared to the initial baseline and control. Yanclo et al. [2] also observed an increase in the TA for dried mango slices in comparison to the baseline. Some enzymes involved in ripening may be inhibited by CP, enzymes responsible for the synthesis or retention of organic acids may be stimulated. This could lead to increased production or reduced degradation of organic acids, contributing to higher titratable acidity as observed in our study [47,48]. CP may help in maintaining the integrity of cell membranes and cell structures in the mango fruit. This can reduce leakage of organic acids from the cells, leading to better retention of acidity within the fruit tissue. Patel and Rao [47] proposed that the metabolism of acid as fruit ripens, results in the change of starch and organic acids to sugars, may be responsible for TA decline during postharvest. On the other hand, the synthesis of various acids linked to the rise in TA. This was demonstrated by the presence of citric acid in the dried mango slices.

A comparative analysis of pH values among freshly harvested 'Keitt' mango revealed that storage duration and treatments resulted in significant increase ($p \leq 0.05$) in pH across all samples at the end of storage, compared to the initial baseline values with a pH of 3.63 ± 0.13 (Table 2). In contrast, it was observed by Hosseini et al. [49] that CP had no effect on the pH of sour cherry, while Rana et al. [50] showed a decrease in the pH content for strawberries (cv. Duch) pretreated with CP at 260 V, and 50 Hz, for 30 min. At the end of the dehydration process, dried mango slices pretreated with SMB exhibited the highest increase in pH values (4.78 ± 0.15), followed by both CP-treated and control samples compared to the freshly harvested pH (Table 2). This increase in pH from the fresh cut state to the dried product can be attributed to the loss of water experienced by the mango samples during the drying process which led to concentration effects. As water evaporates from the fruit tissue, the concentration of solutes increases, potentially leading to a rise in pH [2]. Furthermore, hot air drying can induce structural changes in the mango slices, altering the accessibility of acidic groups to measurement techniques. While the actual concentration of acidic components may remain constant, changes in the structure of the mango slices can affect the pH measured in the dried product. This structural change can alter the availability of ionisable groups, affecting the buffering capacity and pH of the dried product. Hot air drying can disrupt the cellular structure of mango slices, leading to

Table 2
Effect of pre-treatments and storage duration on chemical attributes of fresh mango fruit 'Keitt' at harvest (baseline) and after 30 days of treatment and cold stored at 11 °C and dehydrated at 60 °C.

'Keitt' mangoes	Treatments	pH	TA (% citric acid)	TSS (°Brix)
Harvest (Day 0)	Baseline	3.63 ± 0.13^{e}	0.10 ± 0.01^{h}	13.09 ± 0.58^{e}
Post storage (Day 30)	CP10	4.06 ± 0.03^{d}	0.55 ± 0.01^{e}	13.80 ± 0.06^{e}
	CP5	4.63 ± 0.09^{ab}	0.48 ± 0.01^{f}	14.63 ± 0.03^{d}
	Chronos	4.67 ± 0.08^{a}	0.38 ± 0.003^{g}	14.43 ± 0.12^{d}
	Control	4.23 ± 0.07^{cd}	0.60 ± 0.00^{d}	15.06 ± 0.32^{c}
Dried samples	CP10	4.46 ± 0.15^{abc}	2.25 ± 0.01^{b}	18.00 ± 0.16^{a}
	CP5	4.46 ± 0.11^{abc}	2.23 ± 0.01^{b}	17.84 ± 0.84^{ab}
	SMB	4.78 ± 0.15^{a}	2.16 ± 0.01^{c}	17.40 ± 0.68^{ab}
	Control	4.40 ± 0.04^{b}	2.45 ± 0.01^{a}	16.88 ± 0.38^{b}

Mean ± S.E. presented. Mean values in the same row followed by different letter(s) indicate significant difference ($p \leq 0.05$) according to LSD test.

changes in permeability and the release of cellular contents, including organic acids [2,13]. It is possible that in case there is leakage of acids from the cells during drying process, the actual concentration of acidic components in the surrounding medium could decrease, leading to a higher pH. Also, some components in mango slices, such as sugars and organic acids, may undergo crystallization or solid-state reactions during hot air drying [51]. These changes in physical state and molecular arrangement can affect the mobility and accessibility of acidic groups, influencing the apparent pH measured in the dried product.

3.3. Bioactive compounds

3.3.1. Antioxidant activities

The initial FRAP content of whole 'Keitt' mango fruit at harvest was ≈948.07 mg TE 100/g and after 30 days of storage the FRAP content declined significantly (Fig. 2A). However, pre-treatments prior to storage did not influence the FRAP content decrease as no significant difference was observed amongst the treatments on day 30 (Fig. 2A). Similar trend of decline from harvest content after long term cool storage was observed for TEAC (Fig. 2B) and DPPH contents (Fig. 2C). Similarly, Yanclo et al. [2] observed a decline in antioxidants (TEAC, FRAP and DPPH) of low-pressure CP pretreated fresh 'Heidi' mangoes. Pretreatment of white grapes with dielectric barrier discharge at 80 kV for 4 min also indicated a decrease in antioxidants [52]. The decline in FRAP values of fresh mango fruit pretreated with Chronos suggests that Prochloraz, being a fungicide and active ingredient of Chronos pretreatment, may induce physiological changes in mango fruit that affect its antioxidant capacity [20]. These changes could include alterations in cellular metabolism, gene expression patterns related to antioxidant synthesis, or disruptions in cellular structures [20]. Furthermore, the decrease in FRAP of fresh mango fruit pretreated with CP can be attributed to reactive species generated during CP such as free radicals and ions, which can interact and may cause oxidative damage to antioxidant molecules, leading to their fragmentation or inactivation [53].

In contrast to the results observed in fresh 'Keitt' mango FRAP and DPPH were most sensitive to the impact of drying, while the concentration of TEAC increased significantly under CP5 and CP10 in comparison to the other treatments (Fig. 2B). This suggests that the interaction between pretreatments and drying may lead to synergistic effects on FRAP and TEAC activities in 'Keitt' mango fruit. Samples pretreated with CP10 exhibited the highest FRAP activity and TEAC compared to other treatments and control groups both in

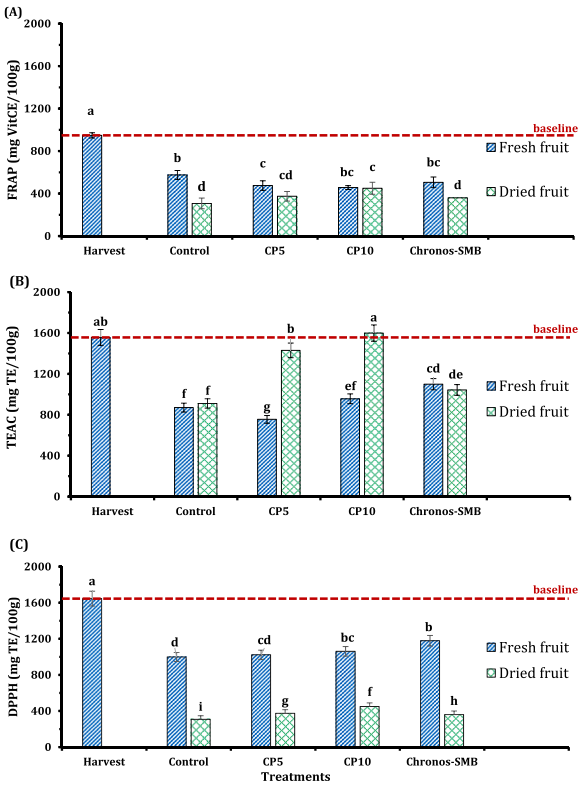

Fig. 2. Effects of cold plasma treatment (5 min, 10 min), Chronos, sodium metabisulphite and untreated control on: **(A)** Ferric Reducing Antioxidant Power (FRAP), **(B)** Trolox Equivalent Antioxidant Capacity (TEAC), and **(C)** 1, 1-Diphenyl-2-picryl-hydrazyl (DPPH) contents of fresh 'Keitt' mangoes stored at 11 °C and dried slices dehydrated at 60 °C. Error bars represent standard error of mean ($n = 6$) values of treatments. Continuous dashed line represents quantified value at harvest. Different lower-case letters indicate significant difference in mean values ($p \leq 0.05$). * *Colored graphs only available online.*

fresh and dried mango. These observations differ for CP pretreated and oven dried 'Heidi' mango slices reported by Yanclo et al. [53]. Samples pretreated with CP10 retained the lowest FRAP and DPPH activity compared to other treatments and control. Water acts as a diluent for antioxidants in fresh mango fruit [54]. By removing water through hot air drying, moisture is removed from mango slices and the antioxidants become more concentrated, which can result in a higher antioxidant capacity on a dry weight basis. Moreover, CP pretreatment modifies the surface properties of mango fruit, potentially leading to increased surface roughness or porosity [55]. This alteration can enhance the penetration of hot air during drying, facilitating the removal of moisture and allowing for more efficient heat transfer throughout the fruit [55]. Reactive species generated during CP, triggered biochemical responses in the fruit including the activation of antioxidant defence mechanisms, such as the synthesis of enzymatic and non-enzymatic antioxidants [7]. Additionally, CP under low-pressure conditions, may induce etching on the surface of the fruit which could lead to changes in the surface morphology, facilitating the release of antioxidants during hot air drying [13]. The reaction power of active species, such as hydroxyl radicals, may vary depending on factors like drying time. Higher reaction power could potentially lead to increase in antioxidant activity of fruit.

3.3.2. *Total flavanols, flavonols and phenols*

In comparison to the freshly harvested 'Keitt' mango fruit there was a significant increase in the total flavanols content after 30 days of cool storage at 11 °C. On the other hand, total flavanols declined significantly ($p \leq 0.05$) in all dried 'Keitt' mango slices compared to the initial fresh-cut value (Fig. 3A). Dried mango slices exhibited lower total flavanols in all the pretreated samples with CP5 (13.49 ± 1.64 mg GAE 100/g), CP10 (20.12 ± 1.42 mg GAE 100/g) and SMB (23.89 ± 3.35 mg GAE 100/g) compared to the fresh samples, but higher that dried untreated samples (6.68 ± 0.53 mg GAE 100/g) (Fig. 3A). This outcome suggests that CP and Chronos pretreatments effectively hindered the production of total flavanols during storage of fresh mangoes. Likewise, Obajemihi et al. [56] observed that by increasing exposure time (>2 min) and voltage (>50 V) resulted in a decline in flavonoids contents of tomato slices treated with cold plasma functionalized water. Similar observations were made by Pankaj et al. [52] in white grape pretreated with cold plasma. Oxidative stress occurs when there's an imbalance between the production of reactive oxygen species (ROS) and the plant's antioxidant defence system. Flavanols, being antioxidants, could be consumed in the process of scavenging ROS, leading to their decrease in content [2]. Moreover, drying combined with CP and SMB pretreatments successfully increased the production of total flavanols in dried pretreated mango slices compared to the untreated ($p \leq 0.05$). This is because CP treatment can cause damage to cellular membranes in fresh cut mango tissues and may result in the leakage of flavanols from the cells during the drying process, reducing their

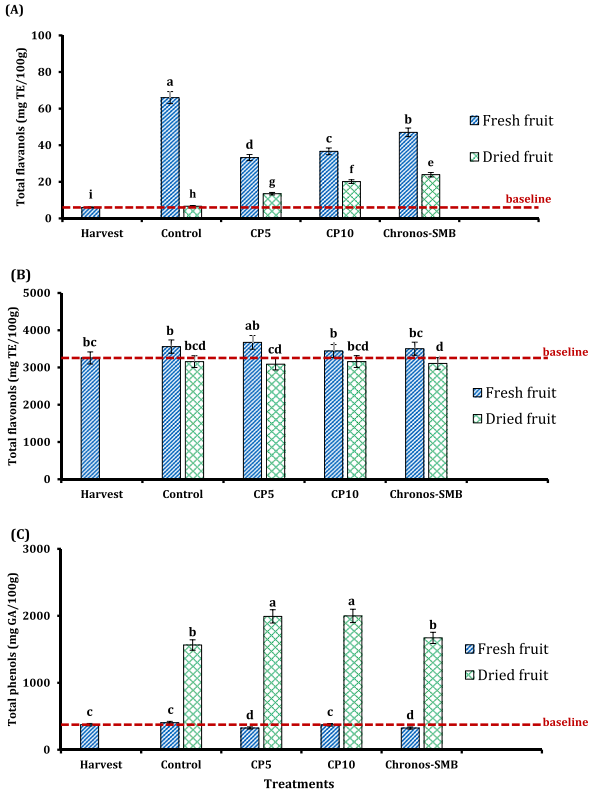

Fig. 3. Effects of cold plasma treatment (5 min, 10 min), Chronos, sodium metabisulphite and untreated control on **(A)** total flavanols, **(B)** total flavonols, and **(C)** total phenols contents of fresh 'Keitt' mangoes stored at 11 °C for 30 days and dried slices dehydrated at 60 °C. Error bars represent standard deviation (SD) of mean ($n = 6$) values of treatments. Continuous dashed line represents quantified value at harvest. Different lower-case letters indicate significant difference in mean values ($p \leq 0.05$). **Colored graphs only available online.*

retention in the final dried mango product. Likewise, the increase in TFA of dried mango slices could be explained by the sodium metabisulphite pretreatment inhibiting oxidation. Enzymatic browning is a common issue in fruits when they are exposed to air, leading to the degradation of certain compounds [57].

There was no remarkable difference in the total flavonols of fresh 'Keitt' mango fruit after 30 days of storage compared fresh samples ($p > 0.05$). Similar trend was observed in the total flavonols of dried mango slices dehydrated at 60 °C where no difference was observed amongst pretreated and untreated slices (Fig. 3B). Total phenol content of pretreated and untreated fresh whole 'Keitt' mango fruit did not changed significantly during storage (Fig. 3C), suggesting that TP was maintained. However, drying led to significant accumulation or increased TP ($p \leq 0.05$). In contrast, to the fresh mango fruits, 'Duch' strawberries pretreated for 15 min with atmospheric cold plasma dielectric barrier discharge at 60 kV with an input voltage of 260 V at 50 Hz showed a rise in total phenolic [50]. 'Shuijing' Pitaya pretreated for 5 min with dielectric barrier discharge cold plasma, at 60 kV, showed an increase in cutting-induced phenolic content [58]. Cold plasma technology, when combined with hot air drying at 60 °C, can stimulate the production of total phenols in dried mango slices through the reactive species produced which modify the surface properties such as wettability and surface tension of the mango slices [59]. This modification improves the penetration of water into the slices during the subsequent hot air-drying process. Enhanced mass transfer facilitates the extraction of phenolic compounds from the mango tissue, leading to higher concentrations of total phenols in the dried slices [2]. Moreover, CP induced structural changes in the cell walls of the mango slices which facilitate the release of phenolic compounds that are bound within the cell wall matrix, making them more accessible for extraction during drying [13]. As a defence mechanism against oxidative stress induced by CP, the mango slices may increase the production of phenolic compounds, such as phenols, flavonoids, and anthocyanins. Furthermore, during hot air drying, as water evaporates from the mango slices during the drying process, the phenolic compounds become more concentrated resulting in a higher proportion of phenols relative to the total weight of dried mango. As the mango slices are heated during dehydration process at 60 °C, the cell walls become more porous, facilitating the release of phenolic compounds [60]. This enhanced extraction efficiency ensures that a greater proportion of phenolic compounds are retained in the dried mango slices, leading to an increase in total phenols. Overall, CP combined with hot air drying at 60 °C promote the concentration, stabilization, and extraction of phenolic compounds from mango slices, resulting in higher levels of total phenols in the dried product.

3.4. Microbial analysis

Results indicated a significant reduction in microbial counts on the fresh mangoes for all treatments (Fig. 4A, B). Fresh untreated whole mango fruit (control) did not diver significantly from the freshly harvest samples but exhibited significantly higher load of aerobic mesophilic bacteria (2.90 ± 0.35 Log CFU/g) (Fig. 4A), and yeast and mould (4.01 ± 0.07 Log CFU/g) compared to CP5, CP10, and Chronos (Fig. 4B). Furthermore, our study showed that pretreatment with CP10 resulted in the lowest reduction ($p \leq 0.05$) in the microbial load in the treated whole fresh fruit (Figure 4A, B). These findings reinforce the literature that extended exposure to cold plasma treatment may effectively suppress microbial growth in fresh produce [61]. In the same manner, reduced bacterial counts from 5.12 Log CFU/kg to 0.33 Log CFU/kg were observed for blueberry pretreated with cold plasma at 45 kV, for 50 s [59]. According to Chen et al. [27], decline in bacteria count due to CP treatment could be associated with the different reactive species discharged, which

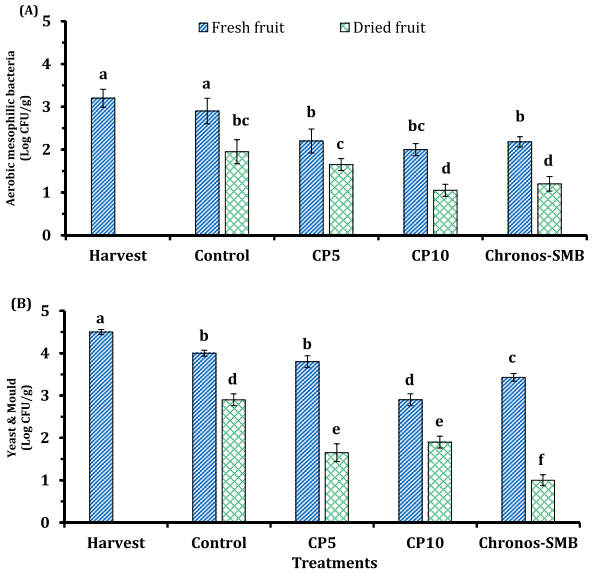

Fig. 4. Effects of cold plasma treatment (5 min, 10 min), Chronos, sodium metabisulphite and untreated control on total counts of aerobic mesophilic bacteria and yeasts and molds contents of fresh 'Keitt' mangoes stored at 11 °C and dried slices dehydrated at 60 °C. Error bars represent standard deviation (SD) of mean ($n = 9$) values of treatments. Different lower-case letters indicate significant difference in mean values ($p \leq 0.05$). *Colored graphs only available online.*

can damage cellular membrane and cause inactivation or death. In addition, cool storage is a widely employed method for preserving fresh mangoes and slowing down microbial spoilage [1]. In our study, storage of fresh mangoes at low temperatures, 11 °C, significantly slowed down or inhibited altogether metabolic activities of microorganisms. Combining CP pretreatment and cold storage at 11 °C minimized the risk of microbial proliferation and consequently, offered the strategy for preserving fresh mangoes against microbial spoilage.

Our study also showed that pretreatment with Chronos resulted in lower microbial count compared to untreated control (Fig. 4A, B). This suggests that Chronos pretreatment contributed to the decontamination of fresh mango fruit and comparable to the CP treatment. Prochloraz zinc complex is a fungicide, commonly used in agricultural applications to control fungal diseases in fruits, including mangoes [62]. Active component of Chronos solution could disrupt the cell membranes of microorganisms. This disruption can lead to leakage of cellular contents and eventual cell death. By compromising the integrity of microbial cell membranes, Chronos effectively decontaminates the surface of fresh mango fruit, reducing the microbial load [63]. Chronos Prochloraz solution contains antioxidants that exert oxidative stress on microbial cells by scavenging free radicals and reactive oxygen species, which can cause damage to microbial DNA, proteins, and lipids [64]. Although, combining cool storage with Chronos pretreatment offered a promising approach to preserving fresh mangoes against microbial spoilage and extending their shelf life. It is crucial move towards more sustainable treatment.

In our study, a decline in AMB and Y&M was observed in all 'Keitt' dried slices compared to the fresh untreated ones suggesting the efficiency of cold plasma and sodium metabisulphite pretreatment. SMB content was below detection limit for Y&M however, SMB is a stable compound that could persist on the surface of dried mango slices even after treatment and residues of the compound may remain on the surface of the dried mango slices [65]. Our study revealed that CP5 had the highest count of AMB compared to SMB suggesting that SMB and CP5 maintained the lowest microbial load. Moreover, pre-treating fresh-cut mango slice with SMB prior drying enhanced the destruction of potentially pathogenic bacteria. During drying process, moisture evaporation takes place, removing water from the mango slices [13]. The environment becomes less conducive to microbial development as the water content drops, preventing the growth of microorganisms due to hot air drying. Microbial cells on the surface of freshly cut mangos get dehydrated and become inactive or die when their cellular structure and metabolic functions are disrupted because of drying [66]. SMB has strong antimicrobial properties due to its ability to release sulphur dioxide gas when dissolved in water which has potent antimicrobial effects against a wide range of bacteria, fungi, and yeasts [67].

Combining CP-pretreatment with drying significantly decreased microbial count on dried mango slices when compared to control samples. The decline in microbial load may be attributed to the combined effects of increased drying temperature 60 °C and lower moisture content during the dehydration process. Furthermore, variables such as pH and moisture content can influence the effectiveness of various antimicrobial agents [68]. Additionally, CP generates reactive oxygen species, which collectively attack microbial cells [45]. Longer exposure times to CP for 10 min allow the reactive species generated by cold plasma to penetrate deeper into mango fruit, reaching areas where microorganisms may be present. Cold plasma treatment offers a natural, additive-free solution for microbial decontamination, ensuring that organic dried mango slices maintain their natural integrity and appeal while meeting rigorous food safety standards. The findings underscore the potential of cold plasma treatment as a valuable tool in controlling microbial proliferation, offering a promising avenue for improving the microbiological quality of 'Keitt' mangoes and potentially other fruits during storage, thereby ensuring a safer and longer-lasting supply of these tropical delights.

4. Conclusion

This study investigated the effects of long-term cool storage and cold plasma treatment on the quality of both whole fresh and dehydrated 'Keitt' mango during storage. The findings revealed the effectiveness of low-pressure cold plasma and showcased its potential to maintain storability and quality of mangoes. Cold plasma for 10 min demonstrated color retention (especially lightness and yellowness). The $+b^*$ value was indicative of the yellowish color of the dried mango slices. CP treatment retained and increased biochemicals, and bioactive contents in the dried 'Keitt' mango. Furthermore, pretreatment with CP10 had the lowest microbial count of the whole fruit, which further extended into drying. The effectiveness was comparable to existing industry practices, underscoring the importance of exploring alternative or extended treatment durations to achieve more significant reductions in microbial loads while maintaining fruit quality. Further research is needed to characterize the impact of cold plasma treatment and handling practices on the non-culturable microbial population associated with mango fruit.

CRediT authorship contribution statement

Loriane A. Yanclo: Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Zinash A. Belay:** Writing – review & editing, Supervision, Resources, Methodology, Formal analysis, Conceptualization. **Buhle Mpahleni:** Software, Resources, Methodology, Data curation. **Feroza October:** Visualization, Software, Resources, Methodology. **Oluwafemi James Caleb:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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