Universiti Malaysia Terengganu Journal of Undergraduate Research
Volume 3 Number 2, April 2021: 13-24
eISSN: 2637-1138

THE EFFECTS OF NITROGEN AND CARBON DIOXIDE GASES IN REDUCING THE PRICKLING AND TINGLING SENSATIONS IN FRESH-CUT PINEAPPLE (*Ananas comosus* L cv. Morris)

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http://doi.org/10.46754/umtjur.2021.04.002

Abstract: Fresh-cut pineapple has experienced an increase in demand due to its great health benefits and is rich in vitamins A, B and C. Moreover, pineapple is known as a source of the enzyme bromelain, which has therapeutic applications, such as reducing inflammation, improving digestion and treating osteoarthritis. However, bromelain generally affects the pineapple's flavour and is less preferred by consumers due to the uncomfortable prickling and tingling sensations it brings. In the present study, two types of gases and their combination, nitrogen (N_2) and carbon dioxide (CO_2), were used to evaluate their impacts on reducing the tingling and prickling sensations, as well as maintaining the postharvest qualities of fresh-cut pineapple stored at 5°C for 12 days. The parameters being evaluated were the bromelain enzyme activity, flesh colour, ascorbic acid concentration, flesh firmness, soluble solids concentration (SSC), titratable acidity (TA) and sensory evaluation. No significant differences were recorded for all parameters tested. Based on the sensory evaluations, all the attributes, such as colour, aroma, texture, sweetness, sourness, tingling and prickling sensations, and overall acceptance were not affected by the different gases application. Even though no apparent effect was observed, the 30 panellists preferred the aforementioned attributes, except sourness. In conclusion, the fumigation treatments with N_2 and CO_2 gases were not effective in reducing the tingling and prickling sensations of pineapples cv. Morris.

Keywords: Prickling, tingling, organoleptic, postharvest, quality

Introduction

The pineapple (*Ananas comosus* L.) belongs to the Bromeliaceae family and is commonly cultivated in most tropical and subtropical countries, including Malaysia (Carlier, *et al*., 2010; Avallone *et al*., 2003). In Malaysia, pineapples are mostly cultivated in Johor because of the enriched peat soil, which is suitable for their growth. It has been reported that 15,649 hectares of land in Malaysia is planted with pineapples, with the total production estimated at 355,000 metric tonnes (Thalip *et al*., 2015). Fresh pineapple contributes 70% and 3% of the total production for the local and export markets, respectively. Meanwhile, 95% of canned pineapple productions are for the export market, and the remaining 5% is for the domestic market (Malaysian Pineapple Industry Board, 2018). The modern lifestyle and purchase behaviour of ready-to-eat food could be another reason for the increasing demand for pineapple locally and globally. In Malaysia, there are many pineapple cultivars available, such as N36, Maspine, Morris Bentanggur, MD2, Morris Gajah, Gandul, Sarawak Green Local, Josapine, and Yankee (Hidayat *et al*., 2012).

Pineapple is consumed in many parts of the world as fresh fruit, juice, jam, jelly and dried products. Pineapple contains an important proteolytic enzyme, bromelain, which acts as anti-inflammatory agent, modulates tumor growth and blood coagulation, improves digestion and treats osteoarthritis, as well as debridement of third-degree burns. Moreover, it is a rich source of vitamins A, B and C, as well as several minerals, such as calcium, phosphorus and iron (Yuris & Siow, 2014). Even though the bromelain enzyme is highly beneficial to human health, it sometimes causes an uncomfortable sensation, such as prickling and tingling in the mouth, when consumed. Prickling can be defined as sharp and blunt taste, while tingling is the itching sensation on the tongue. The high content of bromelain in pineapples is less preferred by consumer due to the uncomfortable sensation, such as tenderness to the mouth, including the lips, tongue and cheeks. In addition, bromelain can also cause an allergic reaction to some people (Juan *et al.,* 2015). All these uncomfortable tastes may contribute to a high amount of food losses. In line with that, a suitable postharvest treatment should be conducted to reduce the sensation mentioned above of fresh -cut pineapple, particularly cv. Morris. Currently, there is no report available on reducing the bromelain enzyme activity or concentration in fresh-cut pineapple fruit. Many previous reports focused on reducing the browning and chilling injury symptoms on fresh-cut fruits by using various chemical-based treatments, such as methyl jasmonate (Gonzalez *et al.,* 2000), salicylic acid (Sayyari *et al.,* 2009), heat treatment (Sayyari *et al.,* 2011), nitric oxide fumigation (Singh *et al.,* 2009), wax edible coating (Qiuping & Wenshui, 2007) and 1-methylcyclopropene (1-MCP) (Salvador, 2004). Thus, the present study aims to reduce bromelain enzyme activities by the application of physical treatment using nitrogen (N_2) and carbon dioxide (CO_2) gases. The mechanism on how these two gases reduce bromelain activity is still unknown. However, these two gases may affect the bromelain enzyme activity by inhibiting the metabolic process during storage by decreasing the reactant and the product of respiration. Therefore, the tingling and prickling sensations could be reduced. However, the exact mechanism on how these uncomfortable sensations could be reduced using these gases warrant further investigation.

Materials and Methods

Plant Materials and Experimental Design

A total of 63 pineapples (*Ananas comosus* L cv. Morris) at maturity index stage 3 were used in the experiment. The pineapples were purchased from Pasar Gong Pauh in Kuala Terengganu. The experiment was conducted at the Post-Harvest Technology Laboratory, Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu. The experiment was arranged in a complete randomised design (CRD), with seven treatments, viz. i) 0 mL gas (serves as control), ii) 15mL of N_2 gas iii) 25mL of N_2 gas iv) 15mL CO_2 gas v) 25mL of CO_2 gas vi) 15mL of N_2 and 15mL of CO_2 gas vii) 25mL of N_2 and 25mL of CO_2 gas, with three replications. For each treatment, four pineapple wedges were represented as an experimental unit.

Preparation of Sample and Parameter Evaluations

A total of 7 plastic containers (20cm x 20cm) were used to place the pineapples wedges. All of the containers, knife, and cutting board were sanitised with 75% ethanol to avoid contamination to the samples. Then, each pineapple fruit was cut into wedges, 2cm thick and 3cm long. A total of 24 pineapple wedges were placed inside the plastic containers and sealed tightly using parafilm and cellophane tape to prevent the gas leakage. Next, the assigned N_2 and CO_2 gases and their combination were immediately injected into the plastic containers through an injection port and left for 20 minutes to enhance uniform absorption of the gas by the pineapple wedges. After 20 minutes, all the pineapple wedges were placed into 168 polystyrene trays, in which each tray consists of four pineapple wedges, and later wrapped using cling wrap. The packaged pineapple wedges were then stored in a chiller at 5ºC for postharvest quality assessments in three-day intervals, i.e. days 0, 3, 6, 9 and 12. The postharvest parameters such as the browning index, total phenolic content, flesh colour, ascorbic acid concentration, flesh firmness, Titratable acidity (TA) and Soluble solids concentration (SSC) were evaluated. The browning index of the fresh-cut pineapple was evaluated visually according to the score given by Ding et al. (2007). The score was given from

0 to 5, in which 0 = none (0-20% browning), 1= trace (20-40% browning), 2 = slight (40-60% browning), 3 = moderate (60-80% browning), 4 = severe (80% browning) and 5 = extremely severe (>100% browning). The flesh colour was measured using the Konica Minolta CR-400 reflectance colorimeter (Minolta camera Co. Ltd., Japan) according to the CIELAB colour parameters: L*, chromaticity a* and chromaticity b* (McGuire, 1992). L* represents the lightness coefficient, which ranges from 0 (black) to 100 (white). a* ranges from -60 to +60, in which +60 indicates the colour red and -60 indicates the colour green. b* also ranges from -60 to +60, but +60 represents the colour yellow, while -60 represents the colour blue. The a* and b* values were used to calculate the chroma value [C*= (a*2+b*2) 1/2] and hue angle (hº= tan-1 b*/a*). Chroma (C*) refers to the colour intensity, while the hue angle represents red-purple (0º), yellow (90º), bluish-green (180º) and blue (270º) angles. The total phenolic content of the fresh-cut pineapple was determined based on the method used by Singleton and Rossi (1965) with a slight modification. The AOAC (2004) method was used to determine the ascorbic acid concentration by using indophenol titration. Flesh firmness was measured using the TA.XT plus texture analyser (Stable Micro Systems, United Kingdom). A probe of P/2 stainless needle was used to penetrate the flesh of the pineapple with a test speed of 5 mm/sec and target distance of 10 mm. The soluble solid concentration was determined using a handheld refractometer, while titratable acidity was measured using the titration method, expressed as % of citric acid. For the measurement of bromelain enzyme activity, the method used was based on the one used by Mohan *et al.* (2016). A UV-vis spectrophotometer was used to determine the enzyme activity at 280 nm. Meanwhile, 30 panellists were selected for the sensory evaluation test. The sensory evaluation test of the pineapple was evaluated from the scores given by the panellists. The score given by the panellist were calculated to identify the level of overall acceptance and quality of the fruit (Aisyah *et al*., 2018)

Statistical analysis

The data were subjected to the one-way analysis of variance (ANOVA) using the GLM (General Linear Models) procedure with the SAS 9.1 software package, SAS Institute Inc, Cary, NC, USA. Treatment means were further separated by Tukey (HSD) for least significance at $p \leq 0.05$ (SAS Institute Inc, 1990).

Results and Discussion

The tingling and prickling sensations in the mouth when consuming pineapple come from the bromelain enzyme, which exists naturally in pineapples fruit. The bromelain enzyme in pineapple is widely known for its benefits in the pharmaceutical and food industries (Bhui, 2009). Even though bromelain in pineapple is beneficial to human health, the tingling and prickling sensations it causes has reduced consumers' decision to purchase the fruit. Among the 7 varieties of pineapple in Malaysia, cv. Morris has been reported to have a high level of bromelain compared with the others. In addition, Morris is normally canned, and not normally used for fresh consumption. In order to increase the demand for Morris among consumer, the tingling and prickling sensations it brings when consumed should be reduced. In the present study, the bromelain activity showed a fluctuating trend throughout 9-day experimental period (Figure 1). On days 0 and 3, the different gas treatments significantly affected the bromelain enzyme activity. However, the specific trend of the activity could not be deduced throughout the 9-day period. In addition, after day 3, the enzyme activities were similar among the treatments as no significant results were recorded. Zhan and Zhang (2005) claimed that N_2 gas can form gas hydrates after coming into contact with water molecules, which in turn reduces the water activity in fruit tissues and influences the structure of the enzyme. This could be the possible reason for the reduction of enzyme activity, thereby reducing the prickling and tingling sensations. Another reason could be due to the maturity stages of the fruit. As the storage period prolonged, the enzyme activity may also be affected. However, the exact mechanism of how the N_2 and CO_2 gases affected the prickling and tingling sensations was unknown. Thus, this warrants further investigation.

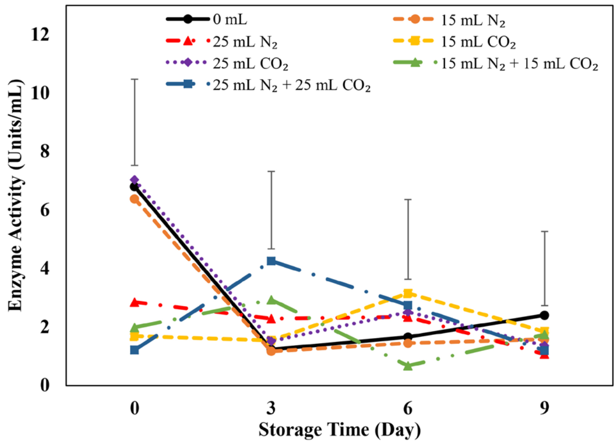

Figure 1: The effects of different volumes of nitrogen and carbon dioxide gases on bromelain enzyme activity of fresh-cut pineapple. The vertical bars represent Tukey at P≥0.05. (HSD value Day0=2.9511, Day3=2.6493, Day6=2.7232, Day9=0.71)

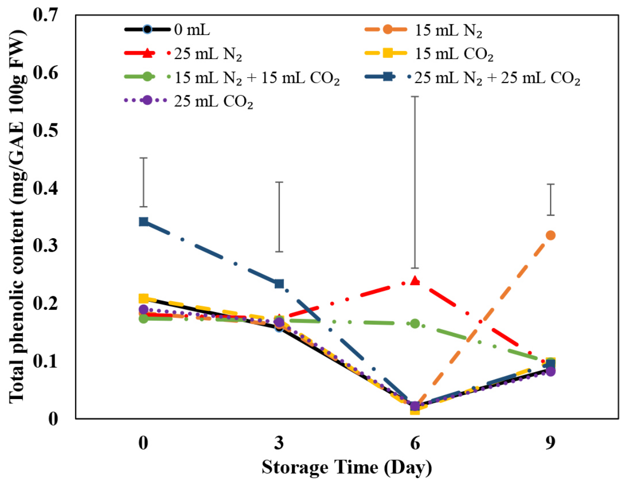

Figure 2: The effect of different volumes of nitrogen and carbon dioxide gases on the total phenolic content of fresh-cut pineapple. The vertical bars represent Tukey at P≥0.05. (HSD value Day0=0.08, Day3=0.13, Day6=0.30, Day9=0.05)

The different concentrations of N_2 and CO_2 either alone or in combination resulted in non-significant values on the total phenolic content (TPC) after fumigation throughout 9-day storage period. After day 3, the application of 25mL of N_2 and 25mL of CO_2 constantly showed a lower TPC after fumigation, compared with other treatments (Figure 2). In contrast, Wan Zaliha and Koh (2016) and Tan *et al*. (2017) claimed that 25% N_2 gas maintained and delayed TPC in fresh-cut carambola and pineapple, respectively. Wu *et al*. (2012) also reported the inhibitory effect of residual N_2 gas in microspores of pineapple wedges, which restricted the intracellular enzyme activity related to phenol degradation. They suggested that the TPC decreased with the oxidation of polyphenoloxidase (PPO) in the presence of oxygen, as the tissue senescence of pineapple wedges increased. Moreover, Alothman *et al*. (2010) reported that the decrease in the total phenolic content was due to the exposure time to ozone, which leads to the production of scavenging free radicals, which can initiate their protective roles (Yeoh *et al*. 2014).

Other postharvest qualities, such as colour, TSS, TA, firmness and ascorbic acid, were not influenced by the gas fumigation. Fruit colour is one of the most important postharvest parameters that usually affects consumer purchase decisions. In this study, fresh-cut pineapple treated with 15 mL of N_2 gas showed high value of lightness coefficient and low value of chromaticity b*, compared with other treatments in the 12 days of storage period. It is indicated that high value of L* and low value of b* showed the lowest rate of browning incidence (Table 1). Similar results were reported by Tan *et al*. (2017). They claimed that pineapple treated with N_2 gas fumigation maintained the pure yellow colour of the flesh throughout the storage period, with only a very mild browning. Similarly, Gil *et al*. (1998) suggests that the change in the total phenolic acid of minimally processed lettuce reduced browning when stored in high CO_2 levels. In contrast, low values of L* and high values of b* indicate the severity of browning incidence and darken the surface colour. The severity of browning incidence can be seen in fresh-cut pineapple treated with 15 mL of N_2 and CO_2. A study suggests that the change of colour in tomato, in which the skin and pulp increased in redness during storage, is closely related to the percentage weight loss caused by the dehydration process throughout the storage period (Khairi *et al*., 2015). In addition, Marrero and Kader (2006) claim that the decrease of colour (L* and b*) of fresh-cut pineapple during storage was due to the development of translucency.

Fruit firmness is an important criterion that influences the quality and freshness of the fruit. Fresh-cut pineapple treated with 15 mL N_2 tends to have a higher firmness value and is indicated as the most rigid and crisp among the treatments (Table 2). In contrast, Benitez *et al*. (2012) reported that the loss in texture might be a consequence of a decrease in cell wall turgor and lower enzymatic activity, as well as lower cell juice loss (Rocculi *et al*., 2005) caused by the N_2 gas throughout the storage period. The enzymes that are responsible for tissue softening are pectinesterase, polygalacturonase and beta-galactosidase (Rocculi *et al*., 2005). In addition, Budu and Joyce (2005) claimed that high concentration of CO_2 stimulate rapid senescence by causing physiological injury in the cellular compartment and sap leakage in the cell wall. A similar result was observed by Deng *et al*. (2007), in which the fumigation of CO_2 in Kyoho grapes was able to reduce the activity of cellulase, polygalacturonase and peroxidase. Another possible reason for the loss in texture is the processing of fruits by cutting and peeling (Saltveit, 2000). The hydrolysis of cell wall components during translucency development has also contributed to the loss in texture in papaya (Rivera *et al*., 2005; Karakurt & Huber, 2003), mango and pineapple (Martinez *et al*., 2002).

In the stage of minimally processed product development, storage conditions in maintaining desirable sensory characteristic while also preserve nutritive value include SSC and TA of the fruit. In the present study, SSC and TA (Table 2) of all treated fruit resulted in non-significant differences after the fumigation of N_2 and CO_2 gases. Similarly, Lau *et al*. (1997) reported that 20 mL CO_2 treatment had no influential effect on SSC of McIntosh apple (Lau *et al*., 1997). El-Rayes (2009) also found that CO_2 and N_2 had no effect on SSC. Similarly, Crisosto *et al*. (2002) reported that the application of high levels of CO_2 did not affect TA of seedless grapes. Meanwhile, the SSC value in tomato is lower when exposed to higher levels of CO_2 as the ripening rate is inhibited by high CO_2 concentration (Ali & Thompson, 1998). Therefore, the production of sugars, organic acids and other substances, which contributes to the TSS value of tomato, was inhibited. Hobson and Davies (1971) reported that higher levels of CO_2 prevented the production of sugars, organic acids and other chemicals, which are the main substance of SSC. In addition, the decrease of SSC, TA and ascorbic acid could be due to the damage of the cell structure caused by the cutting process. Moreover, the increase in metabolic activity also accelerates the decline of these quality attributes (Hodges & Toiyonen, 2008). The qualities of SSC and TA are closely related to the loss of ascorbic acid.

Ascorbic acid is a natural antioxidant compound that is highly susceptible to degradation (Sindumathi *et al*., 2017). Based on Table 2, pineapple treated with different concentrations of N_2 and CO_2 alone or in combination did not significantly affect ascorbic acid concentrations. In contrast, Wu *et al*. (2012) reported that the ascorbic acid content decreased with the increase in storage period, which is due to the degradation of ascorbic acid through oxidative processes. Moreover, enzymes, like ascorbate oxidase, might cause bruising of the tissue due to the amount of ascorbic acid in the presence of O_2.

Table 1: The effects of nitrogen and carbon dioxide gases on the flesh colour attributes of fresh-cut pineapples

Treatment/Day	0	3	6	9	12
Lightness (L*)					
0 mL	73.41[a]	73.48[a]	71.12[a]	69.99[a]	67.83[a]
15 mL N_2	60.46[a]	72.92[a]	73.55[a]	71.48[a]	69.48[a]
25 mL N_2	71.64[a]	71.38[a]	71.36[a]	70.62[a]	67.02[a]
15 mL CO_2	73.06[a]	72.20[a]	71.43[a]	66.64[a]	67.46[a]
25 mL CO_2	74.71[a]	71.46[a]	73.19[a]	70.39[a]	69.06[a]
15 mL N_2 + 15 mL CO_2	75.27[a]	69.62[a]	70.37[a]	67.31[a]	67.34[a]
25 mL N_2 + 25 mL CO_2	71.74[a]	72.35[a]	72.98[a]	69.73[a]	67.55[a]
$HSD_{0.05}$	25.95[ns]	4.64[ns]	7.29[ns]	8.90[ns]	6.42[ns]
Chromaticity a*					
0 mL	-3.52[a]	-2.70[a]	-2.06[a]	-0.36[a]	1.72[a]
15 mL N_2	-3.29[a]	-2.81[a]	-2.42[a]	-1.21[a]	0.59[a]
25 mL N_2	-3.83[a]	-3.03[a]	-1.69[a]	1.943[a]	4.76[a]
15 mL CO_2	-3.89[a]	-2.89[a]	-1.08[a]	-0.27[a]	3.83[a]
25 mL CO_2	-3.45[a]	-2.88[a]	-2.06[a]	0.23[a]	1.85[a]
15 mL N_2 + 15 mL CO_2	-4.63[a]	-2.66[a]	-1.52[a]	1.16[a]	4.38[a]
25 mL N_2 + 25 mL CO_2	-3.58[a]	-2.80[a]	-1.72[a]	0.09[a]	5.28[a]
$HSD_{0.05}$	2.45ns	1.09ns	1.96ns	3.26ns	3.59ns
Chromaticity b*					
0 mL	30.30[a]	23.26[a]	25.53[a]	26.06[a]	21.80[a]
15 mL N_2	30.44[a]	26.12[a]	24.69[a]	25.18[a]	19.98[a]
25 mL N_2	27.01[a]	23.51[a]	23.91[a]	23.51[a]	22.87[a]
15 mL CO_2	28.82[a]	20.48[a]	26.41[a]	22.73[a]	24.25[a]
25 mL CO_2	26.76[a]	23.78[a]	20.44[a]	25.89[a]	22.87[a]
15 mL N_2 + 15 mL CO_2	19.64[a]	19.81[a]	21.62[a]	23.06[a]	24.49[a]
25 mL N_2 + 25 mL CO_2	27.81[a]	22.04[a]	23.69[a]	24.85[a]	26.85[a]
$HSD_{0.05}$	9.26ns	7.86ns	10.92ns	7.72ns	6.08ns

Hue angle (h°)					
0 mL	-83.34 [a]	-83.38 [a]	-85.26 [a]	31.19 [a]	85.47 [a]
15 mL N_2	-83.85 [a]	-83.78 [a]	-84.03 [a]	-87.29 [a]	88.41 [a]
25 mL N_2	-81.91 [a]	-82.51 [a]	-85.93 [a]	85.55 [a]	78.29 [a]
15 mL CO_2	-82.18 [a]	-81.95 [a]	-87.51 [a]	-29.34 [a]	80.97 [a]
25 mL CO_2	-82.63 [a]	-83.08 [a]	-83.92 [a]	89.47 [a]	85.42 [a]
15 mL N_2 + 15 mL CO_2	-76.68 [a]	-82.25 [a]	-86.00 [a]	87.15 [a]	79.677 [a]
25 mL N_2 + 25 mL CO_2	-82.55 [a]	-82.52 [a]	-85.58 [a]	-30.18 [a]	79.14 [a]
$HSD_{0.05}$	5.545ns	3.49ns	6.09ns	183.68ns	7.5294ns

ns= not significant (p>0.05), **= very significant (p<0.05)

Table 2: The effects of nitrogen and carbon dioxide gases on flesh firmness, soluble solids concentration, titratable acidity and ascorbic acid concentration of fresh-cut pineapples

Treatment/Day	0	3	6	9	12
Flesh firmness (N)					
0 mL	3.078 [a]	2.95 [a]	3.37 [a]	2.00 [a]	1.95 [a]
15 mL N_2	3.276 [a]	1.84 [a]	2.11 [a]	2.47 [a]	2.47 [a]
25 mL N_2	2.815 [a]	3.49 [a]	2.56 [a]	1.95 [a]	2.37 [a]
15 mL CO_2	4.368 [a]	2.73 [a]	2.57 [a]	2.26 [a]	2.24 [a]
25 mL CO_2	3.437 [a]	3.13 [a]	2.59 [a]	2.11 [a]	2.05 [a]
15 mL N_2 + 15 mL CO_2	4.247 [a]	2.58 [a]	2.66 [a]	2.13 [a]	2.19 [a]
25 mL N_2 + 25 mL CO_2	4.749 [a]	2.20 [a]	3.34 [a]	1.87 [a]	2.22 [a]
$HSD_{0.05}$	4.48ns	2.14ns	2.60ns	1.07ns	0.71ns
Soluble Solids Concentration (%)					
0 mL	7.86 [a]	9.00 [a]	9.50 [a]	12.00 [a]	8.76 [a]
15 mL N_2	9.06 [a]	9.66 [a]	10.50 [a]	10.73 [a]	10.03 [a]
25 mL N_2	7.33 [a]	9.66 [a]	10.10 [a]	8.86 [a]	9.66 [a]
15 mL CO_2	9.40 [a]	12.00 [a]	11.10 [a]	11.30 [a]	10.06 [a]
25 mL CO_2	9.20 [a]	11.00 [a]	10.66 [a]	10.00 [a]	8.76 [a]
15 mL N_2 + 15 mL CO_2	9.53 [a]	12.00 [a]	9.40 [a]	11.33 [a]	9.70 [a]
25 mL N_2 + 25 mL CO_2	9.53 [a]	11.33 [a]	9.50 [a]	10.70 [a]	9.76 [a]
$HSD_{0.05}$	1.73ns	4.34ns	4.41ns	2.98ns	3.14ns
Titratable Acidity (% Citric Acid)					
0 mL	3.76 [a]	6.60 [a]	6.00 [a]	6.23 [a]	4.80 [a]
15 mL N_2	4.36 [a]	5.43 [a]	7.93 [a]	6.70 [a]	6.46 [a]
25 mL N_2	3.93 [a]	6.00 [a]	6.23 [a]	6.26 [a]	5.46 [a]
15 mL CO_2	3.66 [a]	6.06 [a]	6.66 [a]	5.66 [a]	5.70 [a]
25 mL CO_2	4.83 [a]	5.03 [a]	6.80 [a]	7.90 [a]	5.66 [a]
15 mL N_2 + 15 mL CO_2	4.50 [a]	5.93 [a]	6.33 [a]	5.90 [a]	4.96 [a]
25 mL N_2 + 25 mL CO_2	4.16 [a]	7.36 [a]	5.93 [a]	6.53 [a]	4.43 [a]
$HSD_{0.05}$	2.11ns	2.35ns	3.30ns	2.93ns	2.34ns

Ascorbic Acid Concentration (mg/g FW)					
0 mL	2.32 [a]	1.15 [a]	1.82 [a]	1.32 [a]	1.22 [a]
15 mL N_2	2.51 [a]	0.98 [a]	1.70 [a]	2.16 [a]	1.80 [a]
25 mL N_2	2.00 [a]	1.07 [a]	1.55 [a]	1.85 [a]	1.47 [a]
15 mL CO_2	2.01 [a]	1.18 [a]	2.02 [a]	1.74 [a]	1.48 [a]
25 mL CO_2	1.82 [a]	1.24 [a]	1.56 [a]	2.18 [a]	1.82 [a]
15 mL N_2 + 15 mL CO_2	2.36 [a]	1.28 [a]	1.93 [a]	1.69 [a]	1.33 [a]
25 mL N_2 + 25 mL CO_2	2.11 [a]	1.36 [a]	2.21 [a]	1.33 [a]	1.31 [a]
HSD0.05	0.81ns	0.43ns	1.11ns	0.92ns	1.21ns

ns= not significant (p>0.05), **= very significant (p<0.05)

Sensory assessment is related to the characteristics of the product and consumer preference (Costell, 2002). A total of 30 panellists were randomly chosen for the sensory evaluation. Based on the sensory evaluations, all the attributes, such as colour, aroma, texture, sweetness, sourness, the tingling and prickling sensations, and overall acceptance, were not affected by the different gas fumigations. Appearance and colour play important roles in the quality and freshness of fresh-cut pineapple. Most of the panellist preferred the colour attribute of the control, 25 mL CO_2 and 25 mL CO_2 and N_2 applications. Similarly, the CO_2 reduced the colour in fresh-cut cantaloupe and honeydew melon (Marrero & Kader, 2001). However, the results showed that the prickling and tingling sensations were less preferred by the panellists. Generally, the application of high levels of CO_2 could shift the aerobic metabolism to anaerobic and induce the accumulation of fermentative volatiles, like ethanol and lactic acid (Teles *et al*., 2014). This changes in the metabolism cause alterations in the aroma and produce off flavours in the fruit. According to Ares *et al*. (2009), the fruit starts to decay and ferment as the storage period increases. However, the increase in ethanol in this experiment did not affect consumer acceptance as most of the panellists still preferred all the attributes, except sourness.

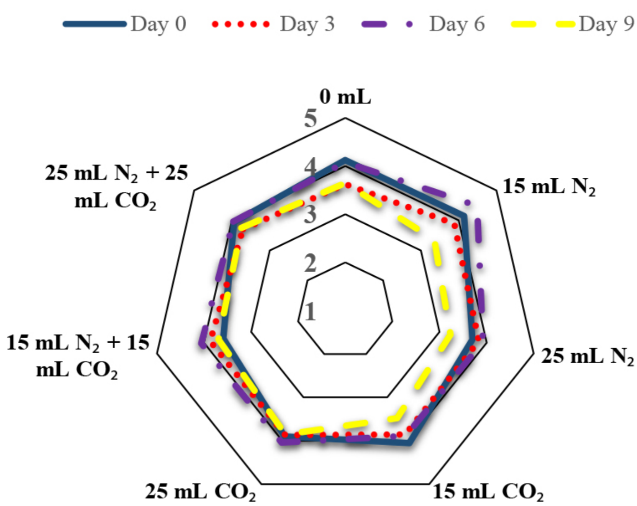

Figure 4: The effects of different volumes of nitrogen and carbon dioxide gases on the overall acceptability attributes of fresh-cut pineapple. The vertical bars represent Tukey at P≥0.05. (HSD value Day0=0.61, Day3=0.86, Day6=0.61, Day9=1.05)

Conclusion

N_2 and CO_2 gases were not effective in reducing bromelain enzyme activity in Morris pineapple, as well as the prickling and tingling sensations it brings when consumed. Similarly, all of the postharvest attributes were also not affected with both gases, either alone or in combination. On top of that, the panellists mostly preferred the taste, which might be due to the ripening condition of the fruit. For further study, it is recommended that different gases are used to effectively reduce the prickling and tingling sensations. Other than that, other chemicals and plant growth hormones could be used.

Acknowledgements

The authors wish to thank Universiti Malaysia Terengganu for the financial support and the staff members of Postharvest Technology Laboratory for their kind help.

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