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Research Application Summary

# The impact of maturity stage, time of harvest and storage temperature of pineapples on quality of MD 2 pineapple juice

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## Abstract

Pre and postharvest factors play an important role in pineapple juice quality and safety. In this study, the impact of maturity stage, time of harvest and storage temperature of pineapples on pineapple juice quality and safety were assessed using a completely randomized design. The results showed that juice prepared morning time of harvest caused an increase in total flavonoids while overripe pineapple juice had the highest total soluble solids (TSS). Storing fruits prior to juicing will also cause a significant increase in Total antioxidant capacity. Best juice quality from MD 2 pineapple was obtained from over-matured pineapples, harvested in the morning and stored in the refrigerator since it produced higher juice quality in terms of total antioxidant capacity (479.46 mg/kg), total flavonoids (10.3 mg/l), total phenolic content (77.04 mg/l), Vitamin C (40.75 mg/100 ml), TSS (14.07 % brix) and total titratable acidity (1.14 % citric acid).

Key words: *Ananas cosmosus,* flavonoids, juice, phenolic, storage, vitamins

## Résumé

Les facteurs avant et après récolte jouent un rôle important dans la qualité et la protection du jus d'ananas. Dans cette étude, l'impact du stade de maturité, du moment de la récolte et de la température de stockage des ananas sur la qualité et la protection du jus d'ananas a été évalué à l'aide d'un dispositif entièrement randomisé. Les résultats ont montré que le jus préparé le matin de la récolte provoquait une augmentation des flavonoïdes totaux, tandis que le jus d'ananas trop mûr avait les concentrations en solides totaux solubles (TSS) les plus élevées. Le stockage des fruits avant l'extraction du jus entraînera également une augmentation significative de la capacité antioxydante totale. La meilleure qualité de jus d'ananas MD 2 a été obtenue à partir d'ananas trop mûr, récoltés le matin et conservés au réfrigérateur car ils produisaient un jus de meilleure qualité en termes de capacité antioxydante totale (479,46 mg/kg), de flavonoïdes totaux (10,3 mg/l ), teneur totale en phénols (77,04 mg/l), vitamine C (40,75 mg/100 ml), TSS (14,07 % brix) et acidité titrable totale (1,14 % acide citrique).

Mots clés : *Ananas cosmosus*, flavonoïdes, jus, phénolique, stockage, vitamines

## Introduction

Pineapple (*Ananas cosmosus*) is among the most important commercial fruits of Ghana. It is processed into various products including pineapple juice. Pineapple fruit is an excellent source of vitamins and minerals and has varieties of different colour, flavor and texture.

Pineapple fruits are perishable and requires coordination of activities such as growing, storage, processing and retailing, in order to ensure quality and reduce food wastage. Several physicochemical modifications after harvest and microbial load lead to fast deterioration of pineapple after harvest. Environmental post-harvest conditions, particularly temperature, have a major impact on fruit quality visual, compositional, and eating parameters. Indeed, temperature is the component of the post-harvest environment which has the greatest impact on fresh fruit and vegetable quality. Harvesting pineapple fruits early in the morning safeguards against the sun (Ahmad and Siddiqui, 2015). Harvesting pineapple fruits early in the morning or late in the afternoon or at night, decrease the heat load on harvested fruits during precooling.

A significant determinant of many quality traits is the maturity stage of pineapple fruit at harvest. Pineapple, which is a non-climateric fruit, can be harvested during maturity at distinct phases. At the point where it is mature green, half mature, or red mature, it can be harvested. Each phase of pineapple fruit harvest has its postharvest attributes tand results in quality variability. Variables of maturity such as firmness, soil colour, starch breakdown, acid, sugars, ethylene, and carbon dioxide manufacturing are helpful indicators for identifying quality characteristics of fruit. Adikaram and Abayasekara (2012), indicated that when the peel color turns from green to yellow at the base of the fruit, then, the pineapple maturation stage is evident. Generally, the fruit becomes ready to harvest when 30–50 percent of the eyes turn yellow from the base.

Pineapple harvesting maturity may also differ based on the intent and destination of the market. For distant markets, it is best to harvest slightly early when it is 10-20% yellow or even 100% green but a mature phase, just before these striking modifications in color start. Preparing pineapple juice is one of the important ways to reduce the postharvest loss that the pineapple fruit may undergo. However, the short life of fresh pineapple juice tends to impede the growth of the domestic juice industry, and this is thought to be mainly influenced by the growth of microorganisms. Minimal studies have been conducted to understand quality and safety of pineapple juice, during postharvest and preharvest, about time of harvest, maturity stage, and storage temperature yet this is important sinse the fruits are metabolically active and undergo processes of maturation and senescence, which may need to be controlled in order to prolong the postharvest quality.

In many pineapple growing areas, the pineapple fruits are mostly cultivated with little or no idea of the effect of time of harvest, maturity stage, and variety on the quality of pineapple fruit and its effects on juice. The inability of pineapple producers to relate the importance of these factors often lead to the many fruit wastage in the pineapple sector. Also, pineapple fruit juice production in Ghana is beset with numerous problems including seasonality of production, insufficient fruit production although some are exported. This studt assessed the impact of maturity stage, time of harvest, and storage temperature of pineapple fruits on pineapple juice quality and microbial safety.

## Materials and Methods

Pinapple fruits of cultivar MD2 were obtained from Greenfields Limited at Ekumfi in the Central region of Ghana. The fruits were harvested in the Morning, Afternoon, and Evening at different ripening stages (unripe, half-ripe, and matured). Harvested fruits were sorted and cleaned to ensure that thre were no bruised ones. Subsequently, fruits were stored either at room temperature (25 ºC) or in a refrigerator (5 ºC) for three days prior juicing.

**Determination of physicochemical properties**. The pH of juice samples was recorded under ambient temperature condition using a digital pH meter. The juice sample was put in a 100 ml beaker, thoroughly stirred, and the electrodes of pH meter immersed in juice samples. The pH values were read from the screen of the pH meter. The pH of samples were taken after three days of storage for ten days.

Seperately, to determine the total soluble solids (TSS) of the pineapple juice, a digital refractometer was used. The obtained values were expressed in % Brix. The TSS of samples were taken after three days of storage for ten days. Also, Titratable acidity (TA) of the pineapple juice was obtained using a modified method of Association of Analytical Chemistry (AOAC, 1984). This was done by pipetting 10ml of the juice into a conical flask. 200 ml of 0.1N NaOH was poured into a burette and was titrated against the sample in the flask with three drops of phenolphthalein as an indicator. The obtained TA values was expressed as a percentage of citric acid (mole equivalent = 0.064). The formula used to calculate the titratable acidity was as follows:

% Titratable acid = (0.1 x 0.064 mL of 0.1 NaOH) x100/ mL (1)

To determine Vitamin C, 10ml of pineapple juice was pipetted and diluted to 100 ml. Sunsequently, 25 ml of the homogenized solution was pipetted into a 250 ml Erlenmeyer flask, and 10ml of 0.5M $H_2SO_4$ and 0.5 g $NaHCO_3$ was added. The solution was then titrated against the standard, $KIO_3$, until a deep blue starch complex was obtained.

**Total Phenolic Content**. To determine total phenol content of the pineapple juice, a modified spectrophotometric method as described by Lu *et al*. (2011) was used. 10ml fruits juice was diluted to 100 ml with distilled water and filtered from which 250 µL of the filtrate was pipetted into a colourimetric tube in triplicate. The 750 µL of distilled water was added, followed by 1ml of 10 fold diluted Folin Ciocalteau phenol reagent. After 5 minutes, 1.5 ml of 10% $Na_2CO_3$ was added to the mixture. The content was allowed to react for about 30 minutes in the dark after which the absorbance of the solution was read at 765 nm using UV mini 1240 (Shimazu Cooperation). A graph of standard calibration and unstandard calibration curve was plotted using Gallic acid equivalents in mg/100 mL juice.

**Total Antioxidant Capacity.** To determine total antioxidant capacity, ethyl acetate, methanol, and water extracts of pineapple juice was evaluated by the method of Prieto *et al.* (1999). An aliquot of 0.1 mL of sample solution (100 µg/mL) was combined with 1 mL of reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate). The tubes were capped and incubated in a boiling water bath at 95 °C for 90 minutes. After the samples had cooled to room temperature, the absorbance of the aqueous solution of each sample was measured at 695 nm against a blank. A typical blank solution contained 1 mL of reagent solution and the appropriate volume of the same solvent used for the sample, and it was incubated under the same conditions as the rest of the sample. For samples of unknown composition, water-soluble antioxidant capacity was expressed as equivalents of ascorbic acid (µmol/g of extract).

**Total flavonoid content.** The total flavonoid content was estimated using the colourimetric assay developed by Zhishen *et al*. (1999) with some modifications. As a procedure, 250 µL of the juice extract was pipetted into colourimetric tubes and mixed with 750 µL distilled water and subsequently 1ml of 5% w/v $NaNO_2$ was added. Therefore, 1ml of 10% $AlCl_3$ was added after 10 minutes incubation time followed by addition of 2.5 ml of 1M NaOH after 5 minutes. The final volume was made up to 6 ml with distilled water. The absorbance was read at 510 nm. The calibration curve was plotted using a standard solution of quercetin. The results were expressed as mg quercetin per L of juice.

**Statistical analysis**. In this study, General Linear Model (GLM) in Analysis of Variance (ANOVA) was performed in Minitab (Version 18.0) to determine the effects of maturity stage, time of harvest, and storage condition on physicochemical properties of MD 2. Tukey's test at $p< 0.05$ level was used to determine the significance between the treatment means.

## Results and Discussion

The results obtained are shown in Table 1 and 2. The stage of maturation is one of the factors which may influence fruit antioxidant activity (Fawole and Opara 2013). The antioxidant activity in the present study increased when the fruit ripening stage advanced. Maturity stage and time of harvest had a significant positive influence ($p \leq 0.05$) on Total antioxidant in MD-2 pineapple juice. Although there was an increase in Total antioxidant, as the fruit was maturing, there was inconsistency in Total antioxidant mean values. The research by Gordon *et al*. (2002) also found that the antioxidant activity was incoherent at various ripening stages in the acai fruit in accordance with its TPC. The overmatured pineapple fruit will lose their functional qualities, and therefore has a reduced antioxidant activity compared with matured fruit (Gruz *et al.,* 2011). There was no significant difference found at the unmatured, matured and overmatured stage of pineapple on total flavonoid contet but there was a decrease in total flavonoid as the fruit advanced in maturity. Fawole and Opara (2013) reported that overall flavonoids decreased with advances in maturity on pomegranate fruits.

Total phenolic content was observed to decrease as the fruit matured. These findings agree in part with the results reported by Gordon *et al*. (2012) that total phenol content decreased with ripening. Although the matured stage of pineapple was observed to record higher vitamin C content, the results obtained from the study was inconsistent. This agrees partly with the study by Arif *et al*. (2010), which determined the contents of vitamin C in berries at three different ripening stages. They found a higher concentration of vitamin C during matured stage. Acidity (pH) is an indicator of inner maturity and can be used to determine the best harvest time. The level of pH in the pineapple varied greatly with ripenesses. Generally, the pH increased as the fruit matures. The high content of TSS is desirable for processed fruits (Ercisli, 2007), making pineapples suited for processing with their remarkably high TSS content estimated at 12.7 oBrix. In addition, determination of obrix is a reliable way of determining maturity and best harvest time. In the course of fruit ripening and maturing, there is a change in total soluble solids, where for example the total soluble solid increased from mature green stage to yellow ripe stage. Titratable acidity has a distinct sour taste and flavour and is often seen as a reliable indicator of overall fruit quality (Bhat *et al*., 2011). From the study, it was observed that the titratable acidity of the Sugarloaf and Smooth Cayenne pineapple was not significantly influenced by maturity stage. On the other hand, MD-2 pineapple was influenced by maturity stage The titratable acidity increased significantly as the MD-2 pineapple fruit matured. This is consistent with the study on strawberries and mulberries (Mahmood *et al*., 2012).

## Conclusion

Harvesting MD-2 pineaple fruit in the morning resulted in an increase in total antioxidant content. It was observed that pH content in unripe MD-2 pineapple fruit juice was significantly higher as compared to pH level in both unripe and overripe juice. Also, evening time harvesting of MD-2 pinenapple fruit was observed to significantly increase TSS content to some extent. Best juice quality from MD 2 pineapple was obtained from over-matured pineapples, harvested in the morning and stored in the refrigerator since it produced higher juice quality in terms of total antioxidant capacity (479.46 mg/kg), total flavonoids (10.3 mg/l), total phenolic content (77.04 mg/l), vitamin C (40.75 mg/100ml), TSS (14.07 % brix) and total titratable acidity (1.14 % citric acid).

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**Table 1. Regression coefficients and $R^2$ values for General Linear Model for MD-2 pineapple juice**

| Response | $b_o$ | Maturity Stage ($X_1$) | | | Time of harvest ($X_2$) | | | Storage condition ($X_3$) | | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Unripe | Half-ripe | Overripe | Morning | After-noon | Eve-ning | Ambient | Refriger-ated | |
| Total antioxidant | 321.36 | **-28.8*** | 9.6 | 19.2 | 11.5 | -13.6 | 2.1 | **-35.21**** | **35.21**** | 0.9985 |
| p= | | 0.041 | 0.485 | 0.169 | 0.405 | 0.325 | 0.879 | 0.001 | 0.001 | |
| Total flavonoids | 6.203 | 0.248 | -0.197 | -0.052 | **0.572**** | **-0.640**** | 0.068 | 0.109 | -0.109 | 0.9468 |
| p= | | 0.170 | 0.275 | 0.773 | 0.002 | 0.001 | 0.705 | 0.389 | 0.389 | |
| Total phenol | 66.02 | 0.08 | 0.83 | -0.91 | 1.96 | **-3.79*** | 1.83 | 1.65 | -1.65 | 0.9193 |
| p= | | 0.964 | 0.650 | 0.619 | 0.285 | 0.041 | 0.316 | 0.202 | 0.202 | |
| Vitamin C | 34.47 | -2.29 | 4.00 | -1.71 | -1.93 | -0.01 | 1.94 | -0.84 | 0.84 | 0.1771 |
| p= | | 0.468 | 0.208 | 0.589 | 0.542 | 0.997 | 0.539 | 0.706 | 0.706 | |
| pH | 4.7343 | **0.0330*** | -0.0004 | **-0.0326*** | 0.0174 | 0.0002 | -0.0176 | **0.0224*** | **-0.0224*** | 0.9987 |
| p= | | 0.030 | 0.980 | 0.032 | 0.244 | 0.990 | 0.239 | 0.037 | 0.037 | |
| Total soluble sugars | 12.728 | **-1.394**** | 0.161 | **1.233**** | -0.178 | -0.228 | **0.406*** | **-0.391**** | **0.391**** | 0.9125 |
| p= | | 0.000 | 0.325 | 0.000 | 0.278 | 0.166 | 0.016 | 0.001 | 0.001 | |
| Titratable acidity | 0.9267 | **-0.0775**** | -0.0064 | **0.0838**** | -0.0289 | 0.0217 | 0.0072 | 0.0191 | -0.0191 | 0.7057 |
| p= | | 0.000 | 0.379 | 0.000 | 0.158 | 0.188 | 0.922 | 0.226 | 0.226 | |

**Table 2. Interaction effect of maturity stage, time of harvest and storage on physicochemical properties of MD-2 pineapple juice**

| Sample ID | TA | TF | TPC | Vit. C | pH | TSS | TTA |
|---|---|---|---|---|---|---|---|
| MD1 | 161.07 $^{k}$ | 7.33 $^{g}$ | 53.33 $^{i}$ | 14.16 $^{e}$ | 4.90 $^{a}$ | 10.00 $^{e}$ | 0.83 $^{c}$ |
| MD2 | 348.98 $^{d}$ | 10.34 $^{abc}$ | 75.08 $^{abcd}$ | 34.87 $^{bcd}$ | 4.80 $^{b}$ | 13.17 $^{abc}$ | 0.82 $^{c}$ |
| MD3 | 335.83 $^{ef}$ | 10.13$^{abcd}$ | 70.17 $^{abcdefg}$ | 29.88 $^{d}$ | 4.70 $^{c}$ | 14.07 $^{a}$ | 0.97 $^{abc}$ |
| MD4 | 222.56 $^{j}$ | 10.23$^{abc}$ | 75.86 $^{abc}$ | 34.63 $^{bcd}$ | 4.90 $^{a}$ | 10.00 $^{e}$ | 0.84 $^{c}$ |
| MD5 | 327.25 $^{f}$ | 8.03$^{efg}$ | 66.47 $^{cdefgh}$ | 38.81 $^{abcd}$ | 4.60 $^{d}$ | 13.33 $^{ab}$ | 0.94 $^{bc}$ |
| MD6 | 241.15 $^{i}$ | 8.86$^{def}$ | 64.01 $^{efgh}$ | 30.64 $^{cd}$ | 4.70 $^{c}$ | 13.33 $^{ab}$ | 1.21 $^{a}$ |
| MD7 | 284.31 $^{g}$ | 10.04$^{abcd}$ | 67.36 $^{bcdefg}$ | 37.59 $^{abcd}$ | 4.70 $^{c}$ | 11.33 $^{de}$ | 0.91 $^{bc}$ |
| MD8 | 286.78 $^{g}$ | 7.85$^{fg}$ | 65.83 $^{cdefgh}$ | 47.29 $^{a}$ | 4.70 $^{c}$ | 11.67 $^{cd}$ | 0.99 $^{abc}$ |
| MD9 | 367.36 $^{c}$ | 9.25$^{bcde}$ | 70.92 $^{abcde}$ | 34.75 $^{bcd}$ | 4.80 $^{b}$ | 14.13 a | 0.99 $^{abc}$ |
| MD10 | 263.74 $^{h}$ | 10.16$^{abcd}$ | 60.56 $^{ghi}$ | 33.88 $^{bcd}$ | 4.70 $^{c}$ | 11.67 $^{cd}$ | 0.76 $^{c}$ |
| MD11 | 408.23 $^{b}$ | 10.53$^{ab}$ | 71.67 $^{abcde}$ | 41.68 $^{ab}$ | 4.80 $^{b}$ | 12.33 $^{bcd}$ | 0.86 $^{c}$ |
| MD12 | 479.46 $^{a}$ | 10.30$^{abc}$ | 77.04 $^{ab}$ | 40.75 $^{abc}$ | 4.61 $^{d}$ | 14.07 $^{a}$ | 1.14 $^{ab}$ |
| MD13 | 484.35 $^{a}$ | 7.15$^{g}$ | 61.32 $^{fghi}$ | 38.83 $^{abcd}$ | 4.70 $^{c}$ | 12.00 $^{bcd}$ | 0.89 $^{bc}$ |
| MD14 | 283.39 $^{g}$ | 8.14$^{efg}$ | 65.08 $^{defgh}$ | 34.16 $^{bcd}$ | 4.80 $^{b}$ | 12.33 $^{bcd}$ | 0.92 $^{bc}$ |
| MD15 | 287.62 $^{g}$ | 5.69$^{h}$ | 40.63 $^{j}$ | 29.64 $^{d}$ | 4.70 $^{c}$ | 14.00 $^{a}$ | 0.89 $^{bc}$ |
| MD16 | 339.22 $^{df}$ | 11.02$^{a}$ | 78.16 $^{a}$ | 33.94 $^{bcd}$ | 4.70 $^{c}$ | 13.00 $^{abc}$ | 0.86 $^{c}$ |
| MD17 | 331.37 $^{ef}$ | 7.12$^{g}$ | 56.91 $^{hi}$ | 33.99 $^{bcd}$ | 4.70 $^{c}$ | 14.50 $^{a}$ | 0.99 $^{abc}$ |
| MD18 | 331.74 e$^{f}$ | 9.07$^{cdef}$ | 67.91 $^{bcdefg}$ | 30.88 $^{cd}$ | 4.70 $^{c}$ | 14.17 $^{a}$ | 0.86 $^{c}$ |
| CV % | 1.2 | 1.1 | 9.9 | 1.2 | 0.1 | 4.1 | 9.5 |
| $LSD_{0.05}$ | 6.167 | 0.06281 | 5.673 | 0.3296 | 0.00582 | 0.8587 | 0.1463 |

Values in each column with different letters indicate significant difference between each other according to least significant difference test

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