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Evaluation of the Changes in the Quality Indices (Firmness and Colour) of Varieties of Apples Stored At Different Temperature

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Abstract: *An experiment was conducted to investigate the possible changes that might occur in the two important quality indices (Firmness and Colour) of an apple fruit stored at room temperature and 4^oC over a period of seven (7) days. Four variety of apple; Braeburn, Granny Smith, Royal Gala and Cox were procured at the local store. The firmness of the apples was obtained by using a 2mm cylindrical probe on the Texture analyzer and the colour measurement was evaluated by using a chroma meter. This procedure was carried out on the apple before and after storing at the different temperature and results were expressed in Newton for firmness and L*, a*, and b* for colour respectively. Cox showed the highest loss in firmness among the apples stored at room temperature (from $1.91^a \pm 0.01N$ to $1.64^b \pm 0.01N$) while varying results were observed for the apples stored at 4^oC; the firmness for Cox and Braeburn surprisingly increased ($1.76^a \pm 0.01N$ to $1.82^b \pm 0.01N$ and $1.46^a \pm 0.02N$ to $1.57^b \pm 0.02N$ respectively), Granny smith showed no significant difference and Royal gala decreased. Also, the total colour difference ΔE*was observed for each temperature treatment for the apples. The ΔE* for apples stored at room temperature were significantly higher compared to those stored at 4^oC*

Keywords: *Apples, Colour, Firmness, Temperature*

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I. Introduction

There are several quality indicators such as appearance, size, shape, soluble solids content and firmness in the fresh-food industry that dictate the consumers' choice of a particular product over another (Gwanpua *et al*., 2013). In reference to apple, fruit firmness and colour among other properties are the quality indicators that are of importance to the stakeholders (plant breeders, post-harvest handlers, fruit processors and fruits suppliers).

The standard method of evaluating the firmness of fruits is the Magness –Taylor puncture test. This is a destructive method whereby the fruits sample undergo an irrevocably changes during the test, which is based on measuring the maximum force required to drive a cylindrical probe in the pulp of the fruit, up to a pre-defined distance (Bourne, 2002). Recent literatures have revealed the development of non destructive methods such as Light backscattering image, Hyper spectral scattering techniques, Electronic nose (Qing *et al*, 2008, Lu (2007). However, the above-mentioned methods have not been widely adopted in the fresh food industry because the correlation of results obtained from the non- destructive methods with MT puncture test has not been satisfactory. A typical example was the research carried out by Shmulevich *et al* (2003) who reported that Impact and sonic methods that were used on "Granny Smith", "Golden Delicious" and "Striking Delicious" varieties of apple correlated poorly ($R2 < 0.36$) with the M-T puncture test. Moreover, the high instrumental cost and complex calibration procedure of the nondestructive methods of evaluating fruits firmness is also a factor that has hindered its wide application.

In order to optimize the standard M-T puncture test on fruits, Sousa *et al* (2003) suggested that obtaining more than firmness from the M-T puncture test for fruit could further help the stakeholders in the industries better understand on how to monitor and ensure that quality of their fruits product is sustained during storage. It was then proposed that 2mm cylindrical probe should be used on unpeeled fruit against the 11.1mm cylindrical probe used for peeled fruits because, at one stroke, additional data such as skin toughness and pulp firmness are obtained and also it saves the time that would have been used in peeling the fruits.

The objective of this report is to observe changes in the firmness and colour of four varieties of apple stored at two different temperatures over a period of seven days using the 2mm cylindrical probe on the texture analyzer.

II. Materials and Methods

2.1 Materials

Four varieties of apple namely; Braeburn, Granny Smith, Royal Gala and Cox were purchased at the local fruits store. The selection was based Size, Shape, Colour and that no blemish was found on the sample.

2.2 Methods

The maximum peak force as an index of apple firmness was measured using 2mm diameter cylindrical probe (Sousa *et al* 2003) on the Texture Analyzer TA.XT Plus (Stable MicroSystem Ltd, Surrey, the UK using expert software version 1.61) with a load cell of 50N.

The colour analysis was done on the different varieties of apple using Konica Minolta CR-400 Chromameter and according to the procedure as described by (East *et al*.2008) using the formula below;

ΔE* = √ [ΔL*2 + Δa*2 + Δb*2] Where ΔL* (L* sample minus L* standard) = difference in lightness and darkness (+ = lighter, - = darker), Δa* (a* sample minus a* standard) = difference in red and green (+ = redder, - = greener) Δb* (b* sample minus b* standard) = difference in yellow and blue (+ = yellower, - = bluer) ΔE* = total colour difference. All the results were obtained in triplicate.

2.2.1Temperature Treatment

Two groups of the four varieties of sampled were prepared and stored at room temperature (≈22 ^{o}C) and Refrigerating temperature (4 ^{o}C) for 7(seven) days. Firmness and Colour measurement were taken before and after storage at each temperature.

2.2.2 Data Analysis

The experimental data were subjected to a repeated measure analysis of variance (ANOVA). The analyses were conducted using the software version 16 for windows. The Least Significance difference was computed at $p < 0.05$ for each apple variety stored at the same temperature.

III. Results And Discussion

The findings from this study suggest that some degree of changes were observed in the firmness and colour of the stored varieties of apple at a different temperature over a period of 7(seven) days. There was an evidence of statistical significance difference (as shown in **Table 1**) in the firmness of all the apple varieties subjected to different temperature treatment. However, an exception was observed with Granny Smith where it showed no significant difference at 4-degree storage. In detailed, apples stored at room temperature tend to show a steady decrease in its firmness while the apples subjected to 4 degrees seem to show a marginal increase in its firmness.

Table 1: Mean and standard deviation firmness for apples stored at 4°C and Room temperature respectively.

Samples	Firmness (N) before storage	Firmness (N) after storage	Firmness (N) before storage	Firmness (N) after storage
Braeburn	$1.46^{a} \pm 0.02$	$1.57^{b} \pm 0.02$	$1.31^{a} \pm 0.03$	$1.22^{b} \pm 0.01$
Granny smith	$1.66^{a} \pm 0.03$	$1.67^{a} \pm 0.01$	$1.89^{a} \pm 0.02$	$1.85^{b} \pm 0.02$
Royal Gala	$1.37^{a} \pm 0.03$	$1.18^{b} \pm 0.01$	$1.70^{a} \pm 0.07$	$1.49^{b} \pm 0.01$
Cox	$1.76^{a} \pm 0.01$	$1.82^{b} \pm 0.01$	$1.91^{a} \pm 0.01$	$1.64^{b} \pm 0.01$

*Means are the numbers with alphabet superscript and standard deviation is the number after (±).

**Means with different alphabet superscript across the row shows there is a significant difference between the two means ($P<0.05$)

The loss of apple firmness during storage depends on the oxygen level (O_2) in the storage atmosphere. The O_2 level does this by influencing the rate at which ethylene is produced. This, in turn, affects the synthesis of the protein that degrades pectin; a heteropolysaccharide that helps bind the fruit cell together. Different studies such as Hertog *et al*., 2001, De Smedt *et al*., 2002 confirmed the above observation of how low oxygen level at 1-1.25% in their respective storage condition shown to have reduced the rate at which firmness is a loss in apple. Conversely, the firmness loss observed in this study across the four varieties of apple stored at room temperature suggests that the level of O_2 present in the storage condition is high (>>1.5%). The O_2 level at 4°C storage condition is lower compared to its level at room temperature. In fact, the suggested optimum storage temperature for apple is 0-3°C where there should be little or no decrease in the firmness of the apples (Veraverbeke *et al*., 2001 and Gwanpua *et al*., 2012). Granny smith and Royal gala stored at 4°C for this study tend to follow the above-mentioned pattern. Similar studies such as Johnston *et al*.,2001 and Roger Harker *et al*., 2001 followed the same trend with this study, where the loss of firmness in Granny Smith stored between 0-12°C tend not to change with increase in time(days) and Royal Gala stored at the same temperature had a minimal decrease as the storage days increases. However, the other two apple types stored at 4°C, Braeburn and Cox, gave a surprising result. Their Firmness increased with time (days). This trend was not expected because apple is a climacteric fruit I.e. a fruit that undergoes a rapid process of ripening as soon as it's harvested due to increased production of ethylene in the fruit. Ripeness is directly proportional to the loss of firmness in fruits and this was the basic rationale behind storing apples at a suitable temperature to retain or to reduce the degree of firmness loss in apple. There might be some explanation for the trend observed by Braeburn and Cox stored at 4°C. The first possible explanation is that the ripening of apple is in three stages; the slow ripening stage, the rapid ripening stage, and the final slow ripening stage. The exact ripening stages for the apples were not known as at the time of the study, so it could be a contributing factor to the observed trend.

Table 2: Mean Colour and Standard deviation of four varieties of apple stored at room temperature

Colour Coordinates of Apples Samples before storage				*Colour Coordinates of Apples Samples after storage*			*Total Colour Difference*
Samples	L*	a*	b*	L*	a*	b*	ΔE*
Braeburn	75.34±0.49	-6.65±0.05	42.48±0.53	75.29±0.48	-6.39±0.03	47.62±0.45	5.14
Granny Smith	57.69±0.42	-20.63±0.35	39.23±0.43	57.09±0.22	-19.40±0.36	35.6±0.35	3.87
Royal Gala	65.69±0.43	14.34±0.43	34.85±0.30	63.47±0.38	14.71±0.35	40.87±0.34	6.42
Cox	56.61±0.41	-3.49±0.41	38.68±0.29	57.87±0.36	-1.83±0.04	43.22±0.29	4.99

Table 3: Mean Colour and Standard deviation of four varieties of apple stored at 4 °C

Colour Coordinates of Apples Samples before storage				*Colour Coordinates of Apples Samples after storage*			*Total Colour Difference*
Samples	L*	a*	b*	L*	a*	b*	ΔE*
Braeburn	58.19±0.31	17.57±0.34	33.32±0.37	59.45±0.41	18.57±0.41	34.74±0.19	2.14
Granny Smith	59.64±0.39	-22.51±0.49	42.82±0.45	59.53±0.28	-22.34±0.25	42.61±0.21	0.29
Royal Gala	42.79±0.41	34.23±0.58	18.78±0.35	43.37±0.45	34.88±0.10	19.49±0.36	1.12
Cox	70.51±0.38	-14.58±0.34	51.68±0.35	71.44±0.35	-13.46±0.36	53.34±0.28	2.20

Alternatively, these apples are possibly from different orchards, so the dosage of ethylene inhibitors such as 1-methlylcyclopropene may vary across the orchard (Fan *et al*, 1999). In the same vein, the general trend in the total colour difference observed in the apples stored at room temperature tends to be significantly higher compared to the apples stored at four degrees (as shown in **Table 2** and **Table 3** respectively). All apples stored at room temperature showed a very distinct total colour difference as observed by Pathare *et al*, 2012(ΔE*>3). While the total colour differences displayed by the apples stored at 4°C are quite small ΔE*<1.5. The colour changes observed in apple during ripening stages is based on a process called "degreening". This is a process that involves the breaking down of chlorophyll in the pericarp of the fruit, thereby "unmasking" the other pigments such as the anthocyanins, carotenoids to give the apple its distinct colour. It is important to mention that, the "de-greening" process is ethylene-dependent (Callahan, 2003) and that the rate of ethylene production in apple depends on the level of O_2 present in the environment. This perfectly explained the distinct colour difference observed by the apples stored at room temperature because the level of O_2 in that atmosphere is high (>>1.5%) and the converse trend with the apples stored at 4°C.

IV. Conclusion

Overall, this study suggests that there were actually some changes in the firmness and colour of four varieties of apples stored at different storage temperature over seven (7) days. Also, the research was able to point out that the ideal temperature storage for the apple would be at 4°C because, at that temperature, the loss of firmness and rapid colour change in the apple were at a minimal rate, hence retaining the quality index of the product over a period of seven days. However, it should be noted that this experiment was conducted with small samples and over a short period of time. Further research should consider using more samples over a longer period and measure the ethylene concentration of the apple before and after storage. This would give an in-depth understanding of how firmness and colour changes during the different temperature treatment. Finally, further studies should consider using a similar probe with the force against distance graph on the texture analyser for the firmness of the apple. This would provide more information like the energy to skin resistance that will enable the stakeholder across the apple industry to better understand how to ensure the quality of the product is retained during storage.

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