2014 5th International Conference on Food Engineering and Biotechnology
IPCBEE vol.65 (2014) © (2014) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2014. V65. 8

Monitoring Mango Fruit Ripening after Harvest using Electronic Nose (zNose^{TM}) Technique

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Abstract. Over the past few years, electronic nose technology is offering a non-destructive method to sense aroma, which can be used to determine fruit ripening stages after harvesting. The objective of this study was to monitor mango fruit ripening after harvest using electronic nose (zNose^{TM}). Data acquisition was started using an electronic nose for a total of one hundred locally grown mangoes cv. Chokanan. The fruits were divided into two different groups, unripe and ripe mangoes. Concentration of volatiles was measured using electronic nose for each of the two groups during storage. However, to be able to classify the mangoes into three classes, namely unripe, ripening and ripe, the experiment was carried out with the unripe samples for three more days, every 48 hrs from the starting day. Besides, observation of new volatiles from the unripe mangoes as they were ripening indicated trend of volatiles during mango ripening, proving the efficacy of electronic nose for the formation of climacteric crops profiles in terms of volatiles liberated during ripening.

Keywords: Maturity analysis, climacteric fruits, Non-destructive method, zNoseTM

1. Introduction

To monitor the ripening process in fruits during storage has become a very important issue to manage fruits because the quality of fruits and other properties are dependent on the ripening stages. There have been many methods or techniques to monitor the ripening of fruits during storage and most of them are basically dependent on firmness and texture [1]. Some of the other techniques require destructive analysis of the samples which is one the major limitation or disadvantage and therefore, they are not practically feasible to use. Thus, the estimation of the right ripening stage is completely dependent on hands-on experience or visual observations such as colour change, which is sometimes less correlated with the actual ripening.

Although testing firmness or measuring starch, sugar and acid content of fruits are among available methods of maturity determination, they are all considered as destructive methods [2]. However, an excessive research has been carried out to develop non-destructive methods for measuring fruit maturity. In fact, it has been reported that an alternative method to determine maturity level of fruits during their ripening stages is the utilization of electronic olfactory systems to sense the volatiles liberated [3].

Being classified as climacteric fruit, mango undergoes some chemical reactions during its ripening stages and therefore, liberate certain volatile organic compounds (VOCs) that can be measured non-destructively using electronic nose technology [4]. Based on this idea, a relatively different electronic nose (zNose™) has been used in this study to measure the concentration of volatile compounds liberated by mango during ripening stages. The main objective of this study was to gather volatile compounds data in mangoes using electronic nose and then decide the right time of harvest so that the fruits can stay longer in the market without losing the important nutrients.

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2. Materials and Methods

2.1. Fruit material

A total of one hundred local mango fruits (cv. Chokanan) were divided into two groups: 50 unripe mangoes with an average weight of 244.7 g, and 50 ripe mangoes with an average weight of 197.9 g. Using an electronic nose (zNose™), concentration of volatiles was measured for each of the two groups during two separate days. However, to be able to classify the mangoes into three classes, namely unripe, ripening, and ripe, the experiment was carried out with the unripe samples for three more days, every 48 hours from the beginning day, so as to measure the concentration of volatiles liberating during mango ripening stages.

2.2. Electronic nose

"Electronic nose systems are sensor arrays which mimic the operation of a human nose. When an atmosphere loaded with volatile components flows over it, each sensor generates a signal. The combined signal of all sensors is then statistically related to, e.g. the response of a human taste panel. Sensors that rely on chemical properties of the target molecule, whether it can adsorb at a particular surface or be oxidized or reduced, have been developed for a variety of analytes. Popular at present are sensors based on the conduction of semiconductors, such as in tin oxide, or polymers such as polypyrrole" [5].

2.3. How zNose™ works

Unlike other electronic noses whose detector unit contain an array of metal oxide semi-conductor sensors, each being responsible for detecting one or more volatiles [3], zNose™ Model 4200 used in this project uses an electronic detector. The system consists of a sensor head, a support chassis, and a system controller and its basis is (gas) chromatography.

2.4. Kovats Retention Indices

Kovats index of a sample component is defined as "a number, obtained by interpolation (usually logarithmic), relating the adjusted retention volume (time) or the retention factor of the sample component to the adjusted retention volumes (times) of two standards eluted before and after the peak of the sample component" [6] (Table 1).

Table 1: List of volatile compounds verified during different ripening stages along with their corresponding Kovats Retention Index for DB-5 column [7].

Volatile Organic Compounds (VOCs)	Kovats Retention Index	Volatile Organic Compounds (VOCs)	Kovats Retention Index
Ethanol	668	α-Pinene	934
Toluene	773	β-Pinene	990
Hexanal	801	3-Carene	1011
Myrcene	994	α-Terpinene	1018
Limonene	1036	γ-Terpinene	1074
cis-3-Hexenal	795	*o*-Cymene	1020
p-Cymene	1033	α-Terpinolene	1096
Octanal	1006	Heptenal	957
cis-3-Hexenol	858	Decanal	1209
Methyle Decanoate	1328	α-Copaene	1391
β-Caryophyllene	1467	α-Humulene	1452
Cedrol	1596		

3. Results and Discussion

3.1. Trend of VOCs liberated

Results obtained for unripe, ripe, and ripening mangoes indicate that a total of 17 volatiles out of the 23 expected volatiles were liberated during five days of measurements (Fig. 1). The most probable reason for observing less VOCs than expected is that VOCs listed in table one are collectively liberated from different types of mangoes, whereas the mangoes tested in this experiment were all of one local type, i.e. 'Chokanan'.

Although some of the volatiles were uniquely liberated from the ripe and unripe mangoes (on the first day measurements), results obtained on the following days indicated that as unripe mangoes were ripening, some of the VOCs liberated from the ripe mangoes were also liberated from the ripening mangoes (Table 2).

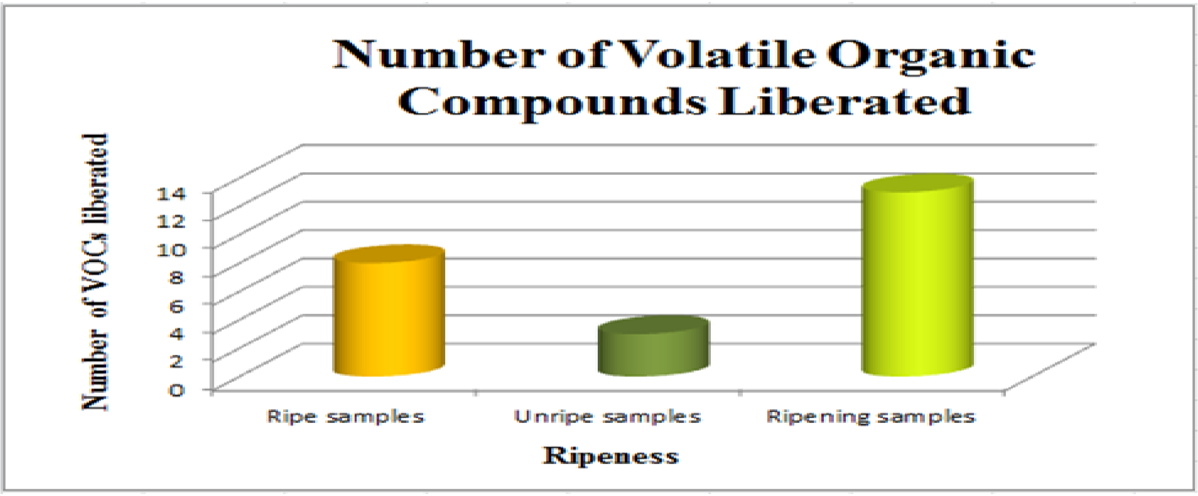

Fig. 1: Number of VOCs liberated based on sample maturity.

Table 2: List of VOCs liberated based on samples ripeness.

VOC name	Samples		
	Ripe	Unripe	Ripening
γ-Terpinene	✔	✔	✔
α-Terpinolene		✔	✔
Decanal	✔	✔	✔
α-Humulene	✔	✔	✔
Octanal		✔	✔
3-Carene		✔	✔
Cedrol	✔	✔	✔
Methyle Decanoate	✔		✔
α-Copaene	✔		✔
β–Caryophyllene	✔		✔
β-Pinene	✔		✔
Ethanol	✔		
α-Pinene	✔		
Myrcene	✔		
Toluene	✔		✔
p-Cymene			✔

As one would expect, the range of maximum peaks observed for each of the VOCs was quite wide (Fig. 2). In fact, the least maximum concentration measured with a value of 170 was the maximum amount of Ethanol liberated from a ripe mango. Whereas the most maximum concentration measured was the amount of Decanal liberated from an unripe mango. It is not quite obvious from the graph, γ-Terpinene is the prominent VOC among the ripe mangoes, whereas Decanal and α-Terpinolene are the most prominent VOCs among the unripe mangoes. While α-Terpinolene was never observed in the ripe mangoes, Decanal was observed in all ripe samples; but with a drastic decrease in value. Values of γ-Terpinene and Decanal in the data acquired indicated that the value of Decanal among the unripe samples is always (much) more than the value of its corresponding γ-Terpinene value for each of the samples.

However, this situation reverses in all but three of the ripe samples. Although the number of ripe mangoes' volatiles is roughly twice as much as that of the unripe mangoes, of the eight volatiles observed specifically in the results obtained for the ripe samples, only Methyle Decanoate was present in all the 50 mangoes (Fig. 3).

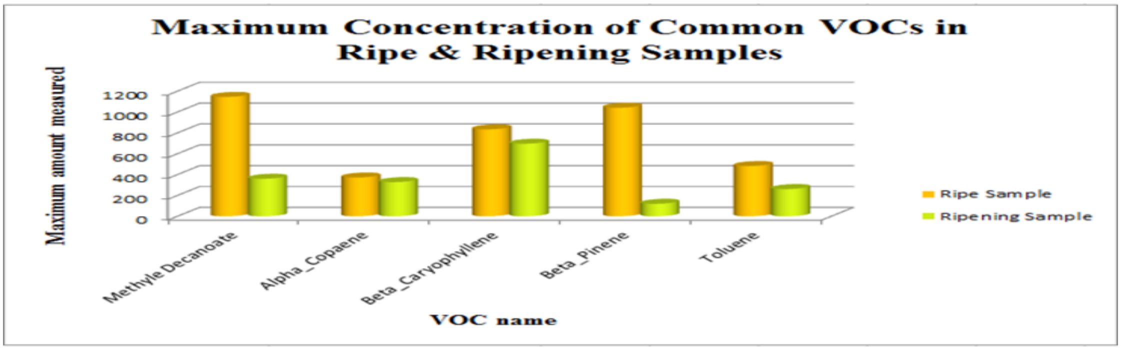

Fig. 2: Maximum amount of each of the VOCs liberated from ripe and unripe mangoes.

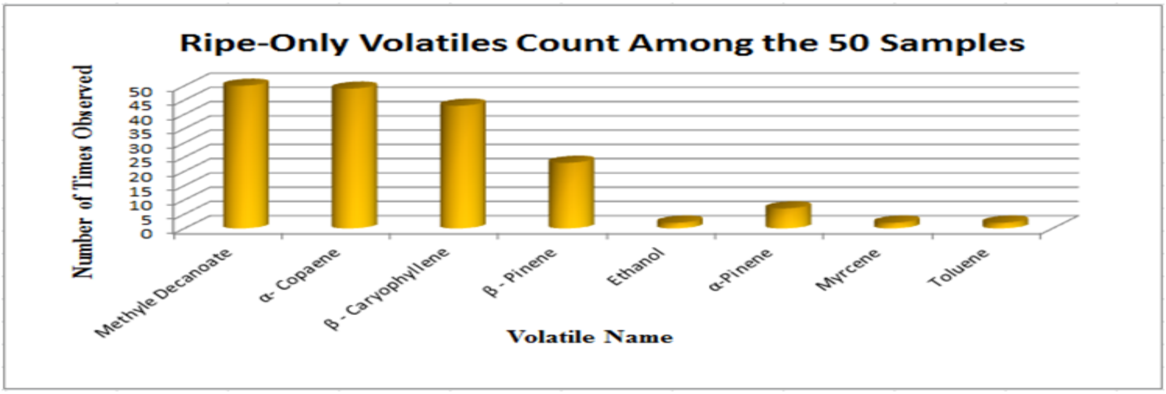

Fig. 3: Ripe-Only Volatiles Count.

Finally, comparison of the first and third columns of table 2 reveals that during the ripening stages of the mangoes, six more volatiles (that were not present on first day measurements) were liberated. However, the bar charts (Fig. 4), indicates that the peaks of some of the volatiles liberated from the ripe mangoes, such as methyle decanoate or beta-pinene, are by no means comparable to those of the ripening mangoes.

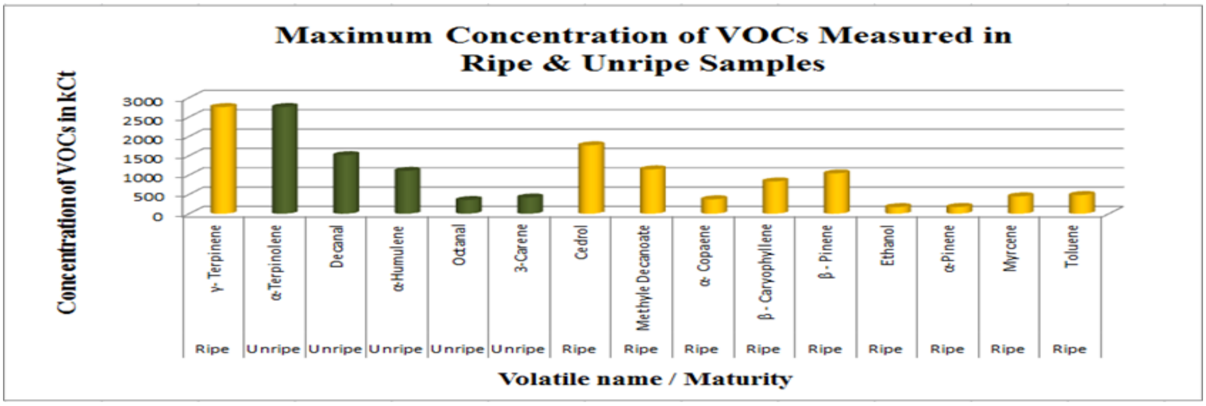

Fig. 4: Comparison of the peaks of common volatiles in ripe and ripening samples.

4. Conclusion

It can be concluded from the results that the trend of liberating VOCs during ripening using zNose™ could potentially be used to predict mango fruit maturity which can help to harvest the fruits on a right maturity stage. However, using reverse engineering method, zNose™ can be used to form an initial list of volatiles for any unripe, ripening, and ripe crop. Once the list is ready, it can be verified using chemical methods and if correctly distinguished, the volatiles can be used in an experiment similar to the one used in this study for the predication of any crop’s maturity and help farmers plan for optimal harvest time.

5. Acknowledgements

The authors would like to thank the Crops For the Future Research Centre for providing partial financial support for the studies and Mr Tibby Lim from Ameritech Sdn Bhd for his guidance to understand the working mechanism of electronic nose (zNose^{TM}).

6. References

[1] J. Wang, B. Teng, Y. Yu. Pear dynamic characteristics and firmness detection, *Eur. Food Res. Technol.* 2004, **218** (3): 289-294.

[2] A. Kader. *Postharvest Technology of Horticultural Crops*. 3rd ed., University of California Publication, 2002.

[3] A.H. Gómez, G. Hu, J. Wang, A.G. Pereira. Evaluation of tomato maturity by electronic nose. *Comput. Electron. Agric.* 2006, **54**(1): 44-52.

[4] M. Lebrun, A. Plotto, K. Goodner, M. Ducamp, E. Baldwin. Discrimination of mango fruit maturity by volatiles using the electronic nose and gas chromatography. *Postharvest Biol. Technol.* **48**(1): 122-131.

[5] W.J. Florkowski, S.E. Prussia, R.L. Shewfelt, B. Brueckner. *Postharvest Handling.* 2nd ed. A Systems Approach (Food Science and Technology) Academic Press, 2009.

[6] A.D. McNaught, A. Wilkinson. *IUPAC Compendium of Chemical Terminology*. 2nd ed. International Union of Pure and Applied Chemistry, 1997.

[7] NIST Chemistry WebBook. http://webbook.nist.gov/chemistry/ 2011.