ELSEVIER

Postharvest Biology and Technology 4 (1994) 111–116

Postharvest Biology and Technology

Ultrasonic evaluation of ripening avocado flesh

G.K. Self [a,*], E. Ordozgoiti [a], M.J.W. Povey [a], H. Wainwright [b]

[a] *Department of Food Science, University of Leeds, Willow Terrace, Leeds, LS2 9JT, UK*
[b] *Natural Resources Institute, Central Avenue, Chatham Maritime, Kent, ME4 4TB, UK*

(Accepted 18 August 1993)

Abstract

During avocado (cv. Fuerte) fruit ripening at 15°C, the volume fraction of intercellular spaces (air content) tended to decrease and was negatively correlated with the density of the flesh. Ultrasonic velocity was measured in sections of flesh sampled during storage, and after an initial increase fell from about 350 m s^{-1} to about 200 m s^{-1} as ripening proceeded over a 12 day period. Velocity was positively correlated with the water content of the flesh, but the nature of this relationship is not presently understood. Further development is needed to extrapolate from velocity measurements in tissue sections to whole fruit in order to provide potentially a non-destructive system for ripeness grading of avocados.

Key words: Avocado; Non-destructive evaluation; Ripening; Ultrasound

1. Introduction

In the UK, the avocado has successfully progressed from being an ethnic fruit to being a mainstream product. Between 1978 and 1987, the imported tonnage of fruit increased almost six fold (Henderson, 1989). The principal factor restricting further expansion of the market is fruit quality at the point of sale (Henderson, 1989). The ability to grade fruit into ripeness classes and to predict the probable rate of ripening of fruit would be of benefit to the retailer and consumer alike.

Low intensity ultrasonics is a potentially powerful technique for the non-destructive evaluation of fruit and vegetables (Sarkar and Wolfe, 1983; Mizrach et al., 1989; Self et al., 1991, 1992). The technique can be used for whole fruits and vegetables and for tissue samples. It is non-destructive when used with samples in that the sample remains physically and chemically unaltered (Povey and

* Corresponding author. Present address: Department of Biology, University of York, Heslington, York, YO1 5DD, UK.

SSDI 0925-5214(93)E0051-E

McClements, 1988). Mizrach et al. (1989) reported that ultrasonic velocity (at 50 kHz) was greater in soft, ripe avocados than in hard, unripe avocados. Ultrasonic velocity measurements might therefore be a means by which avocado fruit could be graded into ripeness classes. This paper reports ultrasonic velocity measurements in sections of ripening avocado fruit, and relates these to the physical properties of the tissue.

2. Materials and methods

'Fuerte' avocados from South Africa were purchased from a local market, and the boxes of fruit immediately placed in a controlled temperature cabinet at 15.0 ($\pm$0.1)°C. The humidity of the cabinet was not controlled. This was day 0. Five avocados were then sampled at either 2 or 3 day intervals during the following 15 days as ripening proceeded.

Four cylindrical sections of flesh were cut with a 20 mm diameter cork borer from each avocado, two from either side of the stone, and the ends trimmed parallel with a razor blade. Physical properties were measured on two of the cylinders, one from either side of the stone, and ultrasonic velocity on the remaining two. The density of the flesh was determined using Archimedes' principle. The cylinders were then dried at 75°C for 24 hours to determine the water content of the flesh. The dried sections at each sampling time were combined and ground to a fine powder using a commercial coffee grinder and then a pestle and mortar. The density of the powder was determined using a density bottle, toluene and water according to Mohsenin (1970). From these parameters, the volume fraction of intercellular spaces (air content) of the flesh for each fruit was determined according to Davies (1962).

Ultrasound was generated using a commercially available non-destructive testing kit (a PUNDIT from CNS Electronics Ltd., 61–63 Holmes Road, London, NW5 3AL) with 37 kHz transducers with a 1 kV excitation voltage. Sections of fruit were placed between the transducers coaxially with a 50 mm long Perspex rod (19 mm diameter) (Self et al., 1992). This is done when the speed of sound in a tissue is less than that in air to isolate the signal which passes through the sample from the signal which propagates directly across the air gap between the transducers. Both the time-base synchronisation pulse and the waveform of the received pulse were displayed on a Tektronix 468 Digital Storage Oscilloscope from which the time of flight of the pulse through the sample could be determined ($\pm \leq 0.05$ μs). The path length was measured as the transducer spacing with Vernier callipers ($\pm$0.02 mm). Fruit sections were serially shortened, and velocities determined from the slopes of plots of transducer spacing against the time of flight.

3. Results and discussion

The fruit began to yield to finger pressure at day 3, and by day 15 were very soft and had developed black spots. This indicates that fruit had fully ripened by the end of the study period, although it is possible that some ripening occurred before day 0.

Table 1
Physical properties of Fuerte avocado flesh stored at 15°C

Property	Days at 15°C						
	1	3	6	8	10	13	15
Density (kg m^{-3})	963	955	971	961	984	964	979
	5.2	7.8	3.4	6.5	2.0	5.5	4.2
Water content (wt%)	73.2	74.2	73.1	72.6	72.5	69.7	71.7
	1.00	0.52	0.53	0.83	1.02	1.66	1.97
Air content (vol%)	5.7	6.0	4.1	4.9	2.5	4.4	2.9
	1.05	0.88	0.42	0.62	0.20	0.68	0.49

Values are means with standard errors. For density $n = 10$, i.e., two samples per fruit; for water content and air content these samples were combined so that $n = 5$.
Data were analysed by analysis of variance. For density (6/63 df), $F = 3.85$, $P = 0.002$; LSD ($P = 0.05$) = 15 kg m^{-3}. For volume fraction of intercellular spaces (6/28 df), $F = 4.60$, $P = 0.003$; LSD ($P = 0.05$) = 1.8%. For water content (6/28 df), $P > 0.05$.

The average water content of the flesh appeared to decrease slightly during ripening, although the changes were not significant (Table 1). The low rate of water loss during storage was probably due to the commercial practice of waxing fruit to improve appearance and reduce fungal attack. The volume fraction of intercellular spaces (air content) of the flesh also tended to decrease during storage, on average by a factor of two (Table 1) and by a maximum factor of four (Fig. 1). This confirms

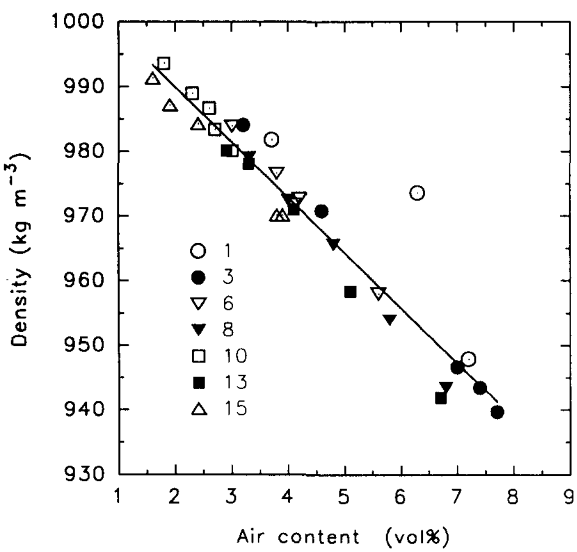

Fig. 1. The relationship between the density and air content of avocado flesh. The equation of the fitted regression is $y = 1007 - 8.532x$, $r = 0.9544$, 31df. The figures in the key refer to the number of days in storage at 15°C.

the prediction of Ben-Yehoshua et al. (1963), based on microscopy, that the air content of avocado flesh should decrease during ripening by a factor of four. The air content of individual fruit at any time varied by between 2 and 5% (Fig. 1). Such variation in air content might be expected to have implications for the physiology of ripening fruit through effects on gaseous diffusion and internal atmosphere caused by changes in the area of exposed cell walls over which diffusion can occur (Ben-Yehoshua et al., 1963; Nobel, 1991), but such effects have yet to be studied.

The density of the flesh was negatively correlated to the air content (Fig. 1), but was not correlated with the water content (data not shown). A similar dependence of density on air content, but not water or dry matter content, has been found for developing and ripening bananas (Self, unpublished results) and apples (Chan, 1991). This relationship is a consequence of the very large density difference between cells and air, such that small changes in air content have a much greater effect on tissue density than similar changes in cellular composition.

In hard avocados at day 1, ultrasonic velocity was 270 m s^{-1} (Fig. 2). This is close to the value of 274 m s^{-1} for hard, unripe avocados in Mizrach et al. (1989). The velocity then increased to a maximum of 350 m s^{-1} at day 3. Thereafter, the velocity decreased linearly to a minimum value of 185 m s^{-1} (Fig. 2). This relationship could be used as the basis of a ripeness grading procedure for avocado fruit. However, further work is required to show whether results obtained with tissue samples can be extrapolated to whole fruit. Work would also be required to determine the influence of storage conditions, cultivar and harvest maturity on such a relationship. There may have been a second increase in velocity as the fruit began to senesce, but the

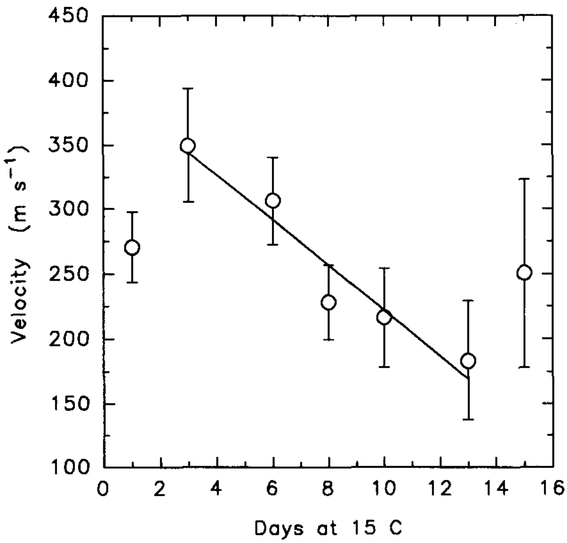

Fig. 2. Changes in the ultrasonic velocity of 'Fuerte' avocado flesh with storage time at 15°C. The equation of the regression, fitted between days 3 and 13, is $y = 396.1 - 17.41x$, $r = 0.9654$, 3df. The bars are standard deviations.

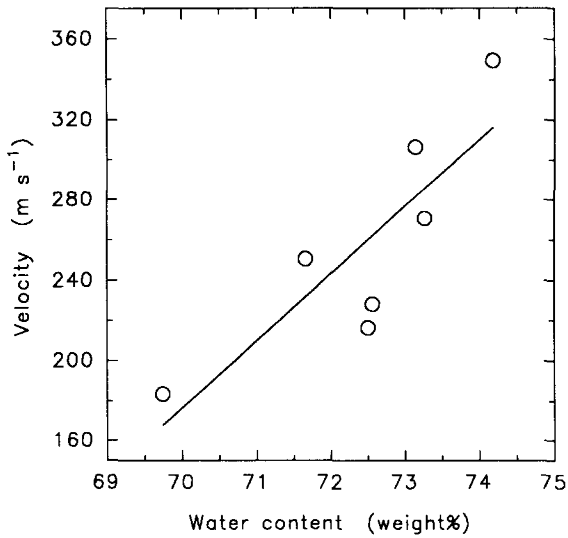

Fig. 3. The relationship between the ultrasonic velocity of avocado flesh and its water content. The equation of the fitted regression is $y = -2160 + 33.38x$, $r = 0.8408$, 5 df.

potential confusion of a such an increase does not arise, because of the obvious appearance of senescing fruit. Mizrach et al. (1989) reported a value for velocity of 383 m s^{-1} in soft avocados. This could correspond to our fruit at day 3 or to very ripe fruit. Unfortunately, neither the cultivar nor the precise condition of the fruit used was recorded. Nevertheless, our results show that over the major period of ripening before signs of senescence, ultrasonic velocity decreases rather than increases as was suggested by Mizrach's data.

Part of the variation in the ultrasonic velocity appeared to be accounted for by the water content of the flesh, even though changes in water content during ripening were not statistically significant (see above) (Fig. 3). If a greater water content corresponds to a greater turgor pressure, a greater velocity would be expected. This is because the ultrasonic velocity in a material depends on its elastic properties (Blitz, 1963), and in some tissues the Young modulus is known to be related to the water potential and its components, particularly turgor (Murase et al., 1980). Clearly, the nature of this relationship needs to be examined further. A comparison between waxed and unwaxed avocado fruit might help to separate the effects of tissue water content and textural softening on ultrasonic velocity, because unwaxed fruit would be expected to lose much more water during ripening than waxed fruit whilst both would soften.

Acknowledgements

This work was funded by the Natural Resources Institute. We should like to thank the referees for their most helpful comments.

References

Ben-Yehoshua, S., Robertson, R.N. and Biale, J.B., 1963. Respiration and internal atmosphere of avocado fruit. Plant Physiol., 38: 194–201.

Blitz, J., 1963. Fundamentals of Ultrasonics. Butterworths, London.

Chan, G., 1991. Ultrasonic evaluation of physical properties in apple and potato. B.Sc. Honours Thesis, Procter Department of Food Science, University of Leeds.

Davies, R.M.D., 1962. Tissue air space in the potato: its estimation and relation to dry matter and specific gravity. Am. Potato J., 39: 298–305.

Henderson, D.W., 1989. The UK market for exotic tropical fruit. Aspects Appl. Biol. 20, Tropical Fruit — Technical Aspects of Marketing, pp. 3–12.

Mizrach, A., Galili, N. and Rosenhouse, G., 1989. Determination of fruit and vegetable properties by ultrasonic excitation. Trans. Am. Soc. Agric. Eng., 32: 2053–2058.

Mohsenin, N.N., 1970. Physical Properties of Plant and Animal Materials. Gordon and Breach, New York, N.Y., 734 pp.

Murase, H., Merva, G.E. and Segerlind, L.J., 1980. Variation of Young's modulus of potato as a function of water potential. Trans. Am. Soc. Agric. Eng., 23: 794–800.

Nobel, P.S., 1991. Physicochemical and Environmental Plant Physiology. Academic Press, London.

Povey, M.J.W. and McClements, D.J., 1988. Ultrasonics in food engineering. Part I: Introduction and experimental methods. J. Food Eng., 8: 217–245.

Sarkar, N. and Wolfe, R.R., 1983. Potential of ultrasonic measurements in food quality evaluation. Trans. Am. Soc. Agric. Eng., 26: 624–629.

Self, G.K., Chan, G., Povey, M.J.W. and Wainwright, H., 1991. Ultrasonic non-destructive evaluation of the maturity and quality of fresh fruit and vegetables. In: Proceedings of the Ultrasonics International '91 Conference. Butterworth-Heinemann, Oxford, pp. 83–86.

Self, G.K., Povey, M.J.W. and Wainwright, H., 1992. What do ultrasound measurements in fruit and vegetables tell you? In: M.J.W. Povey and D.J. McClements (Editors), Developments in Acoustics and Ultrasonics. Institute of Physics Publishing, Bristol, pp. 129–163.