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Abstract. In order to determine the optimization of test conditions for TPA texture properties of avocado flesh, the method of TPA was used to explore the effect of different compression locations and test parameters on the texture properties. The results showed that the middle part of the avocado flesh was the best part for testing the texture properties. through the correlation analysis of the measured values of texture properties by the avocado flesh, the hardness, springiness and cohesiveness were determined as the key investigation indications. The compressed speed had a significant effect on hardness and cohesiveness, and the compression distance had a significant effect on hardness and springiness. The optimization test parameters of avocado flesh were compression speed of 1mm/s and compression distance of 8 mm.

1. Introduction

The texture properties of the flesh were the most intuitive factor that represented the tissue state of the fruit and the taste of the eater [1]. Related research reports indicated that many sensory properties of fruits were closely related to texture, such as hardness, springiness and cohesiveness, among which hardness was the main parameter [2-3]. Traditionally, the hardness tester was used to measure the hardness, but the measurement result was often affected by factors such as the specifications of the probe, the strength of the tester, and the deviation of the penetration angle. In addition, if the characteristics of crunchiness and compactness of the flesh were perceived by human taste and touch, there would inevitably be large errors.

Avocado was an important tropical fruit in China or in tropical region, which was rich in nutrients such as unsaturated fatty acids [4-5]. However, the existing research results indicated that the content and composition of fatty acids and other nutrient components, physical and chemical properties of avocado during ripening after storage would undergo relevant changes [6-7]. At the same time, changes in the nutrient composition of the flesh would inevitably lead to changes in its texture characteristics. The avocado peel was hard, and the problem of over-maturation during storage was not easy to be noticed. The conventional method judged its maturity through the change of apparent colour, and this method often appeared the phenomenon of soft rotten flesh, so it was necessary to establish related test methods and to predict the storage period of avocado or judge its maturity. The method of characterizing post-harvest texture changes of fruits and vegetables through texture feature analysis had been applied to rice quality evaluation[8-9], fruit and vegetable processing method quality evaluation[10-11], fruit and vegetable quality evaluation[12-13], fruit and vegetable Maturity quality evaluation[14] and other texture analysis. The texture profile analysis test（TPA）is a method developed for the texture of food texture. The unique two-pressure action mode simulates the bite pattern of human oral cavity. After analysis of the pattern analysis tool, it can provide nine important texture parameters for testers at one time. However, there were no relevant research reports to characterize the change of flesh texture during the ripening process of avocado through texture characteristics. Therefore, the study determined the most suitable parameters by optimizing the texture parameters, the detection location and the content of the key parameters. It would provide support for the post-harvest quality evaluation of avocado.

2. Materials and Methods

2.1. Materials
Avocado was commercially available, and the variety was 'Hass'.

2.2. TPA test
The TPA curves were obtained by the CT-3 texture analyser (Brookfield engineering laboratories, Inc.). As shown in Figure 1, the ordinate represented the force load, the abscissa represented the puncture time, and the relevant parameter settings during the test as follow: the shape was a cylinder, the trigger point load 0.05N, the test rate 1 mm / s, return rate 1 mm / s, target 6 mm, waiting time 0 s, cycle number 2 times, load unit 50000 g, probe TA-39, fixture TA-BT-KJ.

The meaning and value of each texture characteristic value were calculated as follows [15]: Hardness referred to the peak value generated during the first compression. Springiness referred to the height or volume ratio of the denatured sample to the condition before the denaturation was restored after removing the denaturing force; its measurement was the ratio of the measured height of the second penetration to the height measured in the first time ($t2$ / $t1$).Cohesiveness indicated the relative resistance of the test sample to the second compression after the first compression deformation, which was shown on the curve as the ratio of the positive work of the two compressions ($A4$ / ($A1$ + $A2$)). Resilience referred to the ability of the sample to rebound during the first compression. This value was the ratio of the elastic energy released by the sample when returning during the first compression cycle during the test and the energy consumption of the probe during compression ($A2$ / $A1$). Adhesiveness indicated the work consumed by the probe due to the adhesion of the test sample. Its measure was the negative area ($A3$) of the curve between the first compression curve reaching zero and the start of the second compression curve.

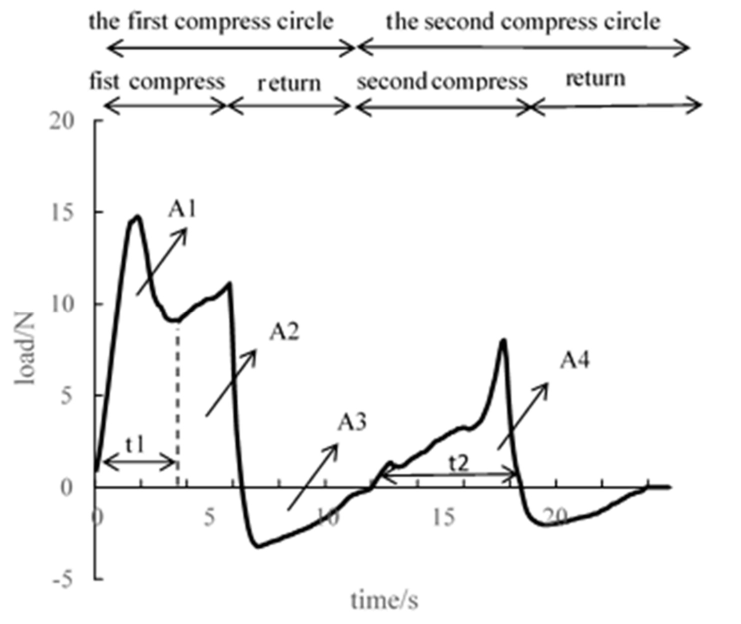
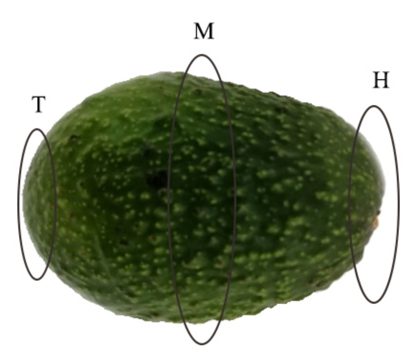


Figure 1. TPA test curve t of avocado.

2.3. Effects of various factors on the texture properties of avocado flesh

2.3.1. Effects of measuring parts on the texture properties of avocado. The avocado measurement parts were set to H, M, and T, as shown in Figure 2. According to the 2.2 TPA test method, the probe TA-39 was used to compress the three parts of avocado H, M, and T with a compression speed of 1 mm/s and a compression distance of 6 mm. The TPA experiment for each part was repeated 20 times. Investigate the effect of different measurement parts on the texture characteristics of avocado flesh (hardness, springiness, cohesiveness, resilience, adhesiveness).



H head, M middle, T tail

Figure 2. Avocado measurement part.

2.3.2. Effects of compression speed on the texture properties of avocado flesh. According to the optimized measurement part of 2.3.1 and the compress test of avocado with probe TA-39 according to the 2.2 TPA test method, the measurement part was in the middle and the compression distance was 6 mm. The compress experiment was repeated 20 times. The effects of 5 different compression speeds of 1 mm / s, 1.5 mm / s, 2 mm / s, 2.5 mm / s and 3 mm / s on the texture characteristics of avocado flesh were investigated.

2.3.3. Effects of compression distance on the texture properties of avocado. According to the optimized measurement part of 2.3.1 and the optimized compression speed of 2.3.2, the avocado compression test was carried out using the probe TA-39 according to the TPA test method of 2.2, the compression experiment was repeated 20 times, and the effects of three different compression distances of 6 mm, 8 mm, and 10 mm on the texture characteristics of avocado flesh were investigated.

2.4. Data processing and analysis
The data obtained from the experiment was plotted and analysed using Excel 2013, Origin Pro 2018 and SPSS 22.0.

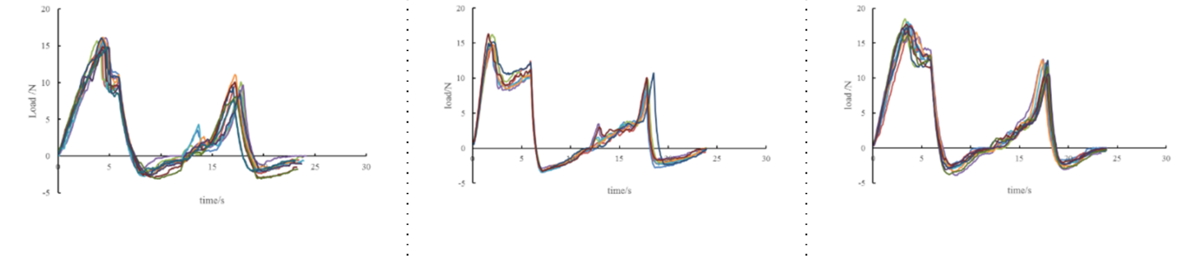
3. Materials and Methods

3.1. Effects of measuring parts on the texture properties of avocado flesh
It could be seen from Table 1 and Figure 3 that the head had the least springiness, chewiness, and adhesiveness, and the cohesiveness and resilience were the largest. The middle part had the smallest hardness and resilience, the most springiness and adhesiveness. The tail had the largest hardness and chewiness. Significance analysis resulted show that the resilience of the three parts of the head, middle and tail were significantly different, and the difference in cohesiveness was not significant; the difference in hardness and chewiness of the head and middle was not significant, and the springiness was significant. The springiness and stickiness of the head and the tail were not significant, and the hardness and chewiness were significant, the chewiness of the middle and tail was not significant, and the hardness and stickiness were significant. Among the TPA curve characteristics of the three parts, the central TPA curve had obvious characteristics, small fluctuations and high reproducibility, while the central standard deviation was minimum, and the dispersion was small. Based on this, the middle avocado flesh was the best measurement site.

Table 1. Analysis of texture characteristics of avocado flesh with different measurement parts

Parts	Hardness	Springiness	Cohesiveness	Chewiness	Resilience	Adhesiveness
H	15.49±0.56^{b}	4.99±0.62^{b}	0.29±0.04^{a}	22.55±4.77^{b}	0.09±0.01^{a}	7.45±2.11^{b}
M	15.16±0.70^{b}	5.70±0.25^{a}	0.28±0.03^{a}	24.74±3.01^{ab}	0.02±0.00^{c}	10.51±1.01^{a}
T	17.36±0.70^{a}	5.32±0.436^{ab}	0.28±0.03^{a}	26.04±3.34^{a}	0.06±0.01^{b}	7.98±2.08^{b}

Not: The same letter in the same column in the table means that the difference is not significant, and the different letter means that the difference is significant.



a head b middle c tail

Figure 3. TPA curves of different measurement parts of avocado flesh.

3.2. Correlation analysis between texture characteristics of avocado flesh

It could be seen From Table 2, the correlation between hardness and springiness was -0.614, which was negatively correlated, and was significant at the level of 0.05; it is not significant with cohesiveness, chewiness, resilience, and adhesiveness. The Pearson values of correlation between springiness and chewiness, resilience and adhesiveness Pearson values were 0.865, -0.872, and 0.870, respectively, and were extremely significant at the level of 0.01, that was, the regularly of springiness could effectively reflect the regularly of chewiness, resilience and adhesiveness, and it was not related to cohesiveness. Yang Zhi et al. [16] studied the evaluation of jujube fruit texture and cluster analysis based on the TPA method. The fruit hardness was extremely significantly positively correlated with the springiness and chewiness of the fruit, the chewiness was extremely significantly positively correlated with the springiness, and the springiness was agglomerated. Significant negative correlation indicates that there was a large difference in the correlation between the texture characteristics of different types of fruits and vegetables. In order to reduce the repeatability analysis, this study focused on the effects of test parameters on the hardness, springiness and cohesiveness of avocado flesh.

Table 2. Correlation analysis between the texture characteristics of avocado flesh

	hardness	springiness	cohesiveness	chewiness	resilience	adhesiveness
hardness	1	-.614*	-0.112	-0.26	0.435	-0.499
springiness	-.614*	1	0.411	.865**	-.872**	.870**
cohesiveness	-0.112	0.411	1	.725**	-0.301	0.09
chewiness	-0.26	.865**	.725**	1	-.755**	.661**
resilience	0.435	-.872**	-0.301	-.755**	1	-.830**
adhesiveness	-0.499	.870**	0.09	.661**	-.830**	1

*. indicated that the correlation was significant at the 0.05 level (Pearson's bilateral test); **. indicated that the correlation was significant at the 0.01 level (Pearson's bilateral test).

3.3. Effects of test parameters on texture characteristics of avocado flesh

3.3.1. Effects of test parameters on the hardness of avocado flesh. It could be seen from Figure 4 that under the same compression distance, when the compression speed was less than 2.0 mm/s, the hardness become smaller as the compression speed increased. When the compression speed was greater than 2.0 mm / s, the hardness corresponding to the compression distance of 6 mm and 8 mm rises sharply, while the hardness corresponding to the compression distance of 10 mm decreased sharply. The compression speed was 2.5 mm/s, and the difference in hardness values corresponding to the three compression distances was the smallest. When the compression speed was less than 1.0 mm/s and greater than 3.0 mm/s, the hardness ranking corresponding to different compression distances was: 6 mm> 8 mm> 10 mm. When the compression speed was 1.5-2.0 mm/s, the hardness sequence corresponding to different compression distances was: 6 mm> 10 mm> 8 mm; when the compression speed was 2.0 mm/s-2.5 mm/s, the hardness sequence corresponding to different compression distances was: 10 mm> 8 mm> 6 mm, under the same compression speed, the regularly of compression distance to hardness was not significant. Considering both the compression distance and the compression speed, the compression distance was greater than 10 mm, the compression speed was too large, which had a great impact on the hardness. During the experiment, it was found that under excessive compression speed and distance, the structure of the flesh tissue was greatly damaged, and the deformation was more serious, resulting in a greater difference in the change trend of hardness. Significance analysis results showed that speed and compression distance had a very significant effect on the hardness of avocado flesh. When Xu Jintao et al[17] studied the texture characteristics of duck pear, the effect of compression speed on the hardness of duck pear was significant, which had the same conclusion as this study, the compression speed had a significant effect on the measurement of fruits and vegetables hardness. Based on the above analysis, it was recommended to choose a compression speed parameter less than 2.0 mm / s and a compression distance of 8 mm.

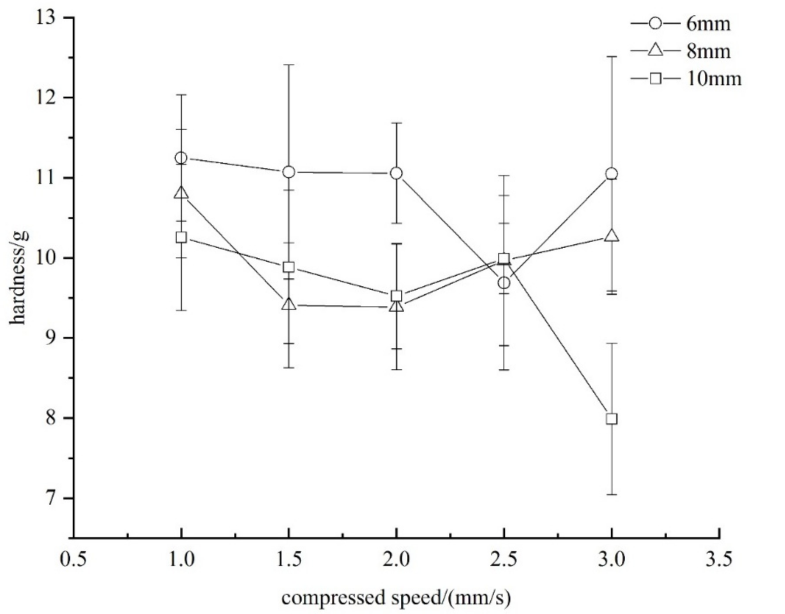


Figure.4 Effects of test parameters on the hardness of avocado flesh

3.3.2. Effect of test parameters on the springiness of avocado flesh. It could be seen from Figure 5 that under the same compression distance, with the increase of compression speed, the springiness of avocado flesh changed little. At the same compression speed, the regularly of springiness corresponding to different compression distances were: 10 mm> 8 mm> 6 mm. The greater the compression distance, the greater the springiness. The significant analysis results indicated that the compression distance had a very significant effect on the springiness of the avocado flesh. When Li Yonghong et al[18] optimized the texture test conditions of fresh peach, it was found that the compression speed had a significant effect on the peach's springiness, and the compression distance had no significant effect on the peach's springiness, which was consistent with the results of this study. Based on the above analysis, it was recommended that the compression distance was 8 mm.

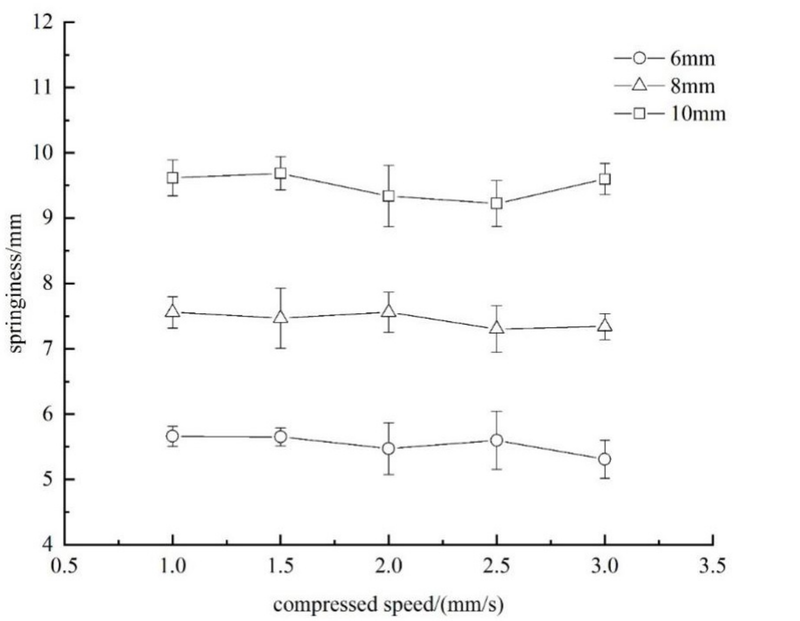


Figure.5 Effects of test parameters on the springiness of avocado flesh

3.3.3. Effects of test parameters on the cohesiveness of avocado flesh. It could be seen from Figure 6 that when the compression distance was 6 mm and 10 mm, the cohesiveness showed a trend of increasing first, then decreasing, and then increasing with the increase of compression speed. Significance analysis results showed that the effect of compression speed on the cohesiveness of avocado flesh was extremely significant, and the effect of compression distance on the cohesiveness of avocado flesh was not significant. When the compression speed was 1.5 mm/s, the cohesiveness had its own maximum value; when the compression speed was 2.5 mm/s, the cohesiveness had its own minimum value. When the compression distance was 8 mm, the cohesiveness changing with the compression speed was not obvious, fluctuating within the range of 0.05. The compression speed was in the range of 2.0-2.5 mm/s, and the difference in cohesiveness between different compression distances was small. Cohesiveness referred to the ability of chewing the flesh to impair the flesh resistance and keep the pulp intact[19]. The results of this study showed that the measured avocado flesh was relatively intact within the parameters selected by the experiment, and the fluctuation of cohesiveness was small.

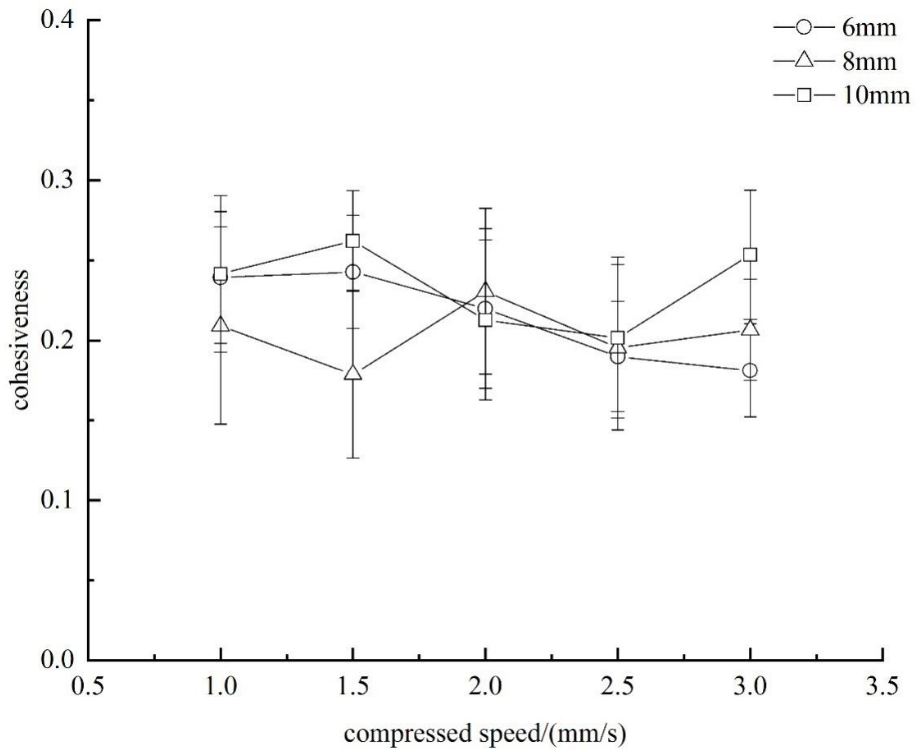


Figure.6 Effects of test parameters on the cohesiveness of avocado flesh

4. Conclusions

In this study, the TPA test was used to explore the effects of different compression parts and test parameters on the texture characteristics of avocado flesh. (1) The best test part for avocado flesh was determined to be the middle. (2) The best texture test parameters for avocado pulp were compression speed of 1 mm/s and compression distance of 8 mm. (3) The hardness, springiness, and cohesiveness were determined as the key indicators for avocado texture.

Acknowledgments

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