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INSTRUMENTAL MEASUREMENTS TO INVESTIGATE APPLE MEALY TEXTURE

Kang Tu, J. De Baerdemaeker

Department of Agricultural Engineering, Katholieke Universiteit Leuven
Kardinaal Mercierlaan 92, 3001 Heverlee, Belgium

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A b s t r a c t. Four apples varieties (Braeburn, Elstar, Jonagold and Teser T219) were tested to study techniques for instrumental measurement of the mealiness of apple fruit. The measurements were done just after cold storage (2 °C, 95% relative humidity) and repeated one week of storage at 20 °C, 65% relative humidity later. The non-destructive acoustic response technique was used as a measure of fruit firmness. Texture profile analysis (TPA) and tensile tests were applied to measure the hardness, cohesiveness and adhesion of the apple tissue. The juiciness, soluble solids content (SSC), pH value and internal air space (IAS) of the apples were determined. The results show that the TPA technique and tensile test may be derived as mechanical ways to measure apple mealiness. Apple fruit internal air space increases and juiciness decreases as the apple becomes mealy, and they may be good indications of mealiness. The mealiness criteria may be different for different varieties of apples.

K e y w o r d s: apple, mealiness, tensile, texture profile analysis, internal air space

INTRODUCTION

The market value of foods is determined by their quality. For apples, the texture seems to be a primary quality attribute which, together with flavor and appearance, should be taken into account when evaluating overall quality of the fruit.

Braeburn, Elstar, Jonagold and Teser T219 are four apple varieties which can be found in the Belgium market. The fresh apples are often firm, crisp and juicy, but the texture can deteriorate during cold storage and during the shelf life. It was reported that apples picked later tend to lose more water during cold storage and shelf display which usually cause significant wilting, soft, shrivelling, dry and mealy taste [3].

Szcześniak [10-12] suggested the texture profile analysis to identify the key texture attributes of food. The mealy texture was classified by Jowitt [7] as: possessing the texture property manifested by the presence of components of different degrees of firmness and toughness. Apple mealiness or woolliness is often described as dry, soft and unpalatable taste in the mouth.

There is small amount of literature concerning fruit mealiness. Harker and Hallett [3] studied physiological changes as apples become mealy during cool storage. They found that the mealiness was associated with low adhesion between neighbouring cells, and a relative high resistance to cell rupture. Luza *et al.* [8] investigated chilling injury in peaches. They characterized mealiness by separation of mesocarp parenchyma cells leading to increased intercellular spaces and accumulation of pectic substances in the intercellular matrix. McComber *et al.* [9] reported the factors related to potato mealiness. Harker and Sutherland [4] studied the cellular characteristics associated with nectarine mealy texture. They determined that the nectarine mealy texture is associated with lack of free juice on the cell wall surface. Although some work has been done on the cellular level, little work has been done on the mechanical measurement to determine the criteria for apple mealiness.

The main objective of this work was using mechanical and analytical methods to study apple mealiness under specified storage conditions. Emphasis was put on finding mealy criteria for apples using instrumental measurements.

MATERIALS AND METHODS

Materials

Four varieties of apples: Braeburn, Elstar, Jonagold and Teser T219 were tested. The apples were picked from a local orchard in the harvesting season of 1993 (September). The apples were first stored under ULO (ultra low oxygen) conditions and then moved to the controlled climate room in the University. The storage condition was set at 2°C, 95% relative humidity (RH). The apples were stored for different numbers of days in the climate room before the experiment began. The Braeburn and Teser T219 were stored for 55 days, the Elstar for 100 days, and Jonagold for 22 days.

Methods

The apple texture was determined just after cold storage at 2 °C, 95% RH. In order to find the shelf life effect, the tests were repeated after 7 days of storage under 20 °C, 65% RH room conditions.

Non-destructive measurements

Twenty apples of each variety were taken out of the cold storage chamber and put in room temperature for some time to get equilibrium temperature with the environment. The non-destructive acoustic impulse response measurement was first carried out. The set up was the same as used by Chen and De Baerdemaeker [2]. The first peak frequency of impact around the apple equator was recorded with an HP 35665A dynamic signal analyser and the average frequency at three points was used in calculating apple stiffness factor. The apple flesh firmness can be indicated by stiffness factor expressed as $f^2m^{2/3}$ (f: peak frequency, Hz; m: mass of the apple, kg).

Destructive measurements

The destructive measurements were performed following the non-destructive measurements. The apple texture was determined with the texture profile analysis (TPA) and the tensile test using the Universal Testing machine System (UTS Test System GmbH).

Texture profile analysis is the procedure to describe food properties by compressing bite-size pieces of food using mechanical device and analysing the force-time curve which indicates the simulated mastication [12]. A typical two-cycle compression TPA curve during compression is shown in Fig. 1. In the experiment, the parameters of hardness (the peak force measured during the first compression cycle), adhesive force (peak negative force during the up stroke of the first compression), and cohesiveness (the ratio of A_2/A_1) were determined for the four apple varieties. Bourne and Comstock [1] studied the compression degree effect on texture profile parameters. In this research, 50 mm/min compression rate

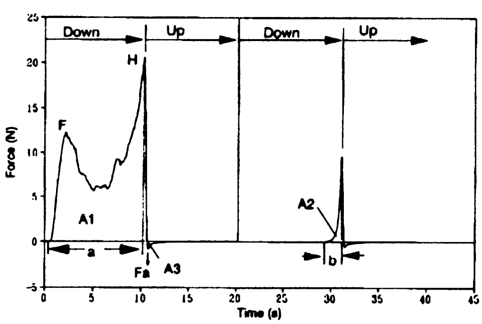

Fig. 1. A typical curve of Texture Profile Analysis (Two-cycle compression. The crosshead of UTS moves down and up twice. F: Fracturability, H: Hardness, A1: Positive area under H, A2: Positive area under second compression, A3: Adhesiveness, negative force area for first cycle compression, Fa: Adhesive force, Cohesiveness=A2/A1, Springiness=b/a, Gumminess=Hardness x Cohesiveness, Chewiness = Gumminess x Springiness).

and 80% compression deformation was chosen based on some previous experiments.

The tensile test was carried out using a ring-shaped sample subjected to radial loading as described by Verlinden and De Baerdemaeker [13]. Verlinden *et al.* [14] applied this kind of set up to study the carrot tissue mechanical and histological properties during cooking. The tensile test set up and the sample is shown in Fig. 2. The considerations of this type of test are to avoid clamping problem of apple specimen and also avoids damaging the sample texture. The device consists of two half ring shaped cylinders over which the ring shaped sample can slide. During the test, the UTS moving crosshead will move at the test speed and the ring shaped sample will deform and eventually break. The force-deformation curve was recorded. The UTS crosshead moving speed was 50 mm/min.

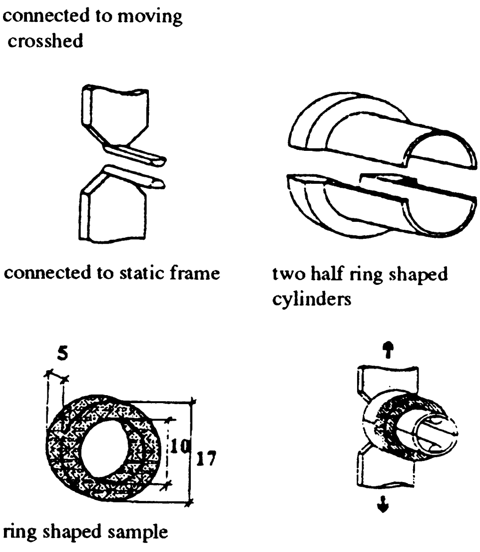

Fig. 2. Schematic diagram of the tensile test set up.

Analytical methods

The pH value, internal air space (IAS), juiciness, soluble solids concentration (SSC), and colour was determined just after cold storage and 7 days later, after storage under room conditions, for the four apple varieties.

PH value: The pH of each apple variety was determined at 20 °C.

Internal air space: The internal air space of whole fruit can be calculated according to the formula (1). The specific gravity (SG) of apple was determined by weighing the apple while it was floating in certain amount of water and weighing it again while submerged in the same way as Hatfield and Knee [5] used. The specific gravity of apple juice was the average of estimations using a pycnometer.

$$\text{IAS}\,(\%) = \left(1 - \frac{\text{SG fruit}}{\text{SG juice}}\right) 100\,\% \qquad (1)$$

Juiciness: In this experiment, the apple juiciness was determined by the weight gain of filter paper (Whatman) and expressed in terms of percentage expressible fluid. The sample (about 1.2 g) was weighed and compressed with UTS along its axis to 80% deformation. The fluid was collected on the four sheets (two on the top and two in the bottom of the sample) of filter paper. Two pieces of metal mesh (with holes dia.=0.5mm) were put between the sample and filter paper to prevent solid residue coming through. The filter paper was immediately reweighed. Juiciness was defined as percent weight loss based on the initial sample weight and is referred to as % expressible fluid. The presence of the filter paper on the top and bottom of the sample did not influence the measurements.

SSC: The juice expressed during compression was collected directly onto a hand-operated refractometer (0% to 85%; Zeiss, Germany) to measure the SSC.

Colour: The apple background colour was determined using the colour chart suggested by the research committee on storage (Belgium) which assigned the greenest fruit score 1 and the yellowest background score 8.

RESULTS AND DISCUSSION

The results of acoustic impulse resonant measurement of apple firmness is shown in Fig. 3. It is obvious that stiffness factor decreased for all apple varieties, which indicates

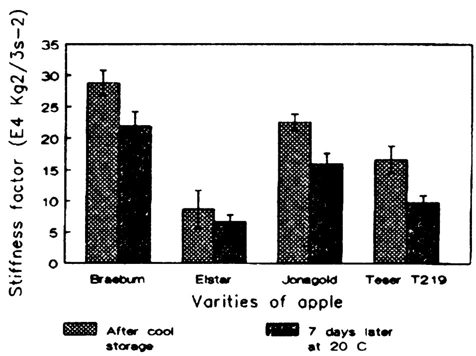

Fig. 3. Non-destructive acoustic impact response measurement results of the apples (with standard deviation).

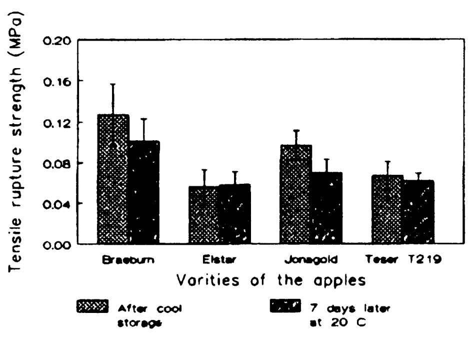

Fig. 4. Tensile measurement results of the apples (with standard deviation).

that the apple became softer after one week under shelf conditions. The firmness of Elstar apple was quite low due to the long cold storage. The firmness decrease of Elstar apple was the smallest. The damping ratio during acoustic test was also observed but the deviation was much higher than the frequency results.

The tensile test seems to be a reliable way to quantify the apple texture deterioration during storage [6]. Previous work done by Harker and Hallett [3] indicated that the tensile test can be used to measure apple tissue adhesion between neighbouring cells. The measured tensile strength is shown in Fig. 4. The rupture tensile strength is decreased after one week storage at 20 °C, 65% RH except for the Elstar apples. The Elstar apple has been stored for more than 3 months and the tensile strength seems not to decrease any more. The low tensile strength indicates the low adhesion between apple cells.

Apple ripeness is associated with decrease of the firmness. However, the decreasing of firmness seems to have a limitation as the apple is over ripened. The low tensile strength indicates the declined texture. Most of the Elstar, Jonagold and Teser T219 apples were tested mealy (by student panel) as the rupture tensile strength below 0.07 MPa. The Braeburn apple showed mealy teste at tensile strength at about 0.1-0.12 MPa.

The three parameters of the texture profile analysis measured in the experiment can be seen from Table 1. The apple normally has no adhesiveness which can be found in Fig. 5(a). As the apple over ripened, the adhesiveness may appear, which is shown in Fig. 5(b). From Table 1, the Teser T219 apple showed obvious increase of adhesive force. Harker and Hallett [3] conclude that mealy apple cells are difficult to rupture while non-mealy apple cells are relatively easy to rupture and release their contents during chewing. In the experiment, the appearance of adhesiveness after one week on shelf may indicate that those apple cells were not ruptured completely and had relatively strong resistance when the UTS crosshead pulled up. The apple flesh hardness and cohesiveness decreased after one week under room conditions. Apple mealiness

Table 1. Results of the Texture Profile Analysis

Apple variety	After cool storage (2°C)			One week later at (20°C)		
	Hardness (N)	Cohesiveness	Adhesive force (N)	Hardness (N)	Cohesiveness	Adhesive force (N)
Teser T219	23.5	0.067	0	21.1	0.037	0.4~0.6
Braeburn	54.7	0.067	0	50.9	0.056	0.1~0.3
Elstar	24.1	0.039	0	25.7	0.041	0.1~0.3
Jonagold	26.7	0.051	0	24.9	0.047	0.1~0.3

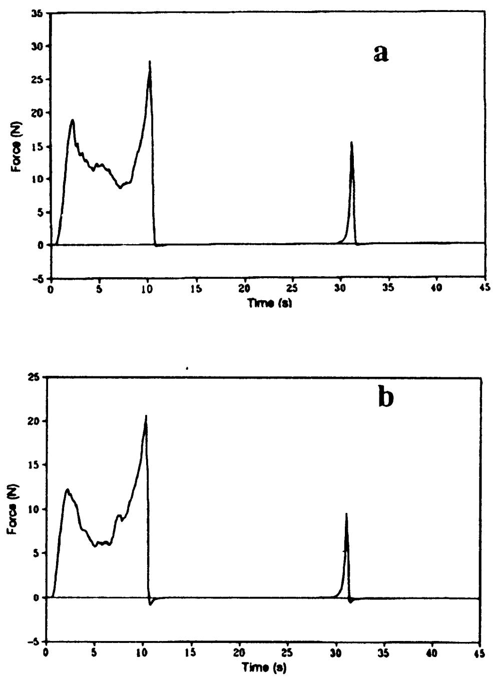

Fig. 5. TPA curves of non-mealy (a) and mealy (b) Teser T219 apple.

development seems associated with the decrease of cohesiveness and a small increase of adhesive force.

The increasing of adhesiveness may be due to the cell wall strength. Early studies on cellular observation [3] indicated that high-maturity apple maintained cell wall strength but tended to lose adhesion between cells. The individual cells are difficult to rupture and this may cause the appearance of adhesiveness as the apple turned to mealy.

The SSC, colour change, and pH value of the apples were determined as shown in Table 2. The SSC value increased after one week under room storage conditions. The apples of the four cultivars were described ripened after one week shelf life based on the colour. The pH value increased for all the apples. It can be concluded that over ripened apple (Elstar) is associated with its high SSC and pH value.

The internal air space and apple juiciness were determined as shown in Table 3. It is clear that the IAS will increase as the apples become ripening and mealy. This observation indicates that the high-maturity apples have more volume of air space and likely cause smaller cell wall surface area. Other researches [3,6,15] also demonstrated that the large internal air spaces were associated with poor apple texture (mealiness). The increased IAS probably caused by degradation of middle lamella. It should be mentioned that the increases of IAS are different for different apple varieties. For Braeburn apple it may be around 17 % when the apple tasted mealy. If we take the long time stored Elstar apple as a reference mealy apple, it may suggest that the apple becomes mealy as the IAS is more than 21 %.

The percentage of expressible fluid is directly linked to the crisp and juicy apple texture. From the Table 3, it is obvious that the apple has less expressible juice after one week under shelf life conditions. Some previous experiments show that the expressible fluid is often between 25-35 % for fresh apples. It may be suggested that the apple is not juicy as the expressible fluid is less than 20 % under these experimental conditions. However, it should be pointed out that juiciness is apple variety dependent and it should be related to sensory (panel) evaluation.

CONCLUSIONS

Texture of apple, especially mealiness were studied with different instrumental methods. The apple firmness decreases under simulated shelf life conditions. The non-mealy apple will not show adhesiveness during texture profile analysis but the ripened, mealy apple

Table 2. Changes of the apple colour, pH value and SSC

Apple variety	After cool storage (2°C)			One week later at (20°C)		
	colour	pH	SSC (%)	colour	pH	SSC (%)
Teser T219	7.0±0.2	3.54±0.05	12.9±0.1	8	3.82±0.05	13.4±0.2
Braeburn	7.0±0.2	3.55±0.05	12.0±0.2	8	3.72±0.05	12.2±0.3
Elstar	>8	3.50±0.05	13.1±0.1	>8	3.88±0.05	14.1±0.2
Jonagold	7.0±0.5	3.50±0.05	11.8±0.3	8	3.69±0.05	12.0±0.3

Table 3. Expressible fluid (Juiciness) and IAS of the apples

Apple variety	After cool storage (2°C)		One week later at (20°C)	
	Expressible fluid (%)	IAS (%)	Expressible fluid (%)	IAS (%)
Teser T219	25.4±5.8	20.2±0.2	25.1±3.7	23.2±0.2
Braeburn	28.8±3.8	14.2±0.2	18.9±2.4	16.5±0.2
Elstar	23.2±2.5	20.7±0.2	17.2±3.0	24.8±0.3
Jonagold	26.6±1.8	19.4±0.2	21.1±0.9	19.8±0.3

may show some adhesiveness, especially for Teser T219 apple which may be a kind of easy to mealy apple. Tensile testing of apple texture may provide information on adhesion between apple flesh cells and, hence, can be applied to measure apple mealiness.

Internal air space seems to be a good indicator of apple mealiness. Although the IAS for different varieties of apples may differ as the apple begins to mealy. The higher IAS normally corresponds to poor, mealy texture.

Apple juiciness is directly indicated by expressible fluid. The apple juiciness is variety dependent. Mealy apple has less expressible fluid.

More work still needs to be done to identify mealiness accurately and reliably with objective methods. Future sensory (panel) evaluation will be compared and related to instrumental measurement results.

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