Mechanical Texture Measurement of Whole and Chopped Peanuts[1]

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ABSTRACT

Different test cells (a Warner-Bratzler type blade, compression cell and a modified Kramer shear-compression cell) were compared to obtain an objective method for texture measurement of whole and chopped peanuts. The modified Kramer shear-compression cell was found to be the most sensitive in measuring textural characteristics of whole peanuts. Objective parameters, force and energy, correlated well with subjective parameters resulting from sensory evaluation, crispness and crunchiness (r^2 = 0.77 and 0.79), respectively. The coefficients of determination (r^2) between whole and chopped peanuts for force and energy were 0.81 and 0.72, respectively; which suggested that the modified Kramer shear-compression cell can be used to evaluate the textural quality of chopped peanuts.

Key Words: Roasted peanuts, textural quality, Instron, sensory evaluation.

Crunchy and crisp are textural attributes that are important and desirable sensory qualities of peanuts. Based on a consumer study, crispness has been reported to be the most versatile single texture parameter (13). Szczesniak (12) defined a crisp food as one that is firm (stiff) and snaps easily when deformed emitting a crunchy/crackly sound.

Matlock (5) reported 19 important factors characterizing peanut quality, four of those factors had no standard objective methods of measurement. Textural quality was one of the four factors. The identification or development of an appropriate test cell and/or procedure should help the food industry to monitor textural changes and to evaluate the shelf-life of peanuts.

A vast array of instruments has been developed for measuring mechanical properties of foods which can be related to texture of foods. Accurate textural determinations are accomplished by measuring resistance of the product to applied force under carefully controlled conditions such as rate of applied force, temperature and humidity. Test samples are subjected to shear, compression, extrusion, tension or other modes of action according to the textural parameter of interest. The mechanical instruments used for texture measurement have been reviewed by Voisey (20) and Bourne (3).

The Instron Universal Testing Machine is used extensively for objective texture testing of food (19). Mechanical force and work usually have strong correlations (inverse) with sensory crispness and crunchiness scores (9). Vivar and Brennan (17) used 6 different test procedures to measure differences in physical properties among raw, blanched and oil roasted peanuts. They found that a compression test best distinguished the physical property differences among raw, blanched and roasted peanuts. Szczesniak *et al.* (14) evaluated the effect of sample weight on the peak area and maximum force of unroasted peanuts in the standard Kramer shear-compression cell; however, they did not correlate their data to any textural characteristic.

Sensory evaluation of texture in foods belongs to the domain of psychology known as psychophysics (7). Psychophysics directly concerns the correlation of sensory experience with physical measures. There are two major classifications of sensory tests, affective and analytical. Affective tests are used to evaluate preference and/or acceptance of products (2). However, this method can not provide a proportional relationship between sensory scores and physical measures. Analytical tests are used for quantification of sensory characteristics. The technique of magnitude estimation is an analytical test described by Stevens and Harris (11). They instructed their observers to assign numbers in proportion to the perceived intensity for evaluation of roughness and smoothness. Magnitude estimation was used primarily to estimate the proportional relationship between physical intensity and sensory magnitude and to index how rapidly sensory magnitude grows with increases in physical intensity (7).

Evaluating the textural quality of peanuts, sensory panelists can either bite or chew those peanuts. Vickers (15) studied the crispy and crunchy textural quality of peanuts by both biting and chewing techniques. Her results demonstrated that changing the testing technique from a chew to a bite increases the reproducibility of crispy measurement for peanuts. There was no significant difference in reproducibility of crunchy measure-

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ment between biting and chewing.

Metwalli *et al.* (6) evaluated the sensory quality of roasted and fried peanuts. They found that the quality of fried peanuts was superior to the roasted peanuts because of crisp texture, pleasant taste and attractive creamy color. When peanuts are exposed to a high relative humidity (RH) environment they absorb moisture and become soggy (23). They used a 5-point category scale to evaluate the effect of moisture content on the sensory texture of peanuts and found salted peanuts cooked in fresh oil turned slightly soggy at 2.4-4.0% moisture content, soggy at 4-6% moisture, and very soggy when moisture content was greater than 6%.

Both the sensory and objective methods reported in the literature as applied to peanuts have been used for whole or half nuts, whereas the adaptability of these methods to measure textural quality of chopped nuts is not known. The overall goal of this study was to evaluate several different test cells for describing two sensory characteristics, crunchiness and crispness, of whole and chopped peanuts. The specific objectives were to: (1) identify an appropriate test cell and procedure for measuring textural quality of whole peanuts, (2) establish the relationship between mechanical and sensory textural measurements of whole peanuts, (3) evaluate the adaptability of selected mechanical method(s) for texture measurement of chopped peanuts, and (4) to demonstrate the application of selected mechanical method(s) for determining the end point at which peanuts lose their desirable crunchy characteristic.

Materials and Methods

Test samples

Peanuts (*Arachis hypogaea* L., cv. Florunner) grown in the summer of 1986 at the University of Georgia southwest branch station at Plains, GA, were harvested at the optimum time based on the peanut pod maturity method developed by Williams and Drexler (22). Peanuts (6.8 kg) were then dried to approximately 7% moisture in a forced air oven (Model No. POM-203C-1, Blue M Electric Company, Blue Island, IL) at 37 C for 24 h and stored in a sealed container at 4 C until used (the storage period did not exceed 2 months).

Dried peanuts were mechanically shelled using standard equipment employed by USDA inspectors at peanut receiving stations; they were then passed through a seed cleaner (Almaco seed cleaner, Allan Machine Company, Ames, IA) to remove the shell and light weight material. Peanut kernels were then blanched in a cold blancher (Model EX, Ashton Food Machinery Co. Inc., Newark, NJ) and passed through the Almaco seed cleaner again to separate the testa from the kernels. Peanuts were roasted in one liter batches in a laboratory scale General Electric Rotissere Oven at 204 C for 15 min. One half of the roasted peanuts were chopped in a Hobart cutter (Model 84142, Hobart Manufacturing Company, Troy, OH). Chopped peanuts which passed through a sieve size 4 and were retained on sieve size 6 were used in this experiment.

In order to obtain peanuts with different textural quality to test the sensitivity of the test cells, peanuts were stored at different water activities (a_w) (Table 1). Chopped and whole peanuts were separately placed in Petri dishes and subjected to seven constant a_w environments by placing the Petri dishes in desiccators partially filled with saturated salt solutions. It was assumed that equilibrium was reached when their weight did not change more than 0.2% during a 24 h period. After reaching equilibrium, the peanuts were evaluated by both sensory and mechanical methods. Moisture contents were determined by the AOAC (1) vacuum oven method.

Mechanical tests

The Instron Universal Testing Machine (Model 1122, Instron, Inc., Canton, MA) fitted with an appropriate test cell and a 500 kg capacity load cell was used in this study. The five test cells and their operating conditions are described below.

Table 1. Equilibrium moisture contents of peanuts at different water activities.

Saturated salt solution	a_w at 25 C*	Equilibrium moisture content (dry basis) (%)
Lithium chloride	0.120	1.61 ± 0.07
Potassium acetate	0.227	2.03 ± 0.06
Magnesium chloride	0.332	2.41 ± 0.03
Potassium carbonate	0.438	3.15 ± 0.01
Magnesium nitrite	0.534	3.89 ± 0.05
Sodium nitrite	0.643	4.35 ± 0.06
Sodium chloride	0.758	5.71 ± 0.05

*Wexler and Hasegawa (17).

Kramer shear-compression cell (Kramer cell): The Model CS-1 (Food Technology Corporation, Reston, VA) was operated at a crosshead speed of 100 mm/min and chart speed of 200 mm/min. 50 ±0.2 g of peanuts (whole or chopped) were tested each time. Four replicates were measured for each a_w. Maximum force and area under the force-deformation curve were measured.

Extrusion cell: The model CE-1 Universal cell (Food Technology Corporation, Reston, VA) was operated at the same condition as the Kramer cell. Maximum force was recorded.

Compression cell: It consisted of a 57 mm plate and a flat sample holder. Individual peanuts were split into two halves and each half with the flat side down was compressed until the point of fracture. Tests were run at a crosshead speed of 10 mm/min and chart speed at 20 mm/min. Thirty replicates were measured for each a_w and maximum forces were recorded.

Modified Warner-Bratzler type meat shear blade (Warner blade): The modified meat shear cell (Model CW-1, Food Technology Corporation, Reston, VA) having a triangular cut-out as described in Hung *et al.* (4) was operated at 50 mm/min and chart speed of 100 mm/min. A single whole peanut was tested each time. Thirty replicates were measured for each a_w and maximum forces were recorded.

Modified Kramer shear-compression cell (modified Kramer cell): A standard Kramer cell was modified as described in Hung *et al.* (4) and is presented in Fig. 1. A typical force-deformation curve using the modified Kramer cell is presented in Fig. 2. Force-deformation curves in Fig. 2 were analyzed to obtain two parameters, maximum force (N) and energy (J) associated with shearing and compression forces. Energy required to shear and compress the peanuts was calculated by integrating the area under the force-deformation curve (shaded area Fig. 2) up to the maximum force.

Sensory tests

Sensory texture was evaluated by fifteen semi-trained panelists in individual taste panel booths. One training session was conducted prior to the actual tests to familiarize the panelists with the test procedure and the testing ranges. Crunchiness was tested for both whole and chopped peanuts. Crispness was tested for whole peanuts only. Sensory crunchiness and crispness of the test samples from the same treatment were performed at separate sessions within a 24 hour period.

Crispness was evaluated by biting a single peanut with the front teeth (15). Magnitude estimation (11) was used to obtain ratio-scale values for crispness. Peanuts stored at 21 C and 0.332 a_w were selected as the standard sample and was assigned a score of "50"; panelists then compared the crispness of peanuts from different treatments with the standard and gave proportionate scores. If the test sample was one half as crisp as the standard, sensory panelists were asked to assign a score of 25. If the test sample was twice as crisp as the standard, sensory panelists were asked to assign a score of 100.

Sensory crunchiness was measured by chewing 1.5 g of whole or chopped peanuts with the molar teeth until swallowing. Panelists were then asked to indicate how crunchy or soggy each sample was by placing a mark along a 150 mm unstructured horizontal line scale. The scale was labelled "very soggy", "neither soggy nor crunchy", and

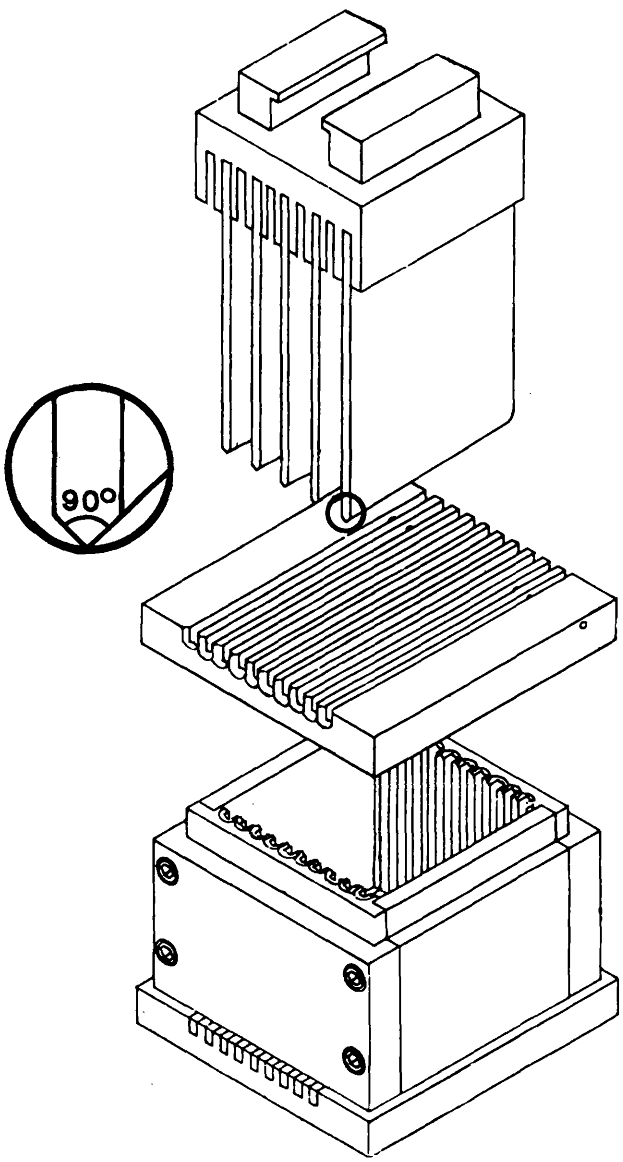

Fig. 1. The modified Kramer shear-compression cell used with the Instron Universal Testing Machine.

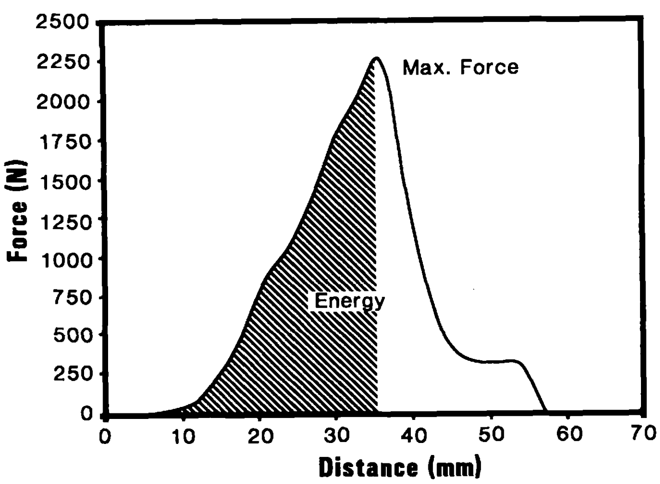

Fig. 2. A typical force-deformation curve from a modified Kramer shear-compression cell test of whole peanuts.

"very crunchy" at 10, 75, and 140 mm from the left end of the line, respectively. This method was selected to determine under what storage conditions peanuts will lose their desirable crunchy textural quality.

Area measurement

Area under the force-deformation curve was measured using a Hitachi digitizer (HDG 1111B) connected to a Zenith 200 microcomputer.

Statistical analysis

Statistical analysis was performed using ANOVA, GLM (General Linear Models) and Student's t-test procedures of Statistical Analysis System (8).

Results and Discussion

The forces developed in testing the Kramer shear-compression and extrusion cells exceeded the load cell capacity (500 kg). Thus only the compression cell, Warner blade and modified Kramer cell were used in the textural measurement of peanuts.

Whole peanuts

Maximum forces recorded from force-deformation curves using different test cells are presented in Fig. 3. Maximum force increased with increasing a_w which is similar to results of Seymour and Hamann (9) for low moisture foods. The coefficient of determination (r^2) of maximum force with the Warner Blade, compression cell and modified Kramer cell were 0.38, 0.28 and 0.90, respectively (see Appendix). Only the modified Kramer cell appeared to adequately detect the textural differences in peanuts stored in different a_w.

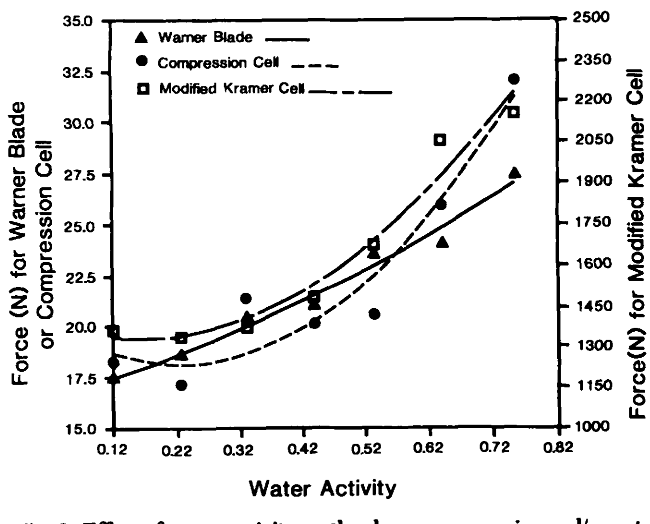

Fig. 3. Effect of water activity on the shear, compression and/or cutting force of whole peanuts.

Sensory crispness (evaluated by biting a peanut between the front teeth and judging the force required to break it) results of whole peanuts are presented in Fig. 4. The higher the a_w, the lower the crispiness scores. A significant reduction in crispness was observed for a_w value greater than 0.643.

Sensory crispness score was found to be inversely correlated with the maximum force which also agreed with the results of Vickers (16) and Seymour and Hamann (9). The r^2 of sensory crispness with the maximum force recorded with the compression cell, Warner blade, and

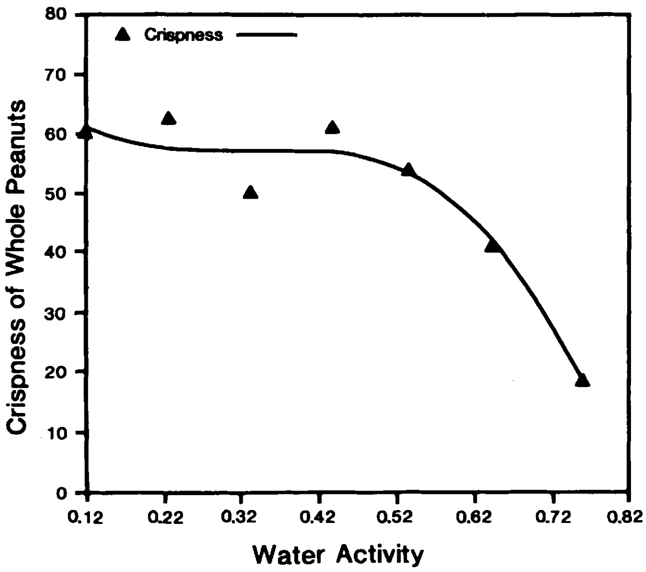

Fig. 4. Effect of water activity on the mean sensory crisp scores of whole peanuts.

modified Kramer cell were 0.96, 0.76, and 0.77, respectively. The maximum force results from the compression cell measurements correlated well (r^2 = 0.96) with the sensory crispness scores. The Warner blade measurements were expected to closely relate to the sensory crispness results because incisors seem to act as apposing to the shearing motion of the Warner blade. However, the results were to the contrary which may be attributed to a lesser degree of change in sensory crispness values for a_w equal or less than 0.534.

The energy required to shear and/or compress the peanuts in different test cells increased with increasing a_w (Fig. 5), similar results have been reported by Seymour and Hamann (9) for potato chips, crunch twist, and saltine crackers. The r^2 of the second degree best fit polynomials of the energy with the Warner blade, compression cell and modified Kramer cell were 0.61, 0.54

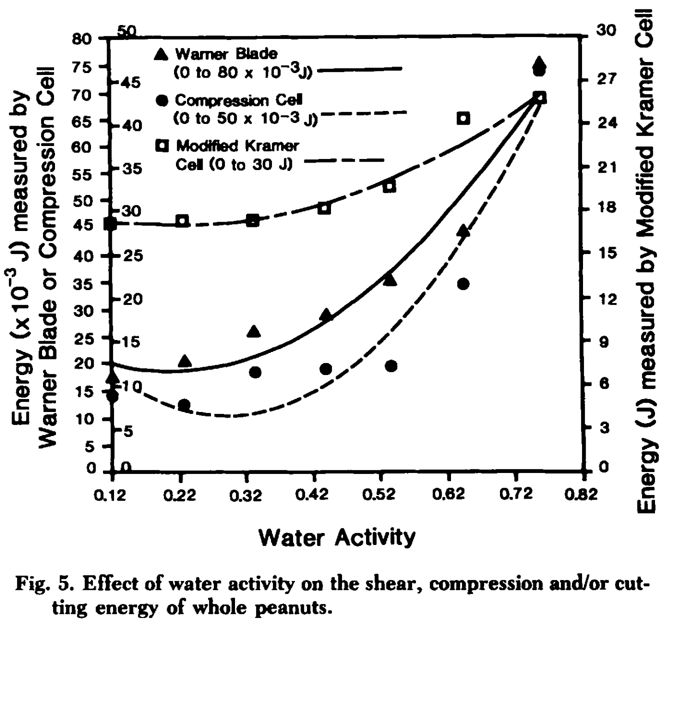

Fig. 5. Effect of water activity on the shear, compression and/or cutting energy of whole peanuts.

and 0.90, respectively (see Appendix). The modified Kramer cell was the best test cell to detect the mechanical property differences in peanuts stored at different a_w.

Sensory crunchiness is the energy required to masticate a solid food (18) was evaluated by chewing a fixed amount of peanuts with the molar teeth and the results are presented in Fig. 6. Sensory crunchiness scores generally decreased with increasing a_w. A significant loss of crunchiness occurred in peanuts when they were stored above 0.534 a_w, correspondingly the energy required to shear and/or compress peanuts by using the modified Kramer and compression cells also increased significantly (Fig. 5). Peanuts completely lost their crunchy textural quality (at a sensory score equal or less than 75) and became soggy when a_w was above 0.643. The r^2 of sensory crunchiness with the energy recorded with the compression cell, Warner blade and modified Kramer cell were 0.97, 0.99 and 0.92, respectively. Both mechanical and sensory methods were measuring energy and were found to correlate well.

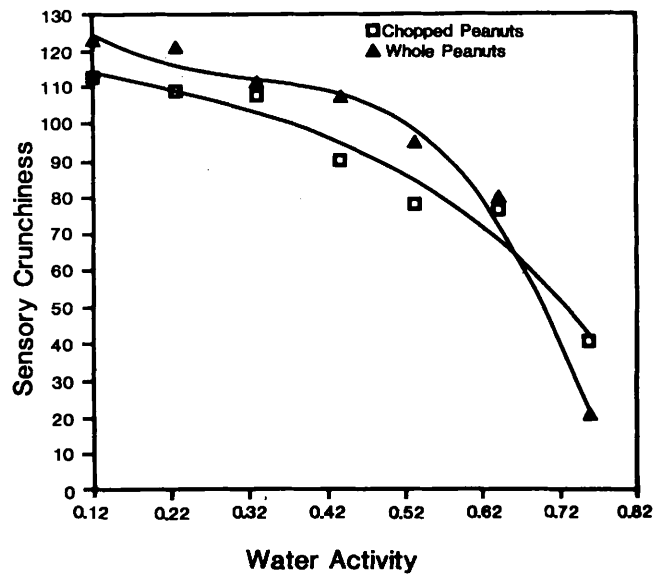

Fig. 6. Effect of water activity on the mean sensory crunchy scores of whole and chopped peanuts.

Coefficient of variation (CV) is a measure often used in describing the amount of variation in a population (10). CV of maximum force values for the compression cell, Warner blade, and modified Kramer cell was computed to be 0.33, 0.18 and 0.05, respectively. The CV of energy values for the compression cell, Warner blade and modified Kramer cell was computed to be 0.54, 0.33 and 0.05, respectively. These values indicate that the modified Kramer cell was more consistent and sensitive than the other two test cells. It also gave reproducible results and consumed less time. Maximum forces and energy values derived from the force-deformation curves of the modified Kramer cell also significantly ($P < 0.01$) correlated with sensory crispness and crunchiness, respectively. The modified Kramer cell also detected the mechanical property differences in peanuts stored at different a_w. Based on these criteria, the modified Kramer cell should be an appropriate choice for measuring the textural quality of whole peanuts.

The ratio of force to energy (FE ratio) was calculated from the measured maximum force and energy. This ratio can be used as a measure of deformation to break and can also be correlated to sensory textural properties. Sensory crunchiness vs FE ratio from the modified Kramer cell measurements are presented in Fig. 7. It appears that the relationship between sensory crunchiness and FE ratio was linear for FE ratio of 77 to 84 then there was a sudden drop in sensory crunchiness with a slight increase in FE ratio. It also implied that the sample stored at a_w greater than 0.643 resulted in a drastic change in its sensory crunchiness. A similar trend was observed between sensory crispness and FE ratio obtained from ther modified Kramer cell.

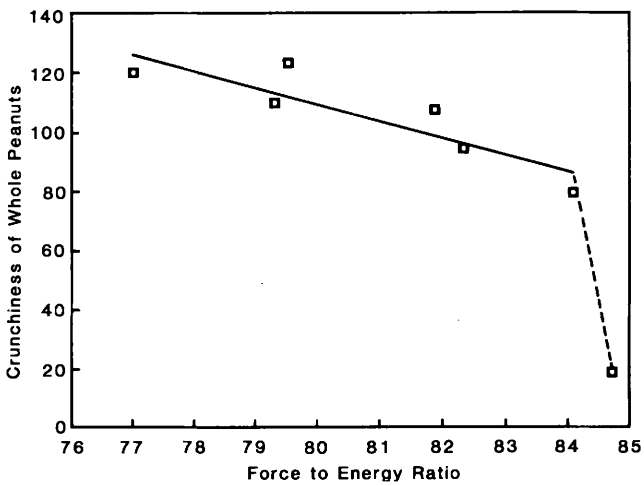

Fig. 7. Interrelationship between mean sensory crunchy scores and force to energy ratio from the modified Kramer cell measurement of whole peanuts.

Chopped peanuts

Textural quality of chopped peanuts stored at different a_w was determined using the modified Kramer cell to evaluate the adaptability of this cell for this product. Both maximum force and energy values increased with increasing a_w(Fig. 8). Maximum force and energy values for chopped peanuts followed the same trend as those for whole peanuts. The r^2 values between whole and chopped peanuts for maximum force and energy were 0.81 and 0.72, respectively. The r^2 value between energy and sensory crunchiness (Fig. 9) for chopped peanuts was 0.83. These indicated that the modified Kramer cell can be adapted for the texture measurement fo chopped peanuts.

Application

Subjective values of crunchiness for whole and chopped peanuts are given in Fig. 6. Peanuts with a score less than or equal to 75 are considered to have lost their crunchiness. Whole and chopped peanuts can be considered to have lost their crunchiness at a_w greater than 0.643 (Fig. 6). This a_w value fell within the same ranges as peanuts which significantly lost their crispy textural quality. Energy vs sensory crunchiness of whole and

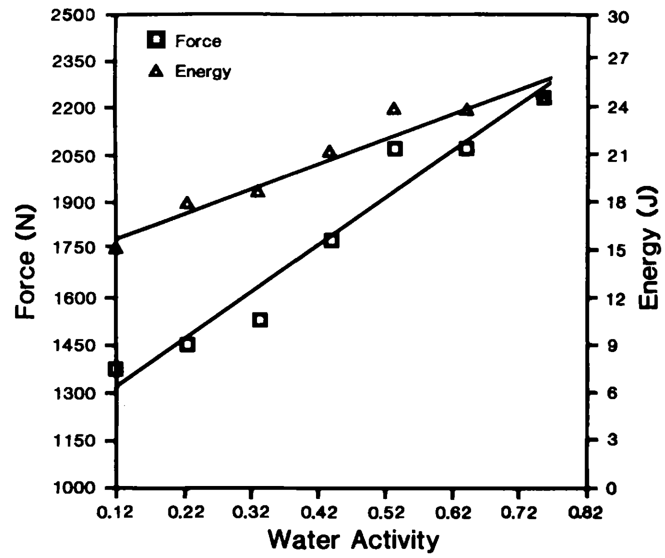

Fig. 8. Effect of water activity on the shear compression force and energy of chopped peanuts measured by a modified Kramer cell.

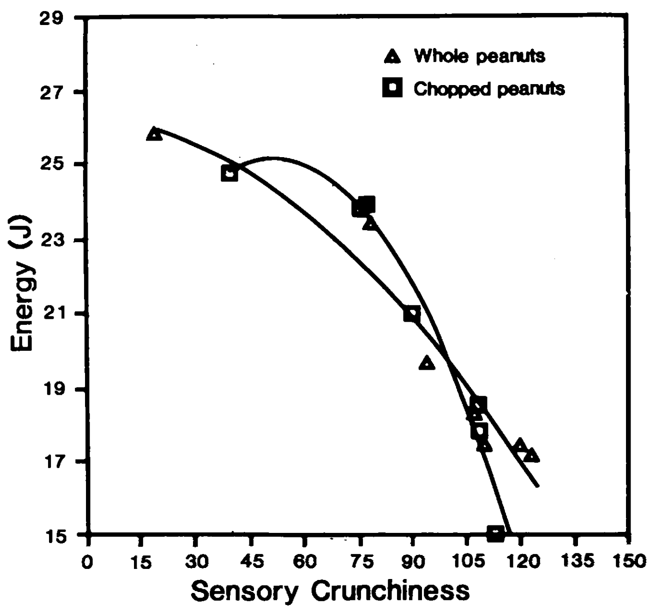

Fig. 9. Interrelationship between mean sensory crunchy scores and shear compression energy measured by a modified Kramer cell.

chopped peanuts are presented in Fig. 8. No conclusive statements can be drawn from the data regarding at what energy level peanuts will lose their desirable textural quality. From the second degree polynomial regression equations, a sensory crunchiness score of 75 was interpolated as equivalent to the energy of 22.5 and 24.0 J for whole and chopped peanuts, respectively indicating that these energy values could possibly be used as an index for evaluating the textural quality of peanuts. When measured energy value exceed the index value, peanuts may be assumed to have lost their crunchy textural quality. More data are needed between 0.5 and 0.8 a_w in order to identify the exact energy level when peanuts became soggy.

Appendix

Coefficients of polynomial regression equation ($Y = b_0 + b_1a_w + b_2a_w{}^2 + b_3a_w{}^3$)

Figure #	Dependent variable.	b_0	Coefficients b_1	b_2	b_3	Coefficients of determination (r^2)
3	Warner blade force (N)	16.4	8.4	7.7	___	0.38
	Compression cell force (N)	20.5	-21.0	46.9	___	0.28
	Modified Kramer cell force (N)	1401	-804	2508	___	0.90
4	Sensory crispness of whole peanuts	74	-158	494	-503	0.35
5	Warner blade energy (10^{-3}J)	52	-143	342	___	0.61
	Compression cell energy (10^{-3}J)	20	-95	164	___	0.54
	Modified Kramer cell energy (J)	18.6	-14.0	31.6	___	0.90
6	Sensory crunchiness of whole peanuts	152	-323	935	-970	0.68
	Sensory crunchiness of chopped peanuts	111	33	-158	___	0.46
7	Sensory crunchiness of whole peanuts	571	-5.8			0.78
8	Modified Kramer cell force (N)	1090	1570	___	___	0.95
	Modified Kramer cell energy (J)	11.9	27.4	-13.4	___	0.93

*a_w = Water Activity at 25 C

Conclusions

The modified Kramer shear cell was found to be the most sensitive cell to quantify the textural quality of both whole and chopped peanuts and yield reproducible results. Maximum force and energy measured from force-deformation curve correlated significantly with sensory scores of crispness and crunchiness, respectively. The method developed may help the peanut industry to estimate the textural quality and determine the end point at which peanuts lose their desirable crunchy textural quality. Although the emphasis of this study is on peanuts, the method developed may be adaptable to other nuts and legumes.

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