HYPOTHESIS PAPER

Effective Discrimination of Meat Tenderness Using Dual Attribute Time Intensity

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ABSTRACT

We examined the effectiveness of Dual Attribute Time Intensity (DATI) method for assessment of temporal changes in perceived toughness and juiciness, within commercially acceptable meat cuts. Usefulness of DATI in assessing temporal aspects of perception of juiciness and toughness was compared with Single-Attribute Time-Intensity (SATI) and Line Scale Profile. Results showed that DATI provided a good separation of attributes and was equal to or better than SATI in differentiating beef samples based on perceived juiciness and toughness. By reducing the dumping effect and the inherent sample to sample variability, this method enabled more precise assessment of the relationship between juiciness and toughness in meat than SATI.

Key Words: Dual Attribute Time Intensity, DATI, meat, juiciness, tenderness, SATI

INTRODUCTION

TENDERNESS HAS LONG BEEN RECOGNIZED AS AN IMPORTANT attribute of meat, greatly influencing consumer acceptability. Consequently, there has been a growing interest developing a technique that would allow accurate assessment of meat tenderness. In sensory meat studies, assessment of meat tenderness evolved from a single scale (Cover and Smith, 1956) for overall tenderness, to a very complex analysis subdividing tenderness into several components (Cover et al., 1962). Introduction of the multicomponent meat texture assessment technique was one of the most notable advances in meat research.

However, recognizing the dynamic nature of meat texture perception, the technique continued to have considerable deficiencies. First, the analysis of multicomponent scores was complex, as was the interpretation of results. Usually, it involved some kind of assimilation and weighting of components to reduce their number and to identify those most important. Most frequently, multivariate analysis confirmed interdependence of the components and indicated that they could be reduced to two fundamental characteristics: juiciness and tenderness, which accounted for most of the variability (Harries et al., 1972; Risvik, 1994). Second, the most important disadvantage of the multidimensional meat texture profile method was that this technique was actually a compilation of several static attributes assessed at different times. This did not provide an accurate account of temporal changes in meat texture perception. The mastication of meat is a dynamic process, not only with respect to the applied force, but also to a continuous change in meat physical properties caused by wetting with saliva.

Development and computerization of time intensity and its subsequent application in meat research was the next notable advancement. By having judges continuously monitor perceived sensations, the time intensity method provided a unique advantage over conventional methods of texture measurements. It measured temporal changes in meat texture perception taking place in the mouth during chewing. The information obtained was expressed as curves representing intensity over time, facilitating intersample comparisons. The technique has been successfully applied to meat research and attempts have been made to relate perceived changes in meat tenderness to changes in juiciness (Duizer et al., 1993; Butler et al., 1996; Brown et al., 1996; Zimoch and Gullett, 1997).

Although time intensity studies are popular for increasing sensory information, caution should be exercised by the researchers who apply the technique (Lawless and Clark, 1992); it may not be free from psychological bias, such as a "dumping" effect. Dumping may occur when a panelist is instructed to evaluate only one attribute in a food. The single attribute is rated as more intense when evaluated alone than when evaluated with other attributes. The development of the Dual Attribute method for time intensity evaluations (DATI) (Duizer et al., 1997) provided a potential means to avoid such methodological defects, since it enables simultaneous evaluation of two attributes. In the Single Attribute Time Intensity method (SATI) two individual meat samples would be required to evaluate juiciness and tenderness separately. Due to the inherent variability between meat samples this may have an adverse effect on the reliability of results. DATI may provide more dependable results because it requires only one sample to assess both attributes concurrently. In addition to removing any meat sample variability, the method substantially reduces the time and cost of evaluation. In the DATI method, the information collected about the product is double that collected by the SATI method. The DATI method has been successfully used for assessment of perceived changes in sweetness/peppermint flavor in chewing gum (Duizer et al., 1997). However, the data collection time was relatively long in that study.

Our objective was to determine the effectiveness of DATI for assessment of the temporal changes in meat texture, where the data collection time is relatively short, and to compare the relative effectiveness of DATI to SATI in assessing temporal differences in perceived tenderness and juiciness of meat.

MATERIALS & METHODS

Sample preparation

Six commercial beef samples of *Longissimus lumborum*, Canada grade A, aged for 21–28 days at 4 to 8°C, were evaluated by DATI, SATI, and Line Scale Profile.

All meat samples were obtained fresh from local meat packers. They were frozen to an end point temperature of −18°C and then cut into 1.2-cm slices using a band saw. The slices were then cut into 1.2 cm cubes. Cubes (62) from each animal were randomly selected then placed into a polyethylene bag, vacuum packaged and sealed. The sealed bags were then placed into a (−18°C) freezer where they were held until testing. During the day of each testing session, four bags of samples were removed from the freezer and placed in a larger bag (Cryovac® 'S' W.P. Grove & Co.) to ensure uniformity of treatment. The bag was sealed and held at 8°C to thaw for 5h. This time allowed for complete thawing without leaking of juice from the cubes. The bags were immersed into a constant temperature water bath (Fisher Versa bath) set at 72.5°C. The samples were heated for 20 min to an end point temperature of 70°C. The temperature was monitored using a Yew model 3087 recorder and nickel chromium thermocouples inserted into the center of the cube package. Upon removal from the water bath, samples were cooled in the bag to the controlled room

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temperature (21.5°C). The cubes were then placed into plastic cups labeled with a three-digit blinding code, lidded and presented to panelists for evaluation.

Selection of panelists

All panelists (30) were selected from a group of individuals with previous experience with line scale evaluation, based on interest in the project and availability. No subject participated in more than one of the methods of assessment.

Panel training-Single Attribute Time Intensity (SATI)

All training and testing sessions were conducted at the Compusense Sensory Research Centre (Guelph, Canada). Ten panelists were trained in the use of time intensity to evaluate beef toughness and juiciness. Five panelists had previous experience with SATI evaluations. The panelists completed 24 1-h training sessions. Toughness and juiciness definitions were discussed during early sessions. Meat toughness was measured as the force to chew the meat and was understood as being the opposite to meat tenderness (high force to chew meant high meat toughness and low tenderness). Meat juiciness was defined as the overall impression of juice perceived in the mouth during chewing. Panelists were first trained to record toughness and juiciness manually on a 10-cm line. Following this, the panelists were trained to evaluate toughness and juiciness in a temporal manner, by evaluating samples for each attribute every 2s. The panelists were then assigned to computers where they input their responses for toughness (vertical scale) and juiciness (horizontal scale) continuously on a time-intensity line, 60 units in length. The scales were labeled with appropriate descriptors (juiciness: not juicy (0) and very juicy (60); force to chew: low force to chew (0) and high force to chew (60)). During training the panelists were provided with the reference samples to calibrate intensity ratings. The computer was programmed to collect responses every 0.5s. The panelists evaluated the meat samples using the computerized time intensity program under red lighting (Compusense Inc., Guelph, Canada).

Panel training-Dual Attribute Time Intensity (DATI)

Eight panelists were trained in the evaluation of beef toughness and juiciness. Four of them had previously participated in DATI testing. The initial training was conducted in the same manner as described for the SATI test. After initial training, the panelists were presented with the DATI test on computers and trained to move a mouse diagonally across a mouse pad to record both attributes simultaneously (toughness-vertical scale and juiciness-horizontal scale). The scales were labeled with appropriate descriptors (juiciness: not juicy (0) and very juicy (60); force to chew: low force to chew (0) and high force to chew (60). During training, panelists were provided with reference samples to calibrate intensity ratings. The panelists evaluated samples using the computerized time intensity program under red lighting (Compusense Inc., Guelph, Canada).

Panel training-Line Profile

Twelve panelists, selected from a pool of individuals with previous experience in line scale evaluations, were trained to evaluate six attributes using a 10 cm line (Table 1). These panelists attended 24 1-h training sessions. During the sessions, the panelists were introduced to the attributes of tenderness, juiciness, beef flavor, chewiness, moisture absorption, and time to chew. Panelists were provided with examples of the ranges of each of these attributes and discussions were held to ensure that panelists understood attribute definitions. Following discussion, the panelists were required to evaluate examples of the beef samples to be used during testing. These evaluations were conducted in individual computerized booths under red lighting.

Sample presentation

A completely randomized design plan was used for testing. In each session, four samples were evaluated by each panelist. Three replications of testing of each sample were completed. A total of five sessions were required to complete the experimental design. Sample presentations to panelists were randomized within each testing session.

Table 1—Line scale attributes, definitions and scale descriptors

Attribute	Attribute definition and the scale descriptors
Tenderness	The force to chew a 1.2 cm cube of meat. Measured after 3 chews. Tough ——— Tender
Juiciness	The amount of moisture released from the meat after 5 chews. Not juicy ——— Very juicy
Flavor	The amount of beef flavor perceived in the meat after 8 chews. Weak ——— Full meaty
Chewiness	The energy (time + force) required to prepare the meat sample for swallowing Not chewy ——— Very chewy
Moisture absorption	The amount of saliva required to lubricate the sample for swallowing. Very little ——— Very much
Time to chew	The length of time required to chew a sample from first bite through to swallowing Very short ——— Very long

Testing-SATI

Panelists were presented 1.2 cm cubes of beef for evaluation. The SATI panelists were presented with separate samples to consecutively evaluate juiciness, on the horizontal time intensity scale, and force to chew (higher force indicating greater toughness) on the vertical time intensity scale. Both scales were 60 units in length. The computer was programmed to collect data every 0.5s. The position of the cursor on the line at any given time was indicative of the toughness or juiciness of the sample at that point in time. During evaluation, panelists were instructed to place the cube between their back molars with fibers perpendicular to their teeth. Panelists were instructed to bite down and begin evaluations on the first bite through to swallowing. Distilled water and crackers were served for cleansing the palate between samples.

Testing-DATI

During testing, panelists simultaneously evaluated juiciness on the horizontal time intensity scale, and force to chew (indicating toughness) on the vertical time intensity scale. Both scales were 60 units in length and joined at the zero point. To input their responses, panelists moved one mouse along a mouse pad diagonally to move two cursors, one on the horizontal scale and the other on the vertical scale. The computer was programmed to collect responses on both the horizontal and vertical scale every 0.5s.

Testing-Line Scale Profile

Panelists were presented with 1.2 cm cubes of beef for evaluation. The line scale profile panelists evaluated cubes for tenderness, juiciness, beef flavor, chewiness, moisture absorption, and time to chew. All responses were input into a Compusense line scale profile questionnaire. All lines were 10 cm long and labeled with descriptors (Table 1).

Analysis of time intensity and line scale data

For both SATI and DATI tests, eight time intensity (TI) parameters were extracted from individual time intensity curves using the Compusense software program (CSA version 4.3) as defined (Table 2, Fig. 1). Generalized Procrustes Analysis (GPA) (*Senstools, version 2.1*, OP&P, Utrecht, Netherlands) was performed on the six meat samples for SATI, DATI, and Line Scale Profile. For clarity, only the most significant parameters for differentiation between sample juiciness and tenderness are shown. These were identified based on our previous experience with TI meat evaluations and correlation coefficients between the GPA dimensions and the TI parameters. The juiciness maximum intensity parameter was chosen for comparison of two methods as best representing juiciness intensity. Toughness of meat was investigated by means of Area under the curve (AUC),

Table 2—Time intensity parameters and definitions

Parameter	Abbreviation	Definition
Maximum intensity	Max	The maximum intensity of an attribute (up to 60 pixels).
Time to maximum	Tmax	The time (in seconds) at maximum intensity.
Duration	Dur	The time (in seconds) for the attribute perception (from the first perception to the perception end).
Increase angle	Inc Angle	The angle of increase to maximum intensity (the rate of onset of the attribute).
Increase area	Inarea	The area under the increasing portion of the curve.
Decrease angle	Dec Angle	The angle of decrease from maximum intensity (the rate of decrease of the attribute).
Decrease area	Dearea	The area under the decrease portion of the curve.
Area under the curve	AUC	The total area under the time intensity curve.

Increase area (Inarea), and Decrease area (Dearea).

RESULTS & DISCUSSION

FOR BOTH TIME INTENSITY TESTS, INDIVIDUAL VARIABILITY was observed as indicated by the large standard deviations (Table 3 and 4). Large individual variability in time intensity measurements is common and has been reported by other researchers. A difference in curve shapes among panelists has been indicated as a cause of large standard deviations in time intensity evaluations (Noble et al., 1991).

Most often, meat studies were performed using samples that greatly differed in juiciness and tenderness. The meat samples used in this study were obtained from six animals of the same meat grade, produced under commercial conditions, thus representing a small range of juiciness and tenderness. To evaluate the reliability of time intensity responses correlation coefficients were calculated for the TI parameters of the DATI and SATI curves (Table 5). They indicated a strong relationship between parameters for both DATI and SATI tests

Relationships between DATI and SATI methods

GPA Structure of the intensity parameters. To visualize similarities and differences between DATI and SATI, Generalized Procrustes Analysis (GPA) was performed on a data matrix that contained the SATI and DATI parameters for the six meat samples. The purpose of the combined GPA analysis was to examine any relationships between SATI and DATI parameters rather than to investigate sample traits, which will be further studied by separate GPA analysis for DATI and SATI data. The two dimensional average GPA plot (Fig. 2) shows the group average explained 73% of the variance in the data. The position of each sample on this plot was defined by both DATI and SATI scores. The distances between samples on the plot reflect relative differences in juiciness and toughness between samples and the vectors indicate the direction of the time intensity parameters used to discriminate between samples. Clearly, there were two main directions (Fig. 2): one defined by meat juiciness and the other defined by toughness. Juiciness vectors were well separated from toughness vectors for both DATI and SATI methods. The juiciness vector for DATI correlated highly with the second Procrustes dimension, while the same vector for SATI loaded evenly on both the first and second dimensions. The second dimension was defined mainly by toughness of meat, although some components of toughness such as those described by Inarea for SATI, and Dearea and AUC for DATI also fell along the negative side of dimension 2. The structure of vectors for juiciness and toughness indicates a better separation between toughness and juiciness for DATI than for SATI. For both methods however, some degree of interdependence between juiciness and toughness was indicated, as shown by the vectors that loaded equally in both dimensions. This effect has been reported in other studies (Zimoch and Gullett, 1997) and further confirmed in this research for both SATI and DATI.

Structure of samples. To explore juiciness and toughness of samples and to visualize relationships between samples for DATI and SATI tests, separate GPA analysis were performed on the two sets of data. Average consensus configurations for SATI (Fig. 3a) and DATI (Fig. 3b) were compared. Relationships between samples for conventional, line scale profile were also studied by means of GPA (Fig. 3c). The GPA analysis for line scale data was included to permit comparison with a standard, widely recognized method. The variance explained by the GPA average configuration was 60%, 67%, and 57% for SATI, DATI, and line scale data respectively. Higher dimensions could also be examined, but for ease of interpretation only the two dimensional results are shown. A permutation test was run to check validity of the consensus space for each method. This test examined the degree to which the consensus plots produced by GPA reflected the true consensus among panelists, regarding sample relationships. The test ran 50 GPA's in which the product labels were varied randomly. The actual % Variance Accounted For (VAF) or 'explained variance' in the real data was then checked against the distribution of the 50 random VAF's to compute the probability. Results indicated that both DATI and Line Scale consensus configurations represented 'good' consensus among panelists ($p<0.001$). However, for the SATI

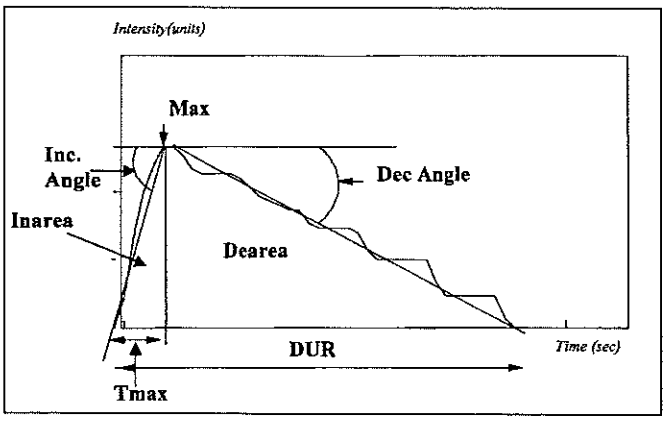

Fig. 1—Time intensity curve parameters and definitions.

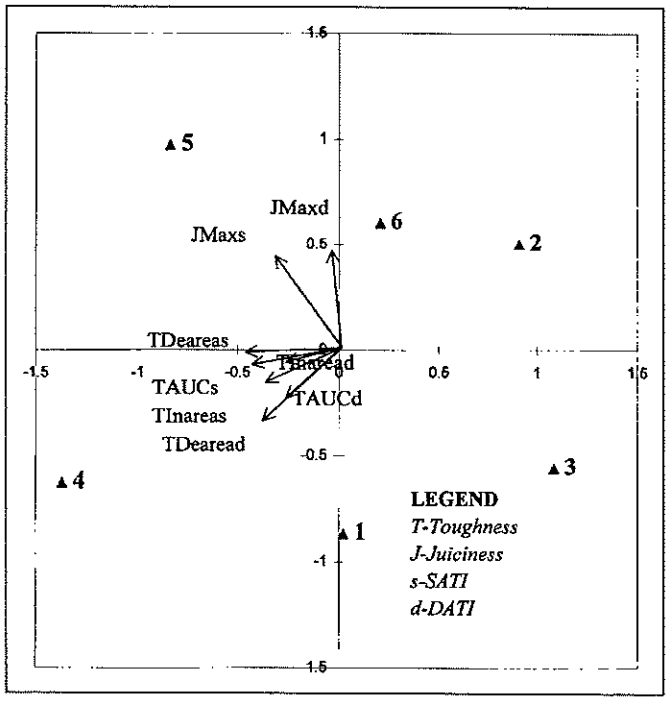

Fig. 2—GPA Group Average of meat from six animals (*Longissimus Lumborum/Canada A/21-28*) and time intensity parameters for DATI and SATI combined data.(Dimension 1 (X-axis) vs dimension 2 (Y-axis)).

Table 3—Mean values and standard deviations for DATI and SATI parameters for tenderness

TI	Sample 1		2		3		4		5		6	
Parameter	SATI	DATI	SATI	DATI	SATI	DATI	SATI	DATI	SATI	DATI	SATI	DATI
Max												
Mean	23.8	23.6	20.9	21.5	24.9	18.6	28.5	24.8	25.5	18.5	22.7	24.4
S.D.	11.1	10.9	9.5	7.4	10.9	7.1	11.5	8.3	12.4	10.3	8.1	8.8
Inarea												
Mean	208.4	216.5	180.0	194.1	211.7	140.3	324.0	224.8	283.9	196.4	188.5	226.5
S.D.	159.5	124.3	192.7	103.4	159.2	88.2	245.6	120.7	300.0	170.3	131.4	128.5
Dearea												
Mean	301.0	437.5	226.2	435.0	276.1	379.4	401.6	624.9	405.3	417.3	272.6	537.7
S.D.	233.1	331.9	163.8	272.9	185.8	239.9	337.7	339.0	378.6	267.9	198.1	311.9
AUC												
Mean	509.5	754.0	406.3	629.1	487.8	519.7	725.6	849.7	689.2	613.7	461.1	764.1
S.D.	335.6	404.4	293.2	329.7	289.0	278.5	446.6	415.9	601.2	401.7	263.1	401.6

Table 4—Mean values and standard deviations for DATI and SATI parameters for juiciness

	Sample 1		2		3		4		5		6	
Parameter	SATI	DATI	SATI	DATI	SATI	DATI	SATI	DATI	SATI	DATI	SATI	DATI
Max												
Mean	28.7	26.8	32.7	28.9	26.4	23.6	31.4	27.1	35.1	30.0	32.7	27.5
S.D.	11.5	10.3	11.9	11.0	12.9	9.9	11.6	10.6	11.1	9.2	10.9	8.4
Inarea												
Mean	297.5	245.5	352.9	303.5	247.0	239.4	361.3	253.7	321.0	314.7	329.1	262.3
S.D.	215.7	128.8	214.5	148.3	168.7	153.6	200.7	139.3	234.7	121.4	183.8	120.3
Dearea												
Mean	312.9	576.9	397.9	495.3	276.4	378.5	398.8	605.4	445.8	591.9	438.8	548.0
S.D.	194.5	255.5	285.1	317.7	140.5	205.9	335.9	262.0	336.5	282.6	362.0	260.9
AUC												
Mean	610.5	822.3	750.8	798.7	523.4	617.9	760.1	859.1	866.8	906.6	767.9	810.3
S.D.	353.7	339.9	418.1	416.8	253.8	319.1	448.9	347.9	490.8	337.1	449.5	338.9

data set 'poor' consensus was shown by the permutation test ($p>0.05$). The 'poor' consensus was not necessarily the result of poor panel training (Bonnie and King, 1991). The poor agreement shown by SATI panelists might have been the result of psychological bias that occurred during SATI evaluations.

The structure of juiciness and toughness vectors (Fig. 3a and 3b) was very similar to that of the time intensity for combined data (Fig. 2). Thus, GPA was able to relate the two time intensity sets with little loss of useful information. For line scale profile data, dimension 1 was mainly defined by meat toughness with tenderness and chewiness components falling on the opposite side of the same dimension. Juiciness seemed to be evenly distributed between dimension 1 and 2, where some aspects of juiciness were highly associated with tenderness.

Generally, the three methods showed a good separation of samples along dimension 1 and 2, and they were in good agreement regarding the predominant sample traits. Yet, some discrepancies between tests could be detected in juiciness and toughness characteristics when the three methods were compared. Sample 4 was shown by DATI as being very tough and dry (Fig. 3b). This was also shown by conventional data, where this sample loaded highly on the negative side of dimension 2 mainly defined by Chewiness, Time to Chew, and Moisture Absorption (Fig. 3c). The position of this sample when judged by SATI (Fig. 3a) shows it as being very tough, though more juicy than implied by the other two methods. Sample 5 was explained primarily by juiciness, as shown by all three methods. SATI (Fig. 3a) indicated this sample was tougher than the other methods (Fig. 3b and 3c). Sample 6 was judged by the three methods as being juicy and quite tender. Minor discrepancies between tests were observed for samples 2 and 3. Conventional profile showed both samples as being best accounted for by dryness and chewiness, with sample 2 exhibiting more chewiness characteristics than sample 3 (Fig. 3c). DATI (Fig. 3b) indicated the dryness of the two samples, but similar to SATI (Fig. 3a), indicated they were less tough. Finally, sample 1 was shown by

Table 5—Pearson Product Moment Correlations of mean values of TI parameters for the six meat samples

	Max	Dur	Inarea	Dearea
SATI tenderness				
Dur	NS			
Inaerea	0.92[a] **[b]	0.91 *		
Dearea	0.86 *	0.96 **	0.95 **	
AUC	0.90 *	0.95 **	0.98 ***	0.99 ***
DATI tenderness				
Dur	NS			
Inarea	0.83 *	0.85 *		
Dearea	0.93 **	0.81 *	0.84 *	
AUC	0.93 **	0.85 *	0.91 *	0.99 ***
SATI juiciness				
Dur	0.92 *			
Inarea	0.96 **	0.97 **		
Dearea	0.95 **	0.90 *	0.87 *	
AUC	0.98 ***	0.96 **	0.96 **	0.97 **
DATI juiciness				
Dur	NS			
Inarea	0.87 *	NS		
Dearea	NS	0.97 ***	NS	
AUC	0.87 *	0.87 *	NS	0.95 **

[a]Correlation coefficient.
[b]prob>R under Ho:Rho=0.

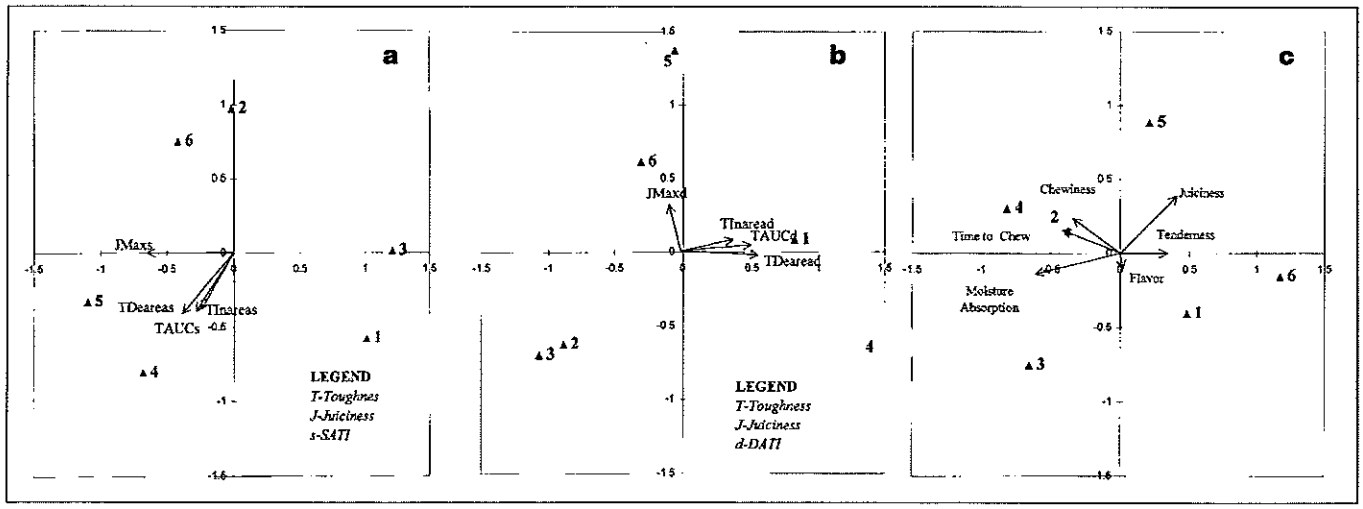

Fig. 3—GPA Group Average of meat from six animals (*Longissimus Lumborum/Canada A/21-28*) (a) for SATI data [Dimension 1 (X-axis) vs dimension 2 (Y-axis)]; (b) for DATI data; (c) for Line Scale Profile data.

line scale profile as being tender and moderately juicy, while both SATI and DATI indicated this sample was more tough and quite dry.

Differences observed between conventional profile and time intensity results were somewhat expected and may be accounted for by differences between temporal and time-averaged techniques. Line scale profile requires judges to arrive at a single intensity value by averaging their responses over time. The averaging process may result in partial loss of important temporal attribute information. Minor differences between both time intensity techniques might be attributable to the dumping effect, which occurs when only one attribute in a food is measured. Frank et al.(1993) suggested that when the number of appropriate response scales increase, the panelist definition of each attribute concept is more narrowly defined. In SATI, one attribute is rated at a time. Judges may use a broad concept of the attribute, which may include other dimensions that are similar to that attribute. The result may be an enhancement or suppression of the perceived intensity of the attribute.

DATI judges can express juiciness and toughness simultaneously which may provide a better perceptual separation of the attribute concepts. A good visualization of such effects may be seen (Fig. 4), when the mean panel curves for juiciness and toughness for the two time intensity tests are compared. The general difference between the two toughness curves was a larger area under the curve for the DATI test. That suggests that, on the whole, SATI panelists perceived meat as being more tender than DATI panelists. This might be a result of SATI panelists using a broad attribute concept, which included some dimensions of juiciness, while evaluating meat toughness. This might suppress the perceived toughness due to positive contribution of juiciness. In contrast, there was no juiciness contribution in the DATI toughness assessment and the panelists perceived the meat as being tougher. The dumping effect observed for SATI may also be responsible for stronger relationships between SATI parameters than between DATI parameters for juiciness (Table 5).

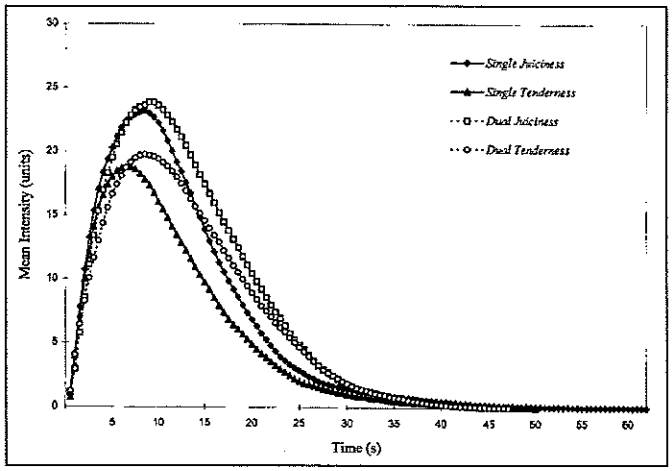

Fig. 4—Mean Juiciness and Toughness curves for DATI and SATI methods.

CONCLUSIONS

RESULTS CONFIRMED THE EARLIER FINDINGS THAT DATI IS A GOOD technique to study temporal characteristics of two attributes simultaneously. The method was useful in a situation where the time course of data collection was short (30s). DATI provided a good separation of the two measured attributes and it was equal to or better than SATI in differentiating beef samples, based on perceived toughness and juiciness. By reducing the dumping effect, the technique allowed for more accurate assessment of meat juiciness and tenderness and thus, more precise evaluation of relationships between them. DATI would be especially useful in meat evaluations, where sample to sample variability makes it difficult to relate temporal changes in one attribute to those in another by consecutive evaluations. The time and consequently the cost of conducting such studies would be substantially reduced.

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