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TEMPORAL ASPECTS OF PERCEPTION OF JUICINESS AND TENDERNESS OF BEEF

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ABSTRACT

This study evaluated temporal differences amongst panellists in perception of juiciness and tenderness of beef samples and explored the temporal relationship between juiciness and tenderness. Ten panellists evaluated samples from 48 animals using CSA computerized time-intensity (TI) procedure. Grouping of panellists for perception based on chewing behaviour using CSA curves was possible. Use of Principal Component Analysis (PCA) to produce curves based on PC scores over time provided more information about the samples and perception variability than simple averaging. Perception of tenderness was influenced by perceptual differences amongst panellists, and by the stage in mastication at which juiciness was perceived in a sample. © 1997 Elsevier Science Ltd

Keywords: Time-intensity; sensory evaluation; meat; texture; Principal Component Analysis; tenderness; juiciness.

INTRODUCTION

A need for a better understanding of meat texture perception in order to better satisfy consumer demand has been well documented in the literature (Brady and Hunecke, 1985; Szczesniak, 1991; Risvik, 1994). Risvik (1994) proposed a simplified model for understanding texture, where water/fat perceptions and structure perception (described as juiciness and tenderness) are orthogonal phenomena by which most of the other textural characteristics can be explained. Since meat texture perceptions occur throughout mastication the use of trained panellists is useful in obtaining this understanding.

The perception of texture is a function of time beginning with the oral introduction of the food which is subjected to manipulation by the tongue and deformation by the teeth, accompanied by the flow of saliva into the mouth. As a result, the particle size of a foodstuff decreases with time, usually occurring over time frames of 5–45 s depending on the nature and the amount of food being masticated (Lee and Pangborn, 1986). The time-intensity (TI) method, by having panellists continuously monitor their perceived sensations, offers a unique advantage over conventional methods of texture measurement by showing the temporal aspects of texture perception. The information obtained is expressed as curves representing intensity over time, facilitating intersample comparisons.

A temporal approach may be useful to study the interactions between texture characteristics to yield a more complete understanding of textural responses (Lee and Pangborn, 1986). However, the TI method, which records data at frequent intervals during a single stimulus experience, is even more susceptible to individual influences than traditional single point scaling methods. Even trained panellists show considerable variation across subjects in their average TI responses to the same stimulus (Cliff and Heymann, 1993; Issanchou and Porcherot, 1992; Fisher *et al.*, 1994; Tuorila *et al.*, 1995). Consequently although reproducibility of time-intensity curves is generally very good, individual curve shapes show a high variance amongst panellists. Ignoring differences between individual curves is a common practice in TI analysis resulting in loss of temporal information. Van Buuren (1992) has suggested Principal Component Analysis (PCA) as a method useful for studying the variations attributable to response patterns of panellists. Dijksterhuis *et al.* (1994) suggested that by using PCA to analyze TI data it is possible to obtain a more representative panel curve than by a simple averaging technique. Brown *et al.* (1994*a*,*b*) suggested that the major discriminating factors between panellists lie in their chewing time and the muscle work rate during chewing. They considered that different chewing behaviours may be responsible for the variability in the perceptions observed for food texture, and indicated a need for taking into account differences in perceptions in the interpretation of sensory trained panel and consumer data.

The purpose of this research was to evaluate temporal differences amongst trained panellists in perception of juiciness and tenderness of beef muscle, and temporal

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differences in the beef samples. To do this the usefulness of PCA in dealing with individual variability and in separating different patterns of temporal perception within a group of trained panellists was explored. PCA was also used as a means for studying the temporal relationship between meat juiciness and tenderness during mastication.

METHODS

Sample preparation and presentation

The 48 animals used in this study were crossbreds of small and large breeds and were a subsample of a larger study involving diet management. Four-centimetre thick steaks of longissimus muscle, from between the 9th and 10th rib on one side of the carcass, aged one week, were obtained from the University of Guelph abattoir, vacuum packaged and frozen (−18°C) until tested. Samples were prepared by defrosting at 4°C for 15 h, roasted in a conventional oven at 177°C to an end-point temperature of 68°C as determined by a type K thermocouple inserted into the centre of the sample. Samples were held covered (1.5 h) in the constant room temperature (21°C), then sliced 1.2 cm thick and 1.2 cm cubes removed from the interior of the centre slices. This ensured easier handling and thus more uniformity in size and temperature. Each panellist was presented with a cube for assessing tenderness and a cube for assessing juiciness. During evaluation, panelists were instructed to place the cube between their back molars with fibers perpendicular to their teeth. Tenderness was assessed as force to chew and juiciness as the amount of moisture perceived in the mouth. A completely random design was used for sample cooking and presentation, with four samples evaluated at a sitting. Samples were evaluated under red lighting using the computerized time-intensity procedure CSA (version 4.3.), Compusense Inc. Guelph, Canada.

Sensory testing

Ten panellists were selected from a pool of panellists concurrently involved in meat testing projects and thus trained for meat evaluation. Long training, consisting of the 12 one-hour training sessions, was to develop the necessary hand-eye coordination required to use the mouse to move the cursor along the 60 pixel line so that it would represent the panellist's perception. The left anchor for tenderness was low force to chew and the right anchor high force to chew; for juiciness the left anchor was not juicy and the right very juicy. Judges were instructed to evaluate juiciness and tenderness of a sample from the first bite through to swallowing. Tap water and crackers were served to the panellists for cleansing their palates between the samples. Duplicated samples were served to the panellists to examine the consistency of panellist judgement. The TI test was programmed to record responses every second up to 60 s when it automatically shut off. In practice, evaluations did not proceed beyond 40 s.

Time-intensity analysis

Eight TI parameters were extracted from individual TI curves using the CSA software program. These were: (1) area under the curve (AUC), (2) maximum intensity (Imax), (3) time to maximum intensity (Tmax), (4) total duration (DUR), (5) increase area (Inc. Area), (6) increase angle (Inc. Angle), (7) decrease area (Dec. Area), and (8) decrease angle (Dec. Angle). To determine the relationship between juiciness and tenderness attributes for individual panellists, Pearson's product moment correlations were calculated (SAS, 1991). Principal Component Analysis (PCA) (Dijksterhuis *et al.*, 1994) was conducted on raw intensity CSA scores for each second to develop stimulus profiles for tenderness and juiciness, and individual profiles for each panellist, for the 48 meat samples (SAS, 1991).

RESULTS AND DISCUSSION

Examination of panellist variability

Information regarding breed and diet management of the animals is not reported in this paper since it was not pertinent to the objectives of this research. One of the aims of this study was to examine temporal differences amongst panellists in perception of meat tenderness and juiciness. Despite a long and intensive training, large variability was observed in TI measurements. A comparable large variability has been observed by other researchers (Duizer *et al.*, 1993; Cliff and Heymann, 1993). This variability may be due to different chewing behaviour and usage of the scale. The lack of significant sample × judge interaction (ANOVA results) indicated that variation was not a result of inconsistency in judge assessment related to the sample (ANOVA results were not shown in the paper because it was used as a check on reliability of the data but the results themselves were not of interest to this study).

On the basis of typical tenderness curves generated for each panellist by the CSA software, panellists were grouped by the visual inspection into three groups (Fig. 1). These could be likened to the chewing patterns established by Brown *et al.* (1994*b*) in that the largest group, containing panellists A, B, C, E and F, were strong efficient chewers masticating the meat in a short time. The second group, consisting of panellists G, H and I, perceived a greater force required to chew for a longer time after obtaining Imax but were also efficient chewers. The last group of panellists J and D may be

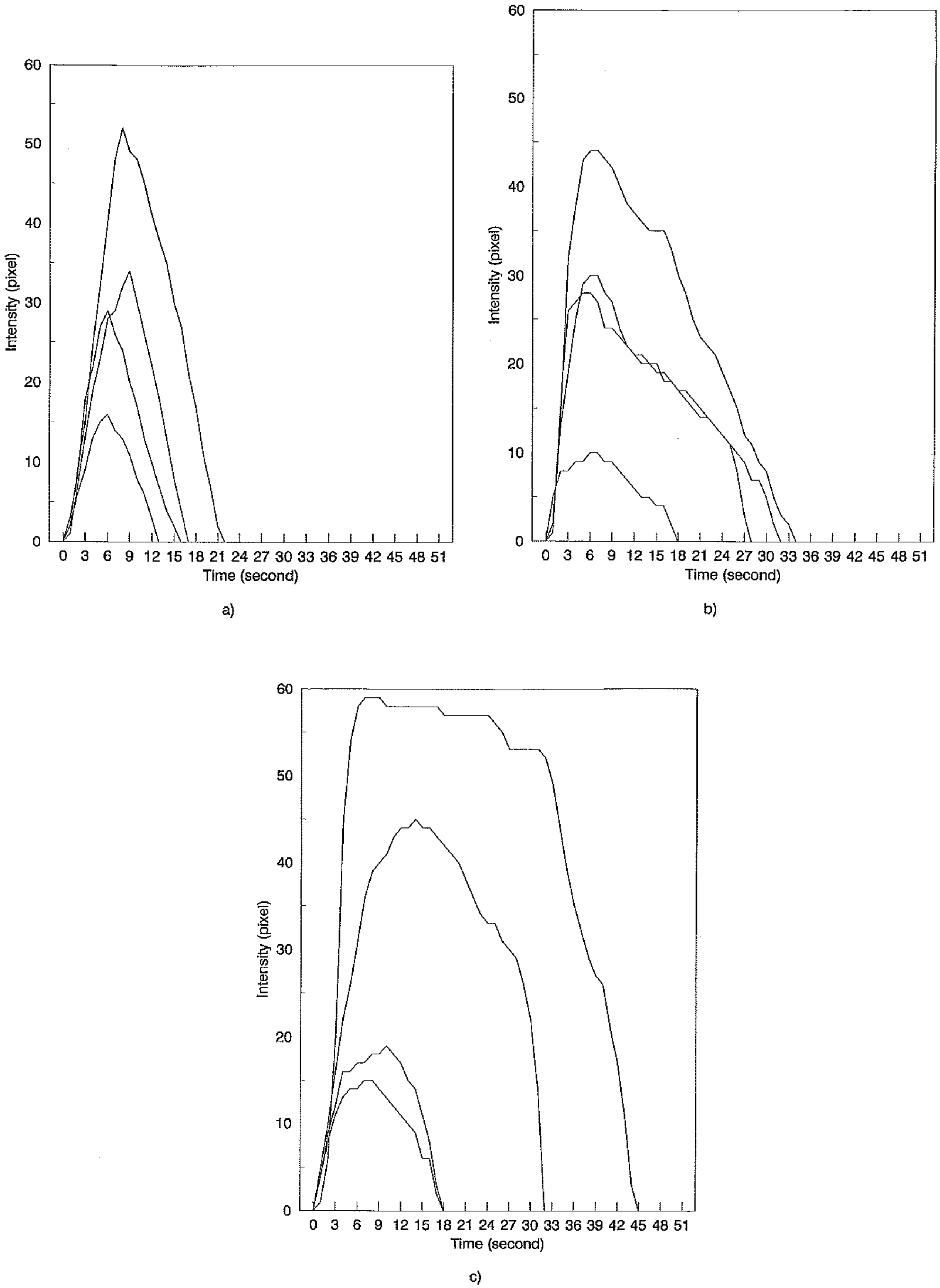

FIG. 1. CSA tenderness curves illustrating chewing patterns of panellists: (a) strong efficient chewers, (b) efficient chewers but requiring longer time after obtaining Imax, and (c) inefficient chewers.

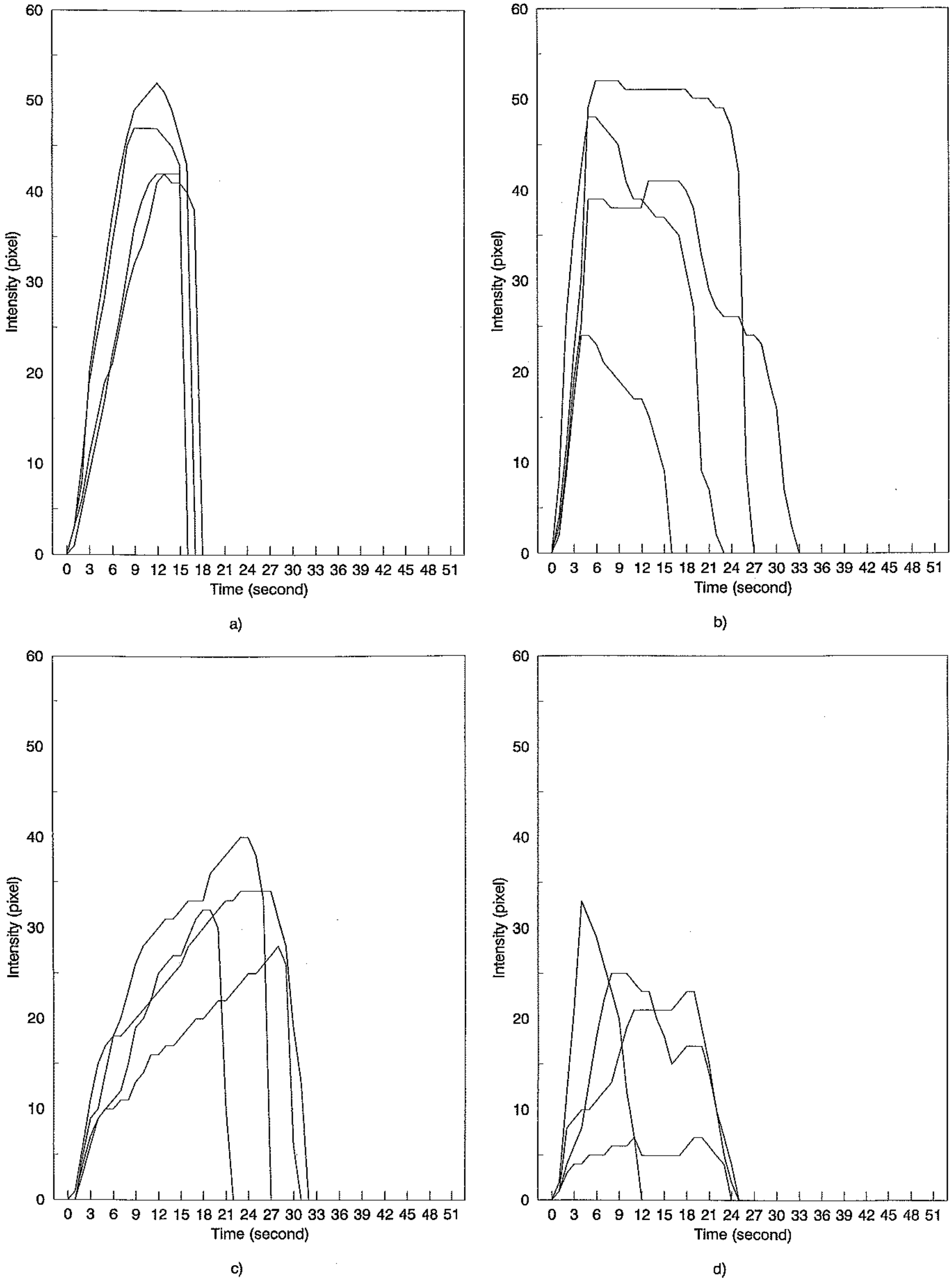

FIG. 2. CSA juiciness curves illustrating differences in panellists perceptions: (a) sharp increase followed by quick decline, (b) marked plateau effect, (c) increase perceived as a series of small plateau followed by sharp decline, and (d) inconsistent.

considered to be inefficient chewers as they perceived a large amount of force being required to chew the samples at Imax for considerably longer than the other two groups. The two groups of efficient chewers were nearer to each other, in terms of amount of force and time needed to chew the samples, than the fast and slow chewers observed by Duizer (1993).

Typical juiciness curves generated for each panellist by CSA software grouped the panellists into four groups for perception of amount of juiciness over time (Fig. 2). Panellists A, B, C and F showed a sharp increase in juiciness with a quick decline which was probably influenced by their chewing style. Panellists D, G and H exhibited variations on a plateau effect for maximum juiciness perception whereas panellists I and J showed increasing perceptions of juiciness by a series of small plateau followed by a sharp decline. Panellist E exhibited inconsistency in juiciness perception. Obviously juiciness perception was influenced by the amount of breakdown caused by mastication at a given point in time. Also eight of the 10 panellists exhibited, to some extent, a 'ski jump' effect at the end of the juiciness evaluation. This was caused by the fact that juiciness, unlike tenderness, persisted throughout the mastication to the point of swallowing and thus terminated abruptly.

Panellist performance for tenderness assessment examined by PCA

The First and Second Principal Components explained most of the variability (84%) in the original ten panellist data matrix. The plot of the loadings of the individual panellists (Fig. 3(a)) provides information about panel homogeneity and indicates where differences between panellists occurred. With the exception of panellist D, who had a much higher loading, the loadings on PC1 represented a small range and all were positive. This indicated a relatively uniform behaviour among the panellists. Panellists A, B and C obtained the smallest loadings and their curves were much smaller than panellist D. It was concluded that PC1 separated panellists on the basis of curve size and higher force intensity values (Imax). The second PC contained both positive and negative loadings, and once more panellist D had a much higher (but negative) loading. Examination of individual panelist curves showed that PC2 separated panellists with tenderness perceptions that quickly increased and decreased, and thus were of short duration, from those whose tenderness perception rose more steadily and slowly declined, thus having longer duration and were identified by negative loadings.

Panellist performance for juiciness assessment examined by PCA

Panellist PCA loadings on First and Second Principal Components for juiciness perception are shown in Fig. 3(b). All panellists were closely grouped on the First Principal Component indicating good homogeneity for the panel as a whole. As for tenderness, this component represented size of curve and Imax juiciness intensity values. More separation was obtained for the Second Principal Component with panellists separating into three groups. The first group included panellist A and the second group panellists B, D, C and E. Both groups exhibited fast rising and fast declining TI curves with short duration. Panellist A exhibited very steep and consistent 'ski jump' effects. The third group consisted of panellists F, H, J, I and G; all had negative loadings and their curves exhibited a long Tmax, flat or blunt maxima and relatively longer duration. With the exception of F these panellists were longer chewers and appeared to take longer to destroy the integrity of the sample to release the juice. This is supported by positive and significant correlations for the Tmax for juiciness and for tenderness obtained for these panellists ($r=0.47$ to 0.57 $p<0.05$ df=46).

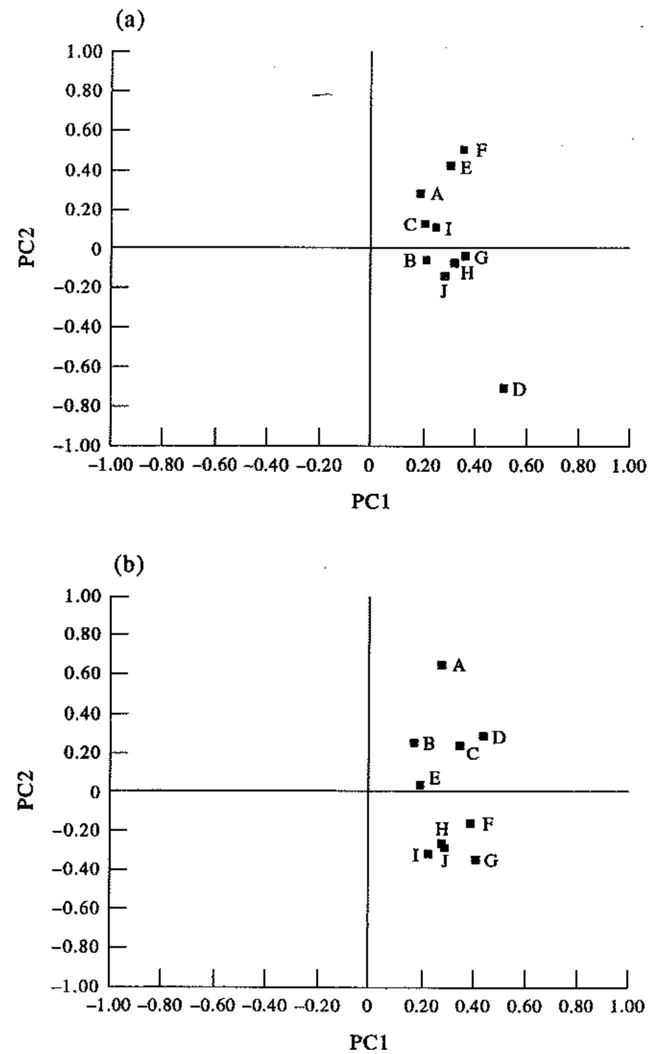

FIG. 3. (a)Plot of panellist loadings on PC1 × PC2 for tenderness perception. (b) Plot of panellist loadings on PC1 × PC2 for juiciness perception.

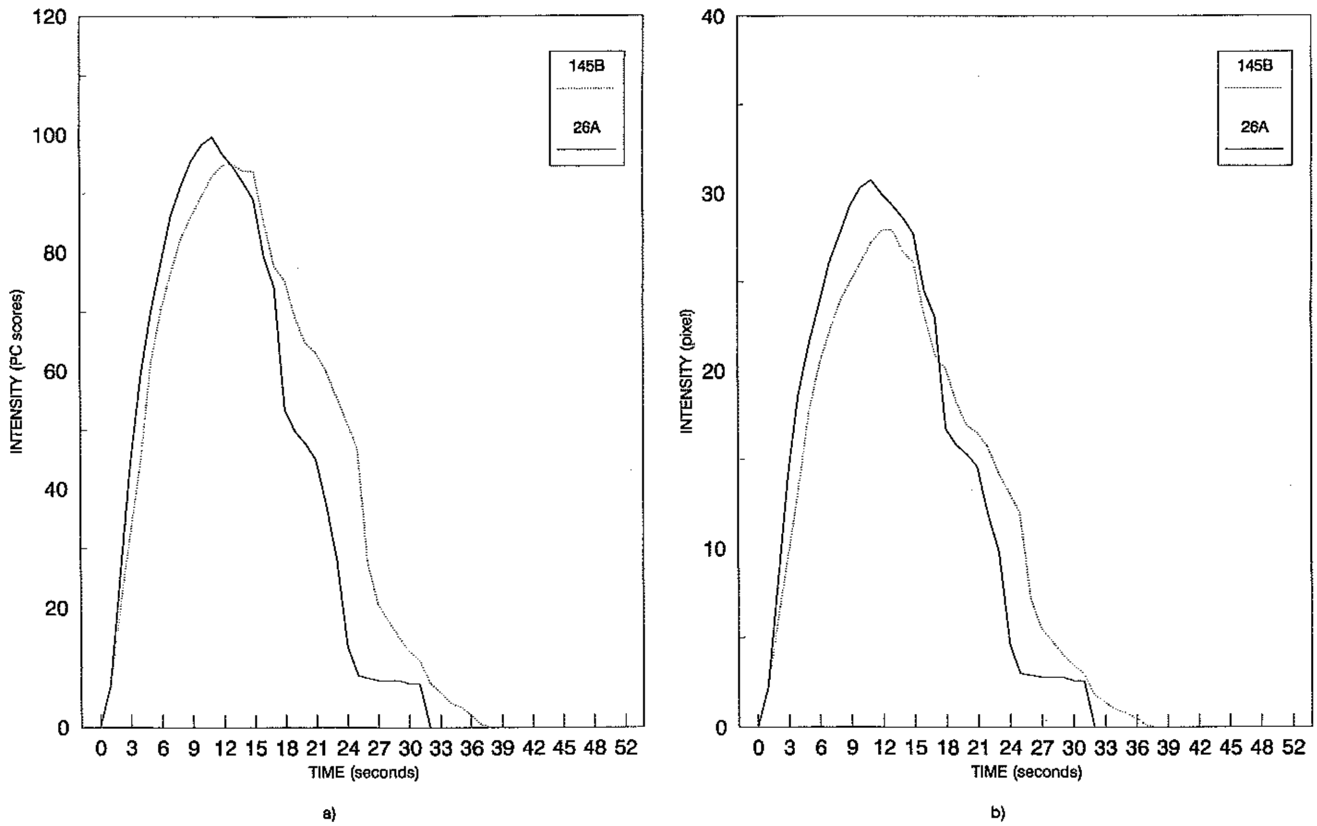

FIG. 4. Juiciness curves for samples 145B and 26A showing differences between those obtained by (a) PCA, and (b) by simple averaging procedure.

Panellist variability examined by PCA and simple averaging methods

In order to explore PCA as a method for examining panellist variability, PC curves were compared with simple averaging curves. Panellist loadings, based on the evaluation of the 48 samples, were used to generate PC curves for individual meat samples for tenderness and juiciness. Direct comparison of curves produced by the simple averaging technique and by PCA was not possible because the two methods used different intensity units. To overcome this, profile curves obtained by the two methods were compared for selected meat samples with similar AUC values as generated by the CSA averaging procedure. This also allowed for input from the panellist individual TI curves. Samples 145B and 26A were selected for comparison of juiciness curves because the CSA parameter AUC was similar for these two samples whereas the AUC for PC scores differed. The First PC curves for juiciness for these samples are presented in Fig. 4(a) and the corresponding averaging curves in Fig. 4(b). Examination of individual panellist TI curves for the samples revealed that a greater disagreement in the perceived juiciness existed for 145B than for sample 26A. It is believed that using the panellist weightings for the 48 samples to produce the PC curves helped overcome the problem of the weighting given to large variances when using PC based on a covariance matrix. Simultaneously differences amongst individual panellists were more accounted for by the PC procedure than by the simple averaging procedure. The many plateaux after Imax, observed for some panellists, appeared to be better accounted for by the PC procedure than by simple averaging technique (Fig. 4, sample 145B). In contrast, examination of individual TI curves for sample 26A showed much closer agreement in the perception of juiciness, and this is reflected in the greater similarity obtained for the PC and simple averaging curves (Fig. 4). The 'ski jump' effect occurred more frequently for sample 26A which was more tender than sample 145B (PC AUC=764.1 vs 839.3). This was considered to be the result of faster disintegration of the more tender sample and the consequent perception of juiciness at the point of swallowing. The similarity between the PC and averaging curves for sample 26A suggests that both methods account for the 'ski jump' effect.

The agreement between the two techniques seems to be affected by the degree of toughness of the samples. This is illustrated by samples 56B and 138B which were rated as being very tender and which produced similar curves by the two methods (Fig. 5), whereas for samples 194B and 193B, which were both rated as being much tougher than samples 56B and 138B, the two techniques produced curves differing in height (Fig. 6). In this case

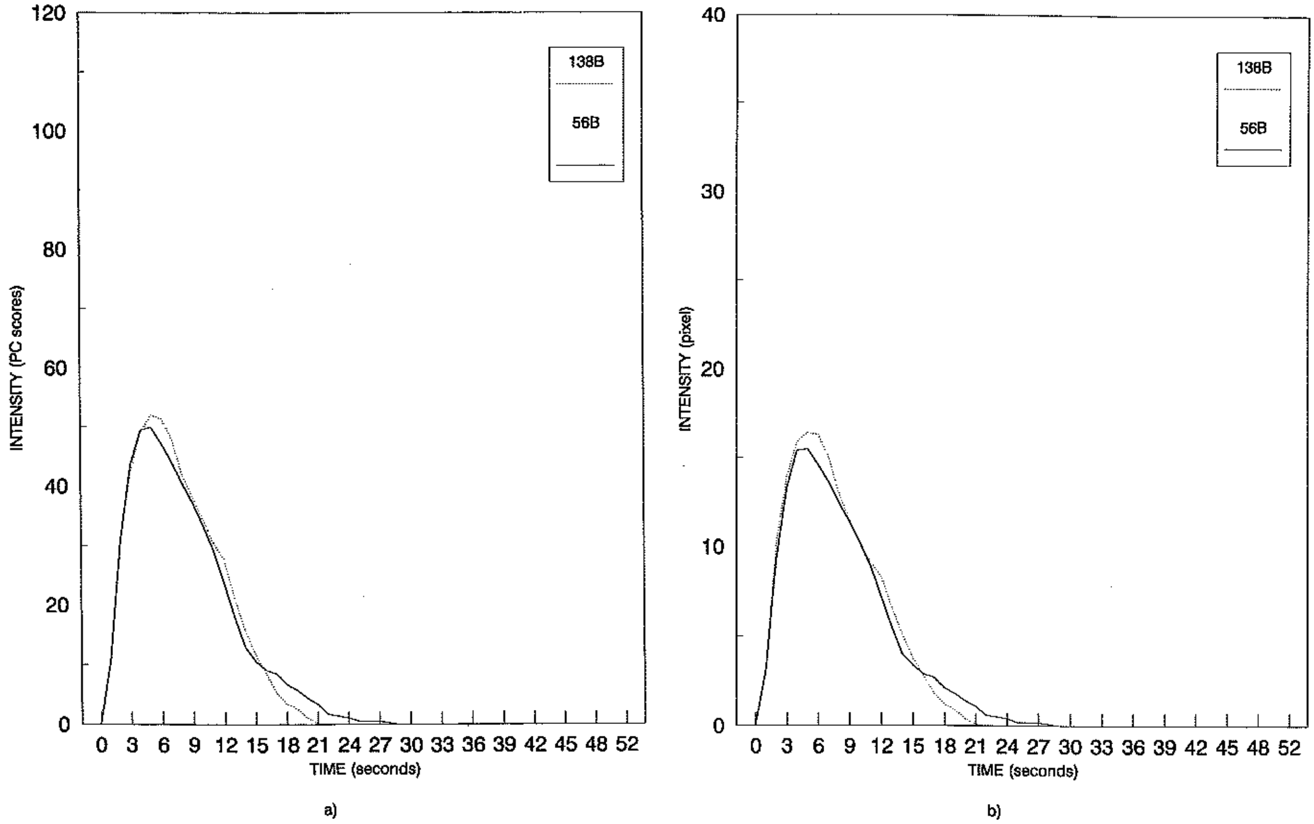

FIG. 5. Tenderness curves for samples 138B and 56B showing differences between those obtained by (a) PCA, and (b) by simple averaging procedure.

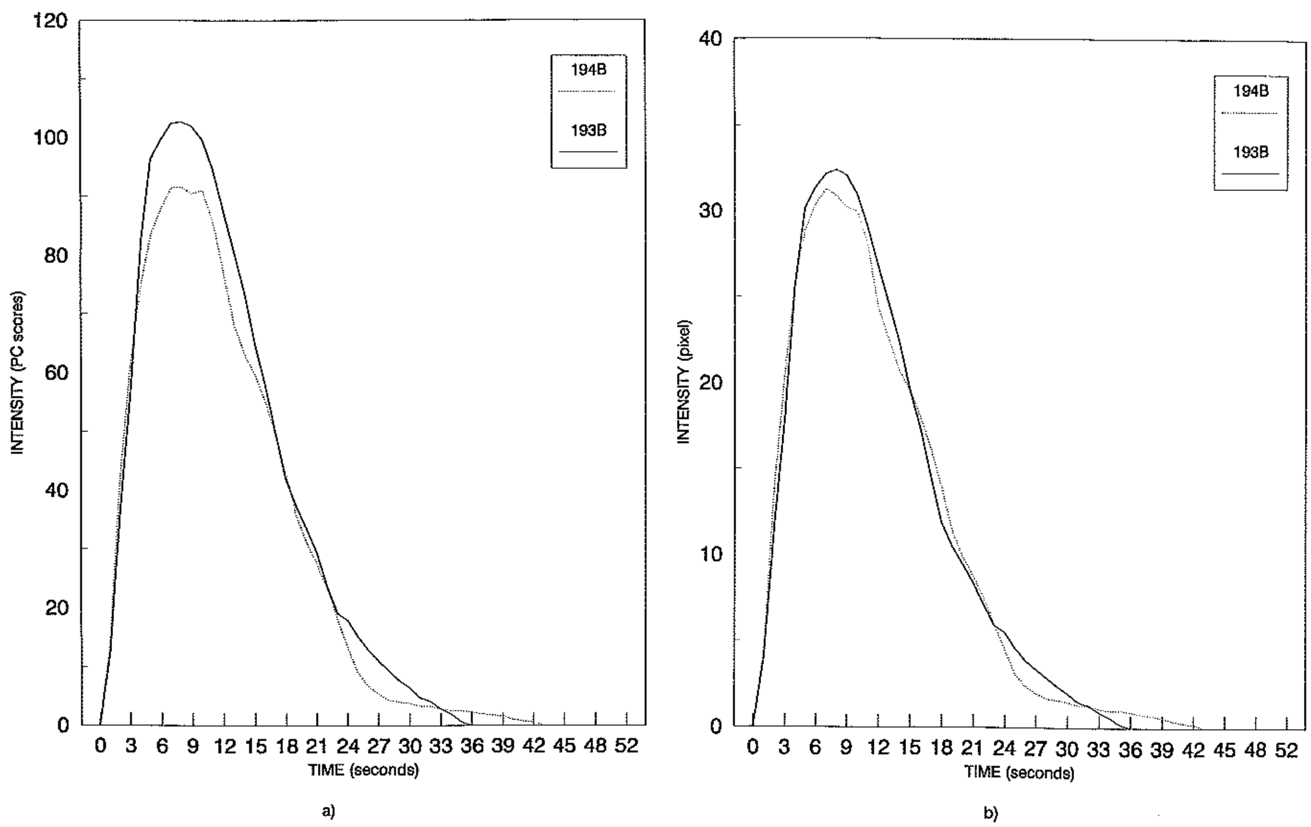

FIG. 6. Tenderness curves for samples 194B and 193B showing differences between those obtained by (a) PCA, and (b) by simple averaging.

panellists C, E and I perceived sample 194B as requiring more force to chew which was opposite to the other six panellists. Using the PC loadings reduced the contribution of these panellists and also increased the contribution of panellist D, resulting in a different shaped curve from that achieved by simple averaging where all panellists were given equal weight. Examination of individual panellist curves indicated that the more tender the sample the closer the agreement in panellist perception, and that as toughness increased differences in perception became larger. In general, the shapes of the First PC curves resembled the average curves. This is in agreement with the findings of Dijksterhuis *et al.* (1994). However, some temporal differences were observed for the PC curves, such as delayed perception of juiciness with a decrease in tenderness that was not always evident by the simple averaging technique. Not unexpectedly, perception of force required to chew peaked earlier than the perception of juiciness (6–7 s vs 11–12 s). The secretion of saliva during mastication also influences the perception of juiciness and may contribute to sustained perception in the post-max phase in contrast to the quick decline in perception of force required to masticate.

Relationship between juiciness and tenderness

Pearson's Product Moment Correlations were computed between the time-intensity parameters of tenderness and juiciness for each panellist. Significant correlations ($p < 0.05$ df=46) were obtained between tenderness and juiciness for the time-related parameters of Tmax ($r = 0.47$–0.57) and DUR ($r = 0.42$–0.76) for all panellists except B and F. This suggests that chewing patterns may have some effect on perception. Sporadic relationships were observed between tenderness and juiciness for other TI parameters but not often enough to be important.

To further explore the relationship between juiciness and tenderness, samples were selected having similar CSA AUC values for tenderness but differing for juiciness and, conversely, similar juiciness values but differing for tenderness. PC curves for these samples were examined for temporal differences that would suggest that perceptions of one attribute might have been induced by perception of the other attribute. Samples 118B and 145B exhibited similar AUC values for tenderness but differing values for juiciness. The more juicy sample, 145B, exhibited a faster decline in amount of force required to chew (tenderness) than the less juicy sample, 118B (Fig. 7). This suggests that 145B disintegrated faster than 118B, the softening effect being especially pronounced at the end of the mastication process. Tornberg *et al.* (1985) suggested that the term "tender texture" could embrace such characteristics as juiciness and amount of residue after chewing in addition to ease of penetration. Dransfield *et al.* (1984) speculated that wetter samples were more easily swallowed because they readily form a bolus.

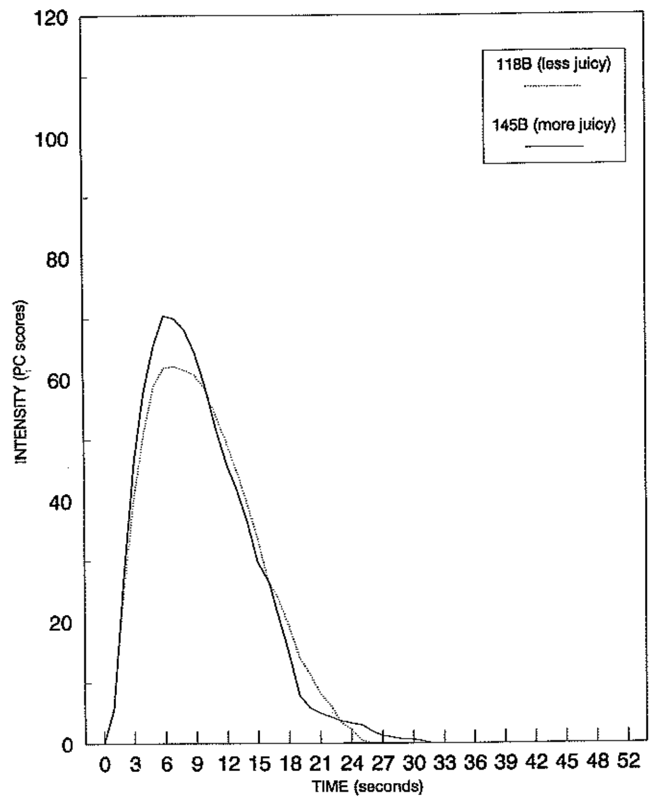

FIG. 7. PC curves showing the temporal effects of juiciness on the assessment of tenderness.

Samples 53A and 125B exhibit similar AUC values for juiciness but differing AUC values for tenderness (Fig. 8). The tougher sample 53B exhibited a flatter curve for the perception of juiciness than the more tender sample 125B. On a temporal basis the reduction in the perceived juiciness for the tougher sample at the initial stage of mastication was compensated for by the lengthening impression of juiciness in the post-maximum phase. This suggests that tougher meat might require more masticatory force to release juice and it may also stimulate saliva flow providing the sensation of juiciness similar to more tender meat. This is supported by a slightly longer Tmax obtained for tougher samples than for more tender samples.

Gullett *et al.* (1996) reported that chewiness assessed as force × time to chew identified more animals as having the characteristics of tough meat than did tenderness assessed as the force to chew early in the mastication process. Juiciness assessed early in the mastication process, as amount of moisture released, correlated better with tenderness, assessed also early in the mastication process, than with chewiness assessed later in the mastication process. The relationship between the perception of tenderness and juiciness throughout mastication in the current study helps explain the previous findings. It also helps explain why there is greater variability and consequently fewer significant differences than obtain with single point measurements of juiciness.

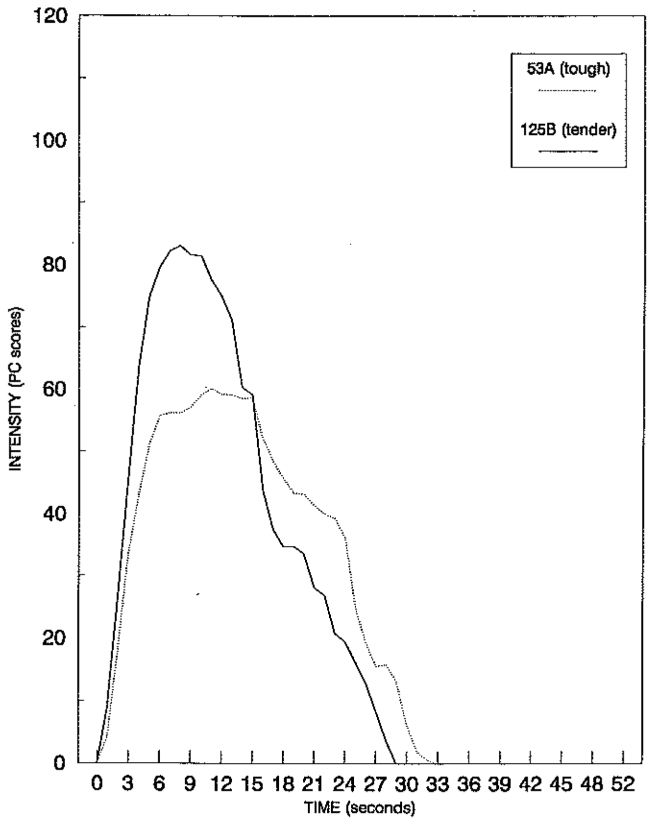

FIG. 8. PC curves showing the temporal effects of tenderness on the assessment of juiciness.

CONCLUSIONS

PCA was found to be a useful tool in exploring temporal differences amongst panellists, perception of juiciness and tenderness of L. *dorsi* meat samples. Construction of profile curves using First and Second PC scores for individual panellists, and for the panel, was useful for grouping panellists with similar chewing behaviour and for identifying the basis of similarity. Using PC scores rather than simple averaging techniques for TI data was found to be particularly useful where panellist differences occurred such as assessment of juiciness and force required to chew less tender meat samples. Use of PC score data in Analysis of Variance procedures may allow detection of treatment effects that are usually lost as a result of panellist variability. First PC curves were useful in examining how perceptions of one attribute could induce perceptual differences in the other. The possibility exists that PC information regarding chewing behaviour of individual panellists, combined with the information regarding the perceptual interrelationships between tenderness and juiciness, could be explored as to the effect on acceptability. Not only would this provide a better understanding of acceptability of meat but it should also make it possible to use trained panel data as an indicator of acceptability.

REFERENCES

Brady, P. L. and Hunecke, M. E. (1985) Correlations of sensory and instrumental evaluations of roast beef texture. *J. Food Sci.* **50**, 300–303.

Brown, W. E., Shearn, M. and MacFie, H. J. H. (1994*a*). Development of a method to investigate differences in chewing behaviour in humans. II. Use of electromyography during chewing to assess chewing behaviour. *Texture Studies* **25**, 17–25.

Brown, W. E., Landgley, K. R., Martin, A. and MacFie, H. J. H. (1994*b*). Characterisation of patterns of chewing behaviour in human subjects and their influence on texture perception. *J. Texture Studies* **25**, 455–468.

Cliff, M. and Heymann, H. (1993) Time-Intensity evaluation of oral burn. *J. Sensory Studies* **8**, 201–211.

Dijksterhuis, G. B., Filipsen, M. and Punter, P. (1994) Principal component analysis of TI curves: Three methods compared. *Food Quality and Preference* **5**, 121–127.

Dransfield, E., Francombe, M. A. and Whelehan, O. P. (1984) Relationships between sensory attributes in cooked meat. *J. Texture Studies* **15**, 33–48.

Duizer, L. M., Gullett, E. A. and Findlay, C. J. (1993) Time-Intensity methodology for beef tenderness perception. *Food Sci.* **58**, 943–947.

Fisher, U., Boulton, R. B. and Noble, A. C. (1994) Physiological factors contributing to the variability of sensory assessments: Relationship between salivary flow rate and temporal perception of gustatory stimuli. *Food Quality and Preference* **5**, 55–64.

Gullett, E. A., Buttenham, S. and Hore, T. (1995) Effect of age and cut on consistency of tenderness and leanness of beef. *Food Quality and Preference* **7**, 37–45.

Issanchou, S. and Porcherot, C. (1992) Problems in time intensity measurements. A case study: bitterness evaluation in water solutions and beer. *Advances in Sensory Food Science, Rose-Marie Pangborn Memorial Symposium,* Abstract B. IV. 66.

Lee, W. E. and Pangborn, R. M. (1986) Time intensity: The temporal aspects of sensory perception. *Food Technology* **40**(11), 71–76.

Risvik, E. (1994) Sensory properties and preferences. *Meat Sci.* **36**, 67–77.

SAS Institute Inc. (1991) *SAS User's Guide: Statistics Version 6*, Fourth Edition, pp. 891, 1241. SAS institute Inc., Cary, NY.

Szczesniak, A. (1991) Textural perceptions and food quality. *J. Food Quality* **14**, 75–85.

Tornberg, E., Fjelkner-Modig, S., Ruderus, H., Glantz, P., Randow, K. and Stafford, D. (1985) Clinically recorded masticatory patterns as related to the sensory evaluation of meat and meat products. *J. Food Sci.* **50**, 1059–1066.

Tuorila, H., Sommardahl, C. and Hyvonen, L. (1995) Does fat affect the timing of flavour perception? A case study with yogurt. *Food Quality and Preference* **6**, 55–58.

Van Buuren, S. (1992) Analyzing time-intensity responses in sensory evaluation. *Food Technology* **46**(2), 101–104.