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DUAL-ATTRIBUTE TIME-INTENSITY SENSORY EVALUATION: A NEW METHOD FOR TEMPORAL MEASUREMENT OF SENSORY PERCEPTIONS

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ABSTRACT

Dual-attribute time-intensity was evaluated as a method for the collection of the perception of two attributes simultaneously. Perceptions of sweetness and peppermint flavour within chewing gum were measured by 10 trained time-intensity panelists using both single-attribute and dual-attribute time-intensity sensory evaluation. Four chewing gum samples, varying in rate of release of sweetness and peppermint flavour were presented for evaluation. In general, dual-attribute time-intensity was as sensitive as single-attribute testing in distinguishing between the sweetness and peppermint perceptions of chewing gum. In comparison to the single-attribute test, the dual-attribute test required half the time to complete and provided a means of assessing complex taste interaction during mastication. The dual-attribute test can be used to study relationships between two attributes within food products which possess a large degree of sample variability, such as the tenderness and juiciness of meat. © 1997 Elsevier Science Ltd

Keywords: Dual-attribute time-intensity; chewing gum; sweetness; peppermint.

INTRODUCTION

Foods possess a composite of many attributes of taste. One of the simplest of these mixtures occurs in chewing gum which is comprised of two tastes; sweetness and flavour. Evaluations of perceptions of these two tastes are typically made for individual attributes. The interactions between these attributes have not been measured simultaneously. Time-intensity sensory evaluation has been used to evaluate single-attribute perceptions. The method elucidates the temporal characteristics of taste perceptions. The research reported in this paper demonstrates how time-intensity can be used for the simultaneous evaluation of two attributes within a food. This technique allows food scientists to directly explore taste interactions as they occur over time.

Although time-intensity is an important advancement in the evaluation of single attributes, it has not been applied to the simultaneous evaluation of two or more attributes. Knowledge of the interactions of taste attributes has positive implications for the development of new food products. After evaluating the taste interactions within a food, the characteristics can be optimized to provide the most acceptable product to the consumer. Therefore, it would be of benefit to product developers to know the combined perceptions of sensory attributes within a food. With the relative ease of collecting time-intensity data using computer programs, it has become possible to modify the time-intensity program for such a purpose.

To allow for the simultaneous evaluation of two food attributes, the current version of the Computerized Sensory Analysis Temporal Profile Analysis package ($CSA_{TPA}{}^{TM}$) from Compusense Inc. was modified. The dual-attribute time-intensity method (DATI) is similar to the single-attribute test with the exception that two time-intensity scales, each representing one taste attribute, appear on the monitor. One taste is presented on the horizontal time-intensity scale, and the other taste is presented on the vertical time-intensity scale. Previous research has shown that horizontal and vertical line orientations can provide similar time-intensity results (Duizer *et al.*, 1994). A mouse is used to move a cursor simultaneously along the two time-intensity lines. Panelists in dual-attribute time-intensity evaluations are trained to direct the movement of the mouse in two directions simultaneously to record the changes in their perceptions of the two attributes.

To investigate dual-attribute time-intensity, four samples of chewing gum, which varied in rates of release of sweet and peppermint flavour, were tested. The manipulation of temporal changes in sweetness and peppermint flavour of chewing gum allowed us to observe four extreme examples of attribute interactions. Our goal was to demonstrate how the dual-attribute method would permit investigators to determine the combination of flavour and sweetness that would produce optimum flavour/sweetness interactions.

The purpose of our experiment was to compare dual– and single-attribute time-intensity on the same parameters, to compare the perception of sweetness and peppermint and to assess the effect of different combinations of sweetness and peppermint by means of dual-attribute time-intensity.

METHODS

Samples

Four samples of chewing gum, varying in the rate of release of sweetness and peppermint flavour, were prepared by Warner Lambert Canada for this research. Combinations of rate of release of sweetness and peppermint flavour within the four samples were as follows: slow sweet/fast flavour release (SSFF); slow sweet/slow flavour release (SSSF); fast sweet/fast flavour release (FSFF); fast sweet/slow flavour release (FSSF).

During both training and testing, the panelists were provided with a sample of 1 g of chewing gum for evaluation. All samples were presented in cups labelled with a 3-digit blinding code.

Training

Ten panelists, experienced in time-intensity evaluations, were selected for this study. Each panelist participated in ongoing time-intensity research, and was trained to record sweet and flavour perceptions of chewing gum on individual horizontal and vertical time-intensity scales. During training, samples of gum individually representing slow sweet release, fast sweet release, slow flavour release and fast flavour release were presented to the panelists, enabling them to experience in advance the sensations of varying rates of release of sweet and peppermint flavour. Once the panelists were familiar with the attributes to be evaluated, samples of gum, similar to the four gums used for testing, were presented for evaluation during training sessions. Eight one-hour training sessions were conducted prior to the test, to familiarize the panelists with the dual-attribute time-intensity scale and the manipulation of the mouse.

Procedure

All sessions were conducted at the Compusense Sensory Research Centre (Guelph, Ontario). On each day of testing, for both the single-attribute time-intensity test and the dual-attribute time-intensity test, the panelists evaluated three replications of two samples (i.e. six trials). The panelists completed both single-and dual-attribute tests for sweetness and peppermint flavour perception of all four samples. For both tests, presentation of the samples was fully randomized amongst the panelists. In addition to the samples, for the single-attribute test, the perception to be tested (sweet or peppermint flavour) was randomized over the entire test. Presentation of the two tests (single- or dual-attribute) was counterbalanced over the 10 panelists to control for possible effects of order. Five panelists completed the dual-attribute time-intensity test first, while the remaining five panelists completed the single-attribute time-intensity test first. In total, 12 days of testing were required to collect the single-attribute data while the dual-attribute data was collected in six days.

Panelists were instructed to place the gum sample in their mouth and bite down with their back molars. Rate of chewing was not prescribed. Panelists were instructed to begin recording their perceptions of taste at the first bite of the sample, and to continue until the perception of sweetness and peppermint flavour disappeared or 15 minutes elapsed. At the start of each trial, panelists used the mouse to move the cursor from the zero point along the time-intensity line(s). When the sweetness and flavour perception ceased, they moved the cursor back to the zero point, ending the test.

Apparatus

All data were collected using the CSA_{TPA}™ program (CSA Version 4.3; Compusense Inc., Guelph, ON). For the single-attribute time-intensity test, the panelists evaluated the gum samples for sweetness and peppermint flavour in individual trials. Sweetness was recorded on a vertical time-intensity line, labelled with the anchors of 'not sweet' and 'very sweet', and peppermint flavour perception was recorded on a horizontal line labelled with the anchors of 'no peppermint flavour' and 'strong peppermint flavour'. Both lines were 60 pixels in length. The software was programmed to collect responses in variable time intervals over a 15 min time span. From the start of the test to the 3 min point, data were collected every 3 s to ensure refined analysis of the fastest changes in flavour perception. From 3 to 7 min, data were collected every 9 s and from 7 to 15 min data were collected every 15 s. In total, 120 data points were collected in the 15 min test interval.

Data collection using the dual-attribute time-intensity test was similar to the single attribute test, with the exception that the CSA_{TPA}™ program was modified to include the presentation of both a horizontal and a vertical time-intensity scale on the same screen. Figure 1 illustrates the dual-attribute test seen by the panelists. The horizontal and vertical scales, both 60 pixels in length, originated at the zero point in the bottom left hand corner of the screen. Sweetness responses were collected on the vertical scale, and peppermint responses were collected on the horizontal scale. To record their responses, each panelist moved a marker along each of the two lines simultaneously by moving the mouse. To do this, the mouse was moved diagonally along the mouse pad. Anchors on the lines were 'not sweet' and 'very sweet' for the vertical axis and 'no peppermint flavour' and 'strong peppermint flavour' for the horizontal axis. Data were collected in a manner which was identical to that of the single-attribute test, with variable time intervals changing after 3 min and again after 7 min. If perception of one attribute ceased before perception of the second attribute ceased, the panelist moved the cursor to the zero point on the appropriate scale. When the second attribute was no longer perceived, the panelist moved the second cursor to the zero point intersection on the bottom left hand corner of the screen. The test ended when both tastes were no longer perceived, or after 15 min.

Analysis of time-intensity data

For both the single-attribute test and the dual-attribute test, eight time-intensity parameters were extracted from the individual time-intensity curves using the $CSA_{TPA}{}^{TM}$ analysis program (CSA Version 4.3). Although the individual parameters were discussed and defined in an earlier paper (Duizer *et al.*, 1994), a summary of terms may be found in Table 1. The panelist reliability measure (T-IR) was also determined for each panelist for each sample. This measure was based on the concept of standard deviation as a measure of variability, and represents the absolute mean of a set of standard deviations (Bloom *et al.*, 1995). Individual reliability scores are inverse measures with a lower score indicating a more reliable panelist.

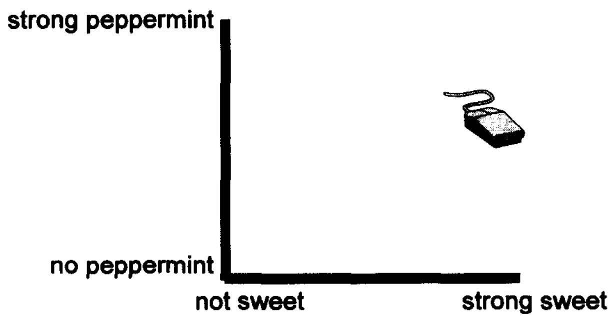

FIG. 1. Dual-attribute time-intensity test as viewed by panelists.

From each test, the eight parameters, as well as the T-IR scores, were analyzed using a repeated measures analysis of variance. These nine variables were analyzed to determine; the effects of single- versus dual-attribute methods, the difference between peppermint perceptions during single- and dual-attribute testing, and the interactions of release times of sweetness and peppermint amongst the four samples using dual-attribute evaluations.

Average time-intensity curves were produced for sweetness and peppermint perception of the four samples as measured by single-attribute and dual-attribute time-intensity. These curves were calculated using simple arithmetic averaging provided in the $CSA_{TPA}{}^{TM}$ analysis package and exported to a spreadsheet for plotting.

RESULTS

Single-attribute vs. dual-attribute methods

Single-attribute time-intensity evaluations of sweet and peppermint tastes were compared with dual-attribute evaluations. The order of the tasks was controlled through counterbalancing: half of the panelists made the single-attribute evaluations before they made the dual-attribute evaluations, and the other half made the dual-attribute evaluations before they made the single-attribute evaluations. Using the combined scores for the four samples of gum as the dependent variable, a two (taste, sweet/peppermint) × two (attribute, single/dual) fully repeated analysis of variance was conducted for each of the eight time-intensity parameters and the measure of reliability, T-IR (see Table 2).

Dual-attribute evaluations did not differ from single-attribute evaluations, with one exception, the INC ANGLE (attribute × taste, $F(1,8) = 6.41, p = 0.035$). The angle of increasing perception (INC ANGLE) of sweetness was greater than the angle of increasing perception of peppermint ($t(9) = 2.98, p = 0.015$) during dual-attribute evaluations. There was no difference in the increase angle during single-attribute evaluations. Single- and dual-attribute evaluations did not differ in reliability, ($F(1,8) = 0.40, p = 0.544$).

TABLE 1. Time-Intensity Parameter Definitions

Abbreviation	Parameter	Definition
IMAX	Maximum intensity	Maximum intensity perceived in the sample
TMAX	Time to maximum intensity	Time in seconds to reach maximum intensity
DUR	Duration	Time in seconds from first perception to the end of perception
INC ANGLE	Increase angle	Angle of increase to IMAX
INC AREA	Increase area	Area under the increase portion of the curve
DEC ANGLE	Decrease angle	Angle of decrease from IMAX
DEC AREA	Decrease area	Area under the decreasing portion of the curve
AUC	Area under the curve	Total area under the T-I curve

TABLE 2. Probability Scores for Each of the Eight Time-Intensity Parameters and T-IR by Taste, Attribute and Taste×Attribute

	Taste[1]	Attribute[2]	T*A
AUC	0.004	n.s.	n.s.
DEC ANGLE	n.s.[3]	n.s.	n.s.
DEC AREA	0.014	n.s.	n.s.
DUR	n.s.	n.s.	n.s.
IMAX	0.001	n.s.	n.s.
INC ANGLE	0.046	n.s.	0.035
INC AREA	0.038	n.s.	n.s.
TMAX	n.s.	n.s.	n.s.
T-IR	n.s.	n.s.	n.s.

[1]Taste = sweet or peppermint.
[2]Attribute = single-attribute or dual-attribute time-intensity test.
[3]n.s. = $p > 0.05$.

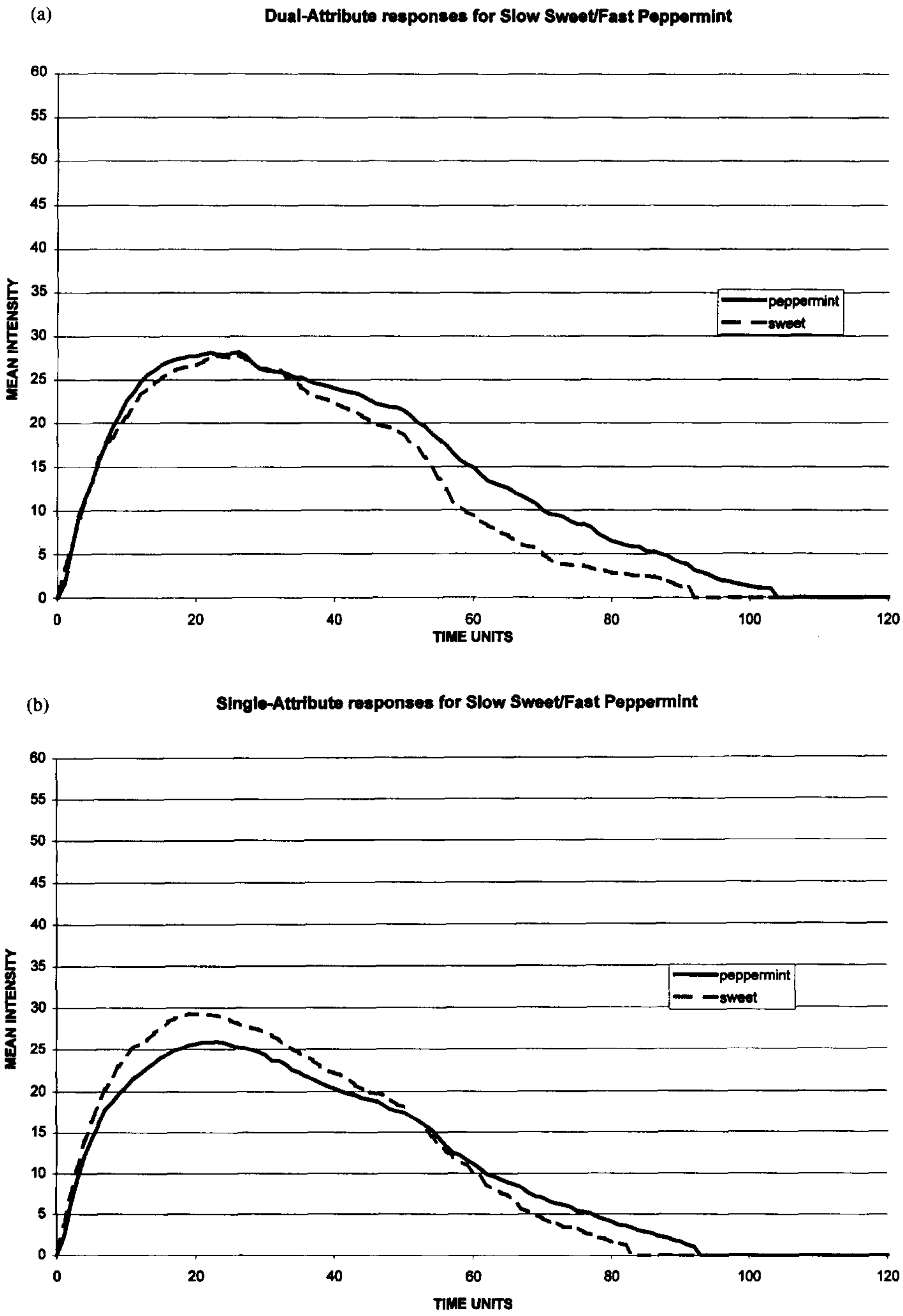

FIG. 2. Average time-intensity curves for slow sweet/fast flavour (SSFF) chewing gum as measured by (a) dual-attribute time-intensity. (b) single-attribute time-intensity.

Sweetness vs peppermint perception

Under both single and dual-attribute methods, perceptions of sweetness and peppermint tastes differed for four time-intensity parameters: IMAX ($F(1,8) = 23.88$, $p = 0.001$), AUC ($F(1,8) = 16.18$, $p = 0.004$), DEC AREA ($F(1,8) = 9.89$, $p = 0.014$), and the INC ANGLE ($F(1,8) = 5.57$, $p = 0.046$) (Table 2). In all four cases, perceptions of sweetness were greater than perceptions of peppermint. Differences in the area under the increasing angle (INC AREA) for sweetness and peppermint ($F(1,8) = 6.16, p = 0.038$) occurred only during dual-attribute testing. Sweetness and peppermint time-intensity curves averaged across all panelists are illustrated in Figs 2, 3, 4 and 5. Each figure shows the time-intensity curve for sweetness and the time-intensity curve for peppermint for the appropriate sample.

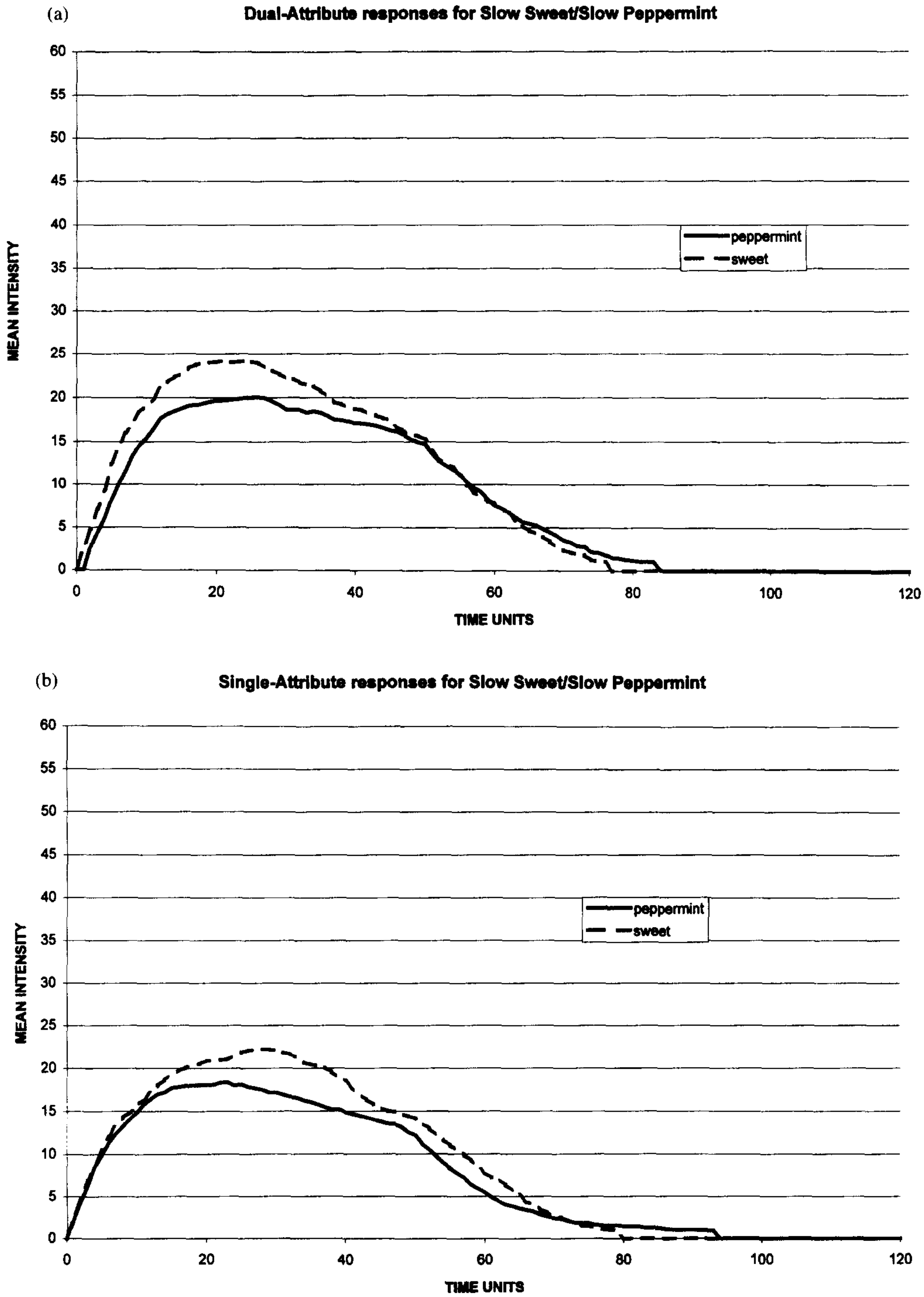

FIG. 3. Average time-intensity curves for slow sweet/slow flavour (SSSF) chewing gum as measured by (a) dual-attribute time-intensity. (b) single-attribute time-intensity.

In summary, the sensitivity of dual-attribute testing in distinguishing between sweet and peppermint time response was equal to, or better than, that of single attribute testing.

Rates of taste release

The four samples of gum were designed to demonstrate two outcomes of the dual-attribute method for sweet and peppermint evaluations: the comparison of the homogeneous, i.e. slow-slow and fast-fast samples for slow-vs. fast-release (SSSF vs. FSFF), and the comparison of the contrasted samples, i.e. slow-fast and fast-slow for slow-versus fast-release (SSFF vs. FSSF). Graphical representations of these results can be seen in Fig. 6.

Slow-release (SSSF) gum was compared with fast-release (FSFF) gum separately for sweet and peppermint perceptions (Fig. 6, comparison of solid lines). On the parameters of AUC, DEC AREA, DUR, IMAX, INC ANGLE, the fast-release gum was perceived as sweeter, and as having a faster TMAX, than the slow-release gum ($p < 0.05$). Fast-release gum also elicited stronger per-

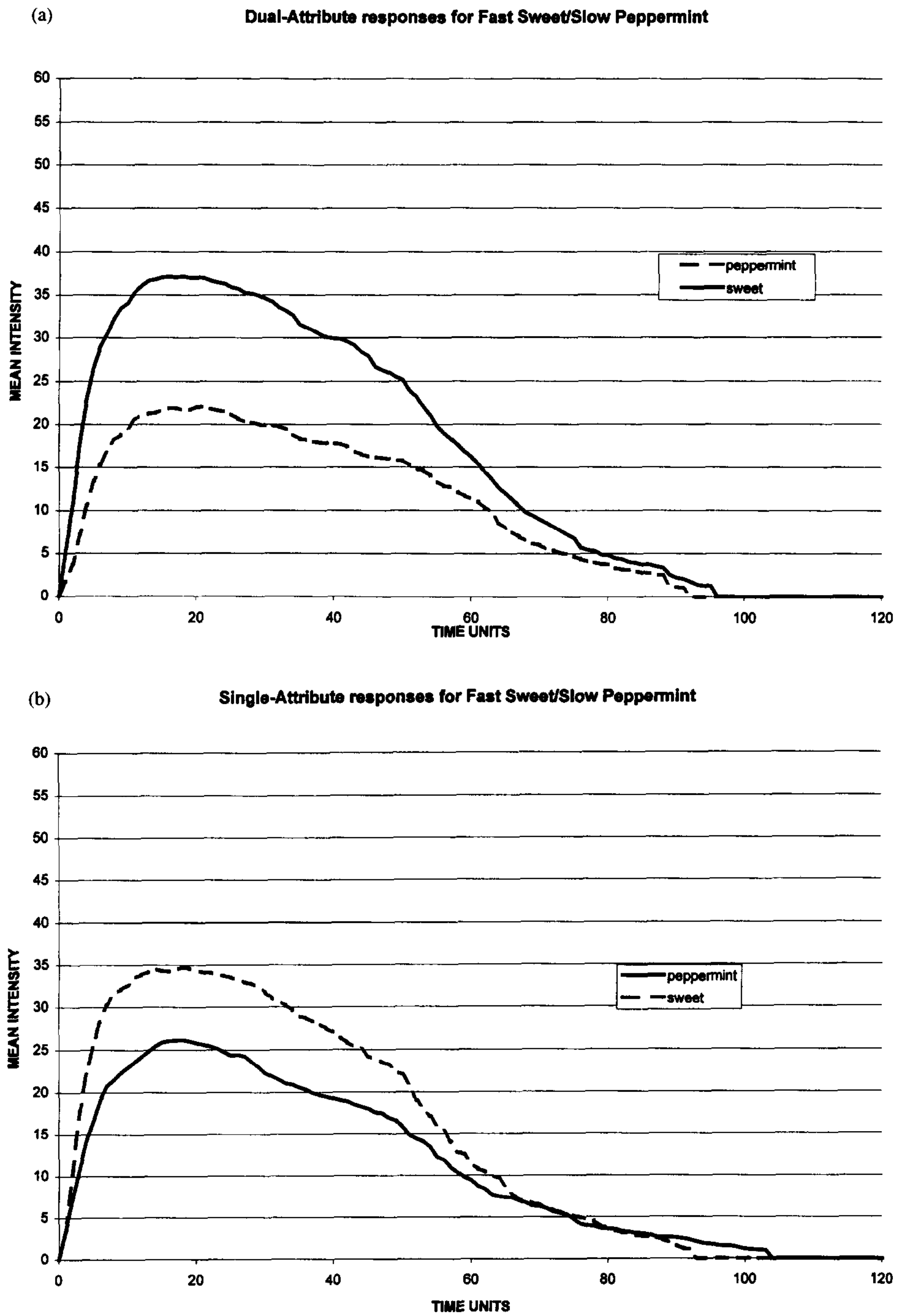

FIG. 4. Average time-intensity curves for fast sweet/slow flavour (FSSF) chewing gum as measured by (a) dual-attribute time-intensity. (b) single-attribute time-intensity.

ceptions of peppermint for the parameters: AUC, DEC AREA, DUR, IMAX, INC AREA ($p < 0.05$). Finally, over three replications, the perceptions of fast-release gum were more reliable. When the release times were crossed (contrasted) in samples, i.e. fast release of sweet was combined with slow release of peppermint, slow release of sweet was combined with fast release of peppermint (Fig. 6, dashed lines), the fast release of sweetness produced greater sensations of sweetness in AUC, DEC AREA, DUR, IMAX, INC AREA. The fast release of peppermint enhanced peppermint perceptions only for AUC, when the corresponding release time of sweet was slow. Therefore, by using the four gums and the method of dual-attribute testing, it was possible to study the interactions between and amongst characteristics of taste.

The absence of significant differences in time-intensity parameters between single-attribute time-intensity testing and dual-attribute time-intensity testing has positive implications. Measuring two sensory attributes simultaneously permits the sensory scientist to determine the interaction of perceptions in the mouth during mastication.

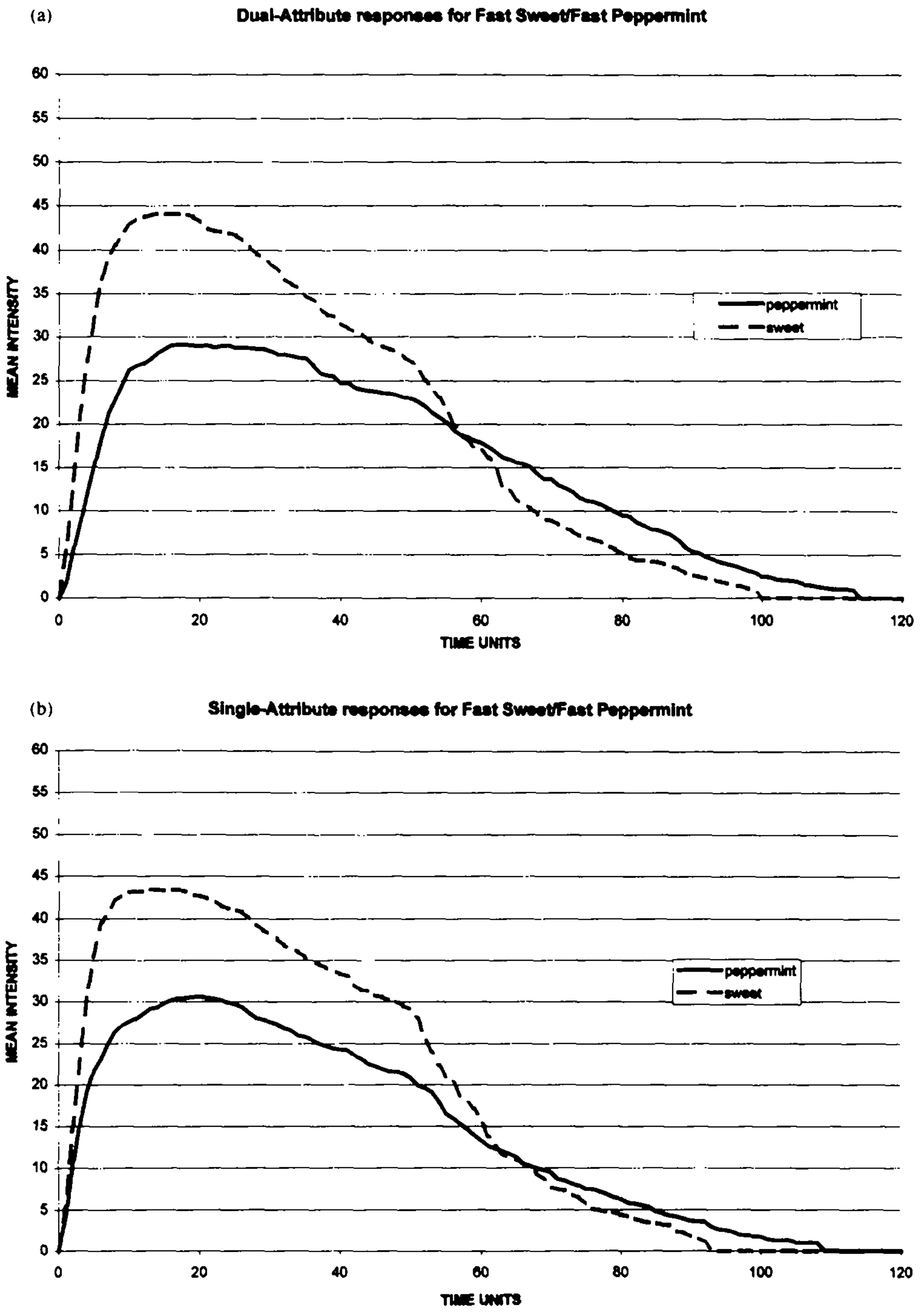

FIG. 5. Average time-intensity curves for fast sweet/fast flavour (FSFF) chewing gum as measured by (a) dual-attribute time-intensity. (b) single-attribute time-intensity.

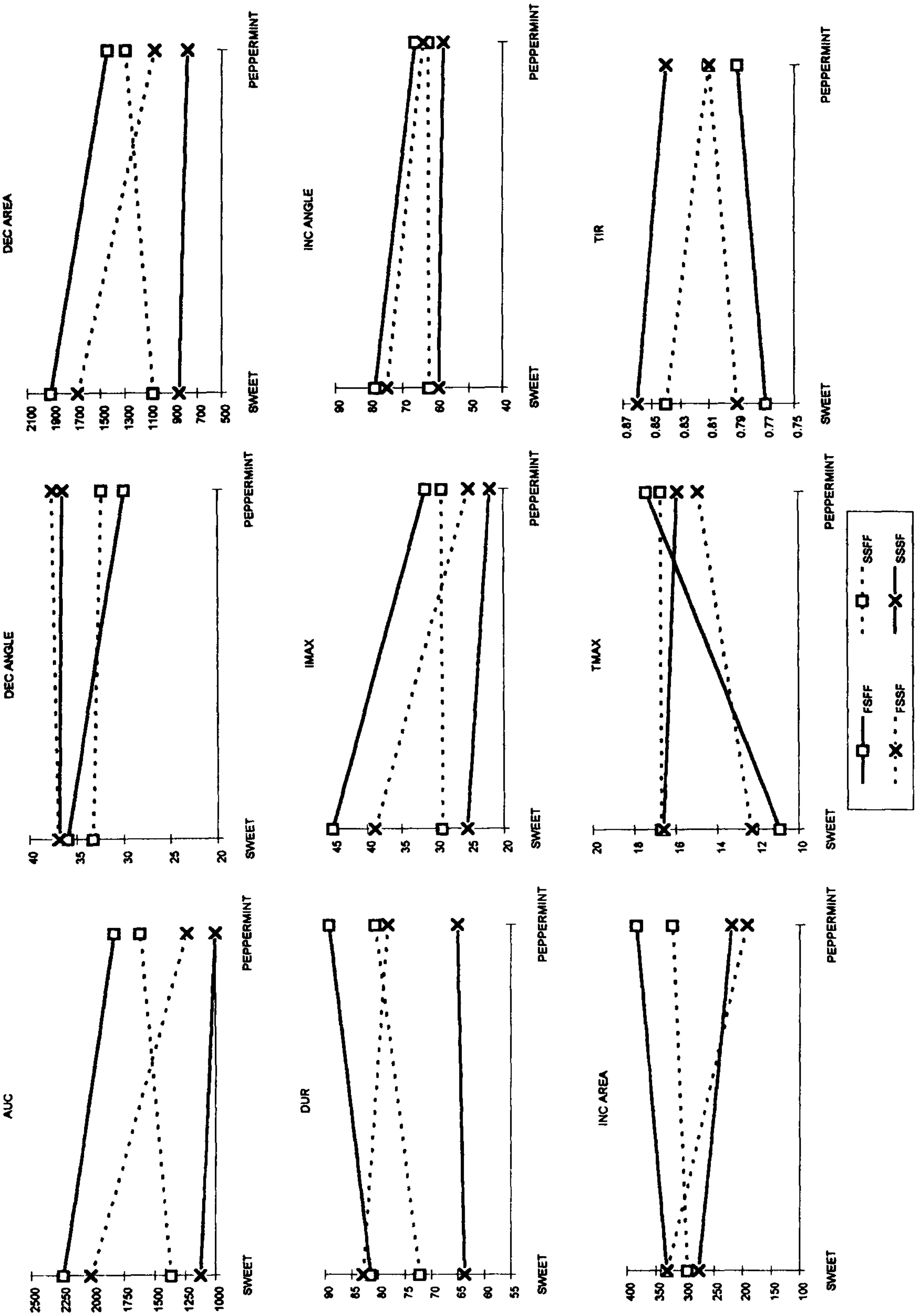

FIG. 6. Means of eight time-intensity parameters and T-IR extracted from dual-attribute time-intensity curves for four chewing gum samples.

The time required to collect data by dual-attribute time-intensity is one half that required to collect the same information by single-attribute time-intensity. For this research, 12 days of testing were necessary to collect information about sweet and peppermint flavours of four chewing gums in three replications by single-attribute time-intensity sensory evaluations, while only six days of testing were required to collect the same information by dual-attribute time-intensity sensory evaluation. This decrease in time can minimize the cost of conducting time-intensity tests, and still provide practical information on the time course of two sensory attributes.

In addition to providing the evaluation of interaction of tastes, and reducing the time and costs of evaluation, the dual-attribute time-intensity test provides solutions to at least two known methodological problems: dumping and inter-sample variability. Dumping occurs when a single attribute within a food is measured. The single attribute is rated as more intense when evaluated alone than when evaluated with additional attributes (Frank *et al.*, 1990). Lawless and Clark (1991) identified dumping as a problem during time-intensity testing, using the example of sweetness and strawberry flavour of strawberry/aspartame solutions. When panelists evaluated only the sweetness of the solution, the sample with the strawberry flavour was rated as more sweet than the sample without strawberry flavour. If both sweet and strawberry flavour of the solutions were evaluated, the sweetness rating was the same for both solutions. This bias can be minimized through dual-attribute time-intensity sensory evaluation. As well, dual-attribute time-intensity is useful for studying samples which have sample-to-sample variability, such as beef. Time-intensity work has been completed on the tenderness perception of beef (Duizer *et al.*, 1993). It has been difficult to study other characteristics in relation to tenderness because of the inherent variability within the muscle. Dual-attribute time-intensity can be used to study the relationship between tenderness and juiciness using only one sample of beef, overcoming the problem of variability between samples.

CONCLUSIONS

This research demonstrates that dual-attribute time-intensity allows collection of sensory data which more accurately reflects what is taking place in the mouth during consumption of a food. The success of the dual-attribute test in this research provides a tool for the study of many sensory interactions within foods. By quantifying interactions, the dual-attribute test can be used to study relationships such as juiciness and tenderness of meat, as well as other dynamic texture/flavour characteristics within food. Finally, dual-attribute testing can be accomplished in half the time required for single-attribute sensory evaluations. The method also offsets the problems of 'dumping' and sample variability. This initial dual-attribute research was conducted on chewing gum to provide a relatively long time for panelists to respond to intensity changes to reduce the potential for overloading the panelists. Since completing this study, further DATI research into meat tenderness and juiciness has been conducted collecting data successfully over time courses of 60–90 s. Panelists can readily perform DATI on relatively fast food events. It has been observed by panelists that dual-attribute testing is easier than single-attribute because they can shift their attention between the two attributes without concentrating too much on a single factor. It is this immediate sensory response that we are trying to measure without the filtering of cognitive process. The best-trained descriptive panelists respond at an automatic level to intensities. The same holds true for dual-attribute time-intensity.

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