AN ABSTRACT OF THE THESIS OF

Debbie L. Barnes for the degree of Master of Science in Food Science and Technology presented on November 20, 1990.

Title: Consumer and Descriptive Panel Analysis of Commercial Yogurts

Abstract approved: _____
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A consumer and a trained descriptive panel was utilized to determine liking ratings and flavor profiles, respectively, for commercial brands of pre-stirred yogurt. Once the consumer and descriptive panel data was collected, the data was combined to determine the interrelationship of these two sets of data and to determine the conditions necessary to optimize the sensory characteristics of commercial yogurt. This study was broken down into two parts: (1) evaluation by a 90 to 182 member consumer panel and an 11 member descriptive panel for 14 strawberry and 6 lemon yogurt brands, and (2) correlation of the sensory measures of sweetness and sourness, and analytical measures of sugars and acids for 14 strawberry, 12 raspberry, 6 lemon, and 17 plain yogurt brands.

Large sensory differences were found between yogurts for both flavors (strawberry and lemon) by both panels. Correlation and principal component analysis (PCA) indicated that two distinct groups of descriptors contributed to the liking of the yogurts: one

associated with the fruity and sweetness characteristics, and the other related to the plain yogurt and sourness descriptors. Consumers based their overall liking ratings on fruit flavor, sweetness, sourness, and a balance of sweetness/sourness liking. Males and females rated samples differently by as much as one full scale value on a 9-pt. hedonic scale. Use of PCA to relate the two panels revealed that high consumer acceptance corresponded with the PC loaded with fruity and sweet characteristics while lower consumer acceptability was noted with high loadings on PC2 which was comprised of plain yogurt, acetaldehyde, and sourness descriptors. The results from the first part of the study indicate that to produce a highly acceptable yogurt, processors should strive to provide a balance between sweetness and sourness and provide enough fruit flavor to mask plain yogurt characteristics.

In the second part of this study, titratable acidity and pH were measured for all the yogurts, while sugars were measured by HPLC only for the fruit flavored yogurts. Consumer overall liking was significantly correlated with sweetness intensity, sweetness:sourness (sw:so) ratio, and the summed impact of sweetness and sourness from the trained panel for strawberry and raspberry yogurt. No correlations between analytical measures and overall liking were found for any of the yogurts. A sw:so ratio greater than 1.0 for strawberry, and .8 for raspberry and lemon appeared necessary for high consumer acceptance. Generally, it was found that the sweeter the yogurt, the higher the consumer acceptance of fruit flavored yogurt. No relationships were found for any sensory and analytical measures for predicting the overall liking of plain yogurt. However,

the best predictors of consumer liking of fruit flavored yogurt were the descriptive panel ratings.

Consumer and Descriptive Panel Analysis of Commercial Yogurts

by

Debbie L. Barnes

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed November 20, 1990

Commencement June 1991

APPROVED:

Associate Professor of Food Science and Technology in charge of major

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Date thesis is presented November 20, 1990

Typed by the author Debbie L. Barnes

ACKNOWLEDGMENT

The work contained in this thesis would not have been possible with out the guidance, support, and dedication of many people. First, I would like to thank Steven J. Harper who shared an equal responsibility on this project. Without his dedication and support, this research would not be in the form it is today. I would like to thank Dr. Mina R. McDaniel for giving me the opportunity to continue my education, and for guidance and continued encouragement that made reaching this goal possible.

Many thanks go to my committee members, Floyd W. Bodyfelt and Ken Rowe, for their willingness to answer questions and for their support. This research was solely possible due to the continued dedication and hard work by the eleven super panelists. I would like to thank the entire sensory group for their assistance with every aspect of this research. Thanks go to Bob Durst for analyzing the yogurts for sugar content using the HPLC, and the Western Dairy Foods Research Center for financial support.

Finally, I would like to thank and dedicate this thesis to all of my family members and friends who lended their emotional support throughout the past year and a half.

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CONTRIBUTION OF AUTHORS

As major professor and advisor for the author, Dr. Mina R. McDaniel was also the principal investigator for the yogurt research of which this thesis is a part. Floyd W. Bodyfelt, as faculty member and co-investigator, was directly involved with the technological aspects of yogurt production and evaluation. He was also instrumental in securing funding for the research and provided guidance to the author. Steven J. Harper is a fellow graduate student who actively participated as co-researcher in the research.

CONSUMER AND DESCRIPTIVE PANEL ANALYSIS OF COMMERCIAL YOGURTS

INTRODUCTION

Consumption of yogurt in the U.S., from the time of introduction in 1939 to 1988, has generally increased (Knutson 1978, Baxter 1985, Cooke 1986). However, during 1989 sales of yogurt decreased approximately 12% (Sandra Wood, Milk Industry Foundation, Personal Communication). This decrease had been expected for some time due to the varied composition, marketing strategies, and numerous brands on the store shelves. It is thought that consumers have become "confused" about the type of yogurt they desire (Kroger, 1973). Very few studies have been conducted to determine consumer likes and dislikes, and almost no studies have related consumer panel responses to a trained descriptive panel in order to optimize the sensory characteristics of yogurt.

This study was constructed in two parts with the main objectives to develop a flavor profile of commercial yogurts, and to find direct measures to help predict consumer overall liking. The specific objectives of Part I were: to determine consumer panel responses to commercial brands of strawberry and lemon yogurts; to determine and rate sensory attributes of these flavored yogurts by using a trained descriptive panel; and to examine the possible interrelationships between consumer and descriptive panel results. In Part II, the specific objectives were: to determine how sensory

attributes of sweetness and sourness relate to consumer overall liking; to determine if analytical measures of pH, titratable acidity and/or total sugars by HPLC relate to consumer overall liking; and to determine if sensory characteristics of sweetness and sourness of yogurts can be correlated to analytical measures of sugars and acids.

REVIEW OF LITERATURE

I. YOGURT

Yogurt is a fermented milk product which is known by several different names throughout the world. The origin of yogurt goes back to the Middle East where it has been an important food staple since at least 5000 B.C.; however, there are no precise records which actually date the product (Tamime and Robinson, 1985, Bodyfelt et al., 1988).

Commercial production of yogurt increased rapidly in Europe early in the twentieth century after Dr. Eli Metchnikoff published that regular consumption of yogurt led to 'prolongation of life.' The earliest successful introduction of commercial yogurt in the United States occurred in 1939 in New York City (Bodyfelt et al., 1988).

A. Yogurt Consumption Patterns

Since the introduction of plain or natural-style yogurt in 1939, manufacturing techniques have changed very little, but consumption patterns have changed dramatically. Knutson (1978) reported that consumption between 1962 and 1970 grew 270%, while during the years 1970 to 1977, consumption grew 260%. According to Baxter (1985), production of yogurt expanded by 325% from 1968 to 1984. In fact, sales have increased over the past few decades according to the Milk Industry Foundation (1989). Many investigators have reported that addition of fruit, flavoring and sweeteners have led to the increased popularity of yogurt (Kagen 1985, Davis 1970). However, during the year 1989, yogurt consumption decreased by

approximately 12% (Sandra Wood, Personal Communication). Varied composition and lack of specific standards are probable contributors to this decrease (Davis 1970, Kroger and Weaver 1973, Kroger 1975a, Kroger 1975b, Kroger 1989). The addition of fruit, flavoring, and sweeteners have served to help increase consumption; now there appears to be a need to concentrate on optimizing sensory characteristics and emphasis on the use of quality ingredients in the manufacture of yogurt.

Yogurt has been marketed as a snack food or quick meal, but advertisers have heavily marketed yogurt as a health food. Several investigators have studied the benefits of yogurt as a healthful product for lactose malabsorbers (Kelley 1984, Rasic 1987, Wytock and DiPalma 1988).

B. Sensory Studies on Yogurt

There have been relatively few studies in the past which have used appropriate sensory methodology for consumer and descriptive tests on yogurt (Lindsay 1981, Ismail 1983, Modler 1983). Previous yogurt studies have focussed on specific properties such as sweetness and its relation to consumer acceptability (Engel 1973, Wilson et al. 1983, Greig et al. 1985, McGregor and White 1986, Keating and White 1990). The majority of these studies reported an optimum level of sweetness where above or below that level, acceptance ratings decreased. These results concur with a model proposed by Moskowitz (1983) where a "bliss point" or optimum level is achieved. McGregor et. al. (1986) discovered a level of 4% added sweetener (sucrose, high fructose corn syrup, or a mixture of

the two sweeteners) yielded high consumer acceptance while Greig et al. (1985) reported an optimum of 2% added sucrose or .14% EQUAL (contains the high potency sweetener, aspartame) level in plain yogurt.

Other studies have focussed on the effect of sweeteners on volatile flavor compounds of yogurt, or the effect on sensory characteristics when yogurts are made with other milk or stabilizer sources (Bills et al. 1972, Ismail 1983, Modler et al. 1983, McGregor and White 1987). Bills et al. (1972) demonstrated with addition of flavoring to yogurt that the important volatile, acetaldehyde, was masked.

From these few studies, relevant information has been gained; however, there have been no recent studies which have combined data from both a trained descriptive panel used to describe, define, and rate characteristics of yogurt products and a consumer panel to determine acceptability.

II. TASTE MIXTURES

Many investigators have studied mixtures of the four basic taste qualities (sweet, sour, salt, bitter). In particular, studies have been conducted on mixtures of two or more substances classified in different taste quality categories or mixtures of substances within the same quality category. The three main effects discovered when mixtures have been studied sensorially are suppression, additivity, and synergism. The suppression effect is noted by the perceived taste intensity of a mixture being lower than the expected sum of the intensities of the individual components. Additivity is the effect

observed when the sum of the perceived taste intensities of the components is equal to the taste intensity of the mixture. Finally, synergistic effects are found when the perceived taste intensity of the mixture is higher than the expected sum of the perceived intensity of the individual components (De Graaf and Frijters, 1987).

Moskowitz (1972) reported that the main effect when mixing sweetness with sourness was the reduction of intensity of each taste in the mixture. The overall taste intensity of the mixture was about half of the sum of the individual intensities of the components in the mix. In this case a suppression effect was observed.

Fabian and Blum (1943) studied saltiness, sourness, and sweetness and the interaction of these tastes. These investigators found that the sweetness of sucrose was increased by lactic, malic, citric, and tartaric acids while HCl and acetic acids did not effect the sweetness. In sub-taste-threshold amounts, sugars reduced the sourness of acids. Basically, five sugars showed a "compensatory" or balancing action on six acids. Pangborn (1960) confirmed the relationship of sucrose decreasing sourness of citric acid. However, Pangborn's statement that citric acid decreased the sweetness of sucrose is in disagreement with the results of Fabian and Blum. Not only were these measurements done in aqueous solutions, Pangborn found similar suppression effects in fruit nectars and tomato juice. In a recent study by Frank and Archambo (1986), results were similar to those of Moskowitz (1972), Pangborn (1960), and Fabian et al. (1943) when using an information integration system for intensity and hedonic measurements.

Lawless (1982) conducted some experiments which investigated adaptation to taste mixtures of salt-sucrose solutions. He found that when one component of a mixture is removed perceptually due to prior adaptation of that component, the intensity of the other component was the same as the unmixed component.

III. SWEETNESS AND SOURNESS

A. Sweetness Perception

Sweetness perception and preference has been established in several species, and ranges from newborns to adults. Steiner (1977) reported that three basic taste qualities (sweet, sour, and bitter) yield different facial expressions in neonate infants only a few hours after birth; thus, indicative that discriminative responses are present at birth and are, therefore, not acquired solely by learning and life experiences.

The different relative sweetness values of various sugars have been documented by Moskowitz (1970, 1971). In these studies, Moskowitz determined the relation of sweetness, pleasantness and the concentration of 43 different sugars. He found that a power function (exponent 1.3) fit the relation of perceived sweetness of most sugars to their concentration which indicated that the sweetness intensity increases faster than the concentration. In a further study, Moskowitz (1973) discussed models of sweetness additivity. His results suggest that the sensory system for taste adds chemical information together and processes mixtures to get an increased perceptual intensity. Moskowitz reported that the exact

mechanism is not known; however, it could be classified into one of two types: Type I additivity would be a perceived summation of the actual concentration of sweeteners while Type II additivity would be the summation of the subjective sweetness of component sugars.

De Graaf et al. (1987) demonstrated that mixtures of glucose and fructose show both properties of synergism and additivity. Synergism occurred at low levels and additivity occurred at intermediate levels. Frank et al. (1989b) also studied binary mixture interactions of sweeteners. He found that mixtures were superadditive or synergistic at low concentrations, additive at intermediate concentrations, and subadditive (suppressed) at high concentrations. From 31 sweetener mixtures studied, 18 had synergistic effects and 2 were suppressed while the others showed additivity. This research does not completely agree with that of McBride (1986, 1988) who explained that mixtures of fructose and glucose exhibit additivity at low levels.

Several studies have questioned whether food color or odor enhances sweetness perception (Frank et al. 1989a, Pangborn et al. 1963a, Pangborn et al. 1963b). In a study of pear-nectar, Pangborn et al. (1963b) reported that correct identification of the sweeter sample was more frequent within pairs of nectars where both samples were uncolored. There was a significant decrease in correct identifications with colored nectars. Results from another study by Pangborn et al. (1963a) on coloring dry table wine indicated that an experienced panel was more influenced by color than was an untrained panel. However, white wines considered the sweetest in the evaluation contained 1.5 and 1.8 percent sucrose while pink

wines were sweetest when evaluation consisted of 2.0 and 2.2 percent sucrose. In a more recent study, Frank et al. (1989a) reported that strawberry odor enhanced perceived sweetness of sucrose solutions while red color had no enhancing effects for both swallowing and expectoration conditions.

B. Sourness Perception

Sourness, one of the four basic taste qualities, has been studied by numerous investigators in an effort to determine chemical or physiological reasons for this particular taste. Several investigators have reported that the perception of sourness is based on chemical reactions; however, the mechanisms reported have not all coincided. Crozier (1916), Hadden (1965), and Ganzevles and Kroeze (1987) have reported that the perceived sourness of HCl solutions is caused by the H+ ion and penetration of this ion through the cell membranes. Ganzevles and Kroeze (1987) also reported that the sourness of carboxylic acids correlated with the dissociation constant, as well as the H+ ion, which is indicative that different receptor processes elicit response. Also, a decrease in the pH of the given acids did not decrease perceived sourness. Pangborn (1963) in a study of the relative sourness of equal sour solutions of lactic, acetic, and tartartic acids found no association between the pH and the relative sourness of the solutions. Moskowitz (1974) reported that additivity models seem useful for prediction of sourness of acids. Subjects in this study were unable to perceive some samples as mixtures of acids, and they did not report any other tastes. In any case,

Moskowitz (1974) proposed a mechanism as total additivity of acids similar to the total additivity of sweetness previously reported.

In a study by Straub and McDaniel (1989) conducted to determine time-intensity curves for several acids, they found various correlations between sensory ratings and chemical measurements such as the dissociation constant, number of carboxyl groups, and normality. They also reported significant negative correlations for sourness against pH, total acidity, and titratable acidity. CoSeteng et al. (1989) studied the comparative sourness of five different acid solutions on the overall acceptability of imitation apple juice. In this study, the investigators reported that the extent of sourness for citric, malic, tartaric, and acetic acid solutions could be related to an interaction of the pH and titratable acidity of the solution; the titratable acidity and pH also influenced the overall liking rating for the juice product.

C. Sweetness:Sourness and Sugar:Acid ratios

Sivetz (1949) discussed the importance of acids and their role in balancing flavor and sweetness. Several studies have investigated perceived flavor intensity or acceptability as a result of sugar or acid content. Board and Woods (1983) reported on prediction of flavor acceptance of apple juice drink based on °Brix and °Brix:acid ratios. They found a °Brix of 12.5 and 13.0 corresponded to maximum flavor acceptability. A study by Dryden and Hills (1957) on apple sauce reported that the higher the acid content, the higher the sugar content required to obtain optimum flavor responses. An acid of .45%

and 22 °Brix (resulting in a °Brix:acid ratio of 50) yielded the optimum flavor response to apple sauce.

In a study of orange juice drink, Pangborn et al. (1960b) reported that a °Brix:acid ratio of 18.5 was the optimum level for consumers. Ennis et al. (1979) found that a sweetness:sourness ratio was the best predictor of frozen orange juice preference. A sweetness:sourness ratio of 1.1 to 1.3 was the most preferred by consumers. A study by Fellers et al. (1986) on frozen concentrated orange juice found, generally, as the °Brix:acid ratios increased, flavor improved and the sensory characteristics of sweetness, tartness and bitterness became closer to "just right." A °Brix to percent acid ratio of 14 to 16 was found to be optimum.

Two studies by Valdes et al. (1956a, 1956b) investigated the effect of sucrose and organic acids on flavor intensity. Both studies found that more flavor intensity was associated with the sweeter sample. In the first study of aqueous solutions, an optimum level of 15% sucrose was noted, beyond which the sweetness tended to mask the given flavor perception. The second study on fruit nectars revealed the same conclusions, except that added acid enhanced apricot flavor. A study by Perng (1988) investigated the influence of sugar and acid on sensory qualities and desirability of blackberry juice drink. Perng found that blackberry flavor intensity was enhanced by sugar level and acid (up to .5% TA). Flavor intensity was observed to be specifically related to the sweetness:sourness ratio and not to the °Brix:acid ratio. However, consumer desirability was related to both sweetness:sourness and °Brix:acid ratio. The most

desirable juice product possessed a sweetness:sourness ratio of .85 to .94.

Simone et al. (1956) studied individual reactions to sweetness in canned cling peaches and found that 24 to 26 °Brix was preferred by consumers. Product acceptability was also optimized when the °Brix:acid ratio was 73.7 to 85.4 . Simone et al. also reported that in a paired presentation of peach samples, males had a greater tendency to choose the sweeter sample.

IV. SENSORY METHODOLOGY

According to O'Mahony (1979) the dairy industry has utilized 2 or 3 member expert panels to assess the sensory characteristics of their products, but use of these so-called "expert panels" can be an inadequate measure of sensory characteristics. Expert panel results should not be compared with descriptive panel methodology, primarily because of teh non-linearity of the panel ratings. In order to determine valid consumer liking of a product, an acceptance test is the best type to use. Meilgaard et al. (1987) discusses the use of numerical hedonic scales to determine the degree of acceptability. For determining individual attribute liking, again the hedonic scales can be used; however, if one wants to use sensory measure for diagnostic purposes, either hedonic or "just right" scales can be utilized.

Meilgaard et al. (1987) describes the use of trained descriptive analysis panels for discrimination and description of both quantitative and qualitative sensory aspects of any product in order to obtain aroma, flavor, texture, or sound profiles of the product.

Panel size is dependent on the type of product being evaluated. The panelists learn to qualitatively describe and define sensory characteristics of a product, and then concisely define each characteristic so that every panelist has a clear picture and understanding of each descriptor. The panelists then learn to quantitatively differentiate and rate the descriptors previously defined, and rate the degree to which each characteristic is present in a sample. Meilgaard et al. (1987) demonstrated that two samples may have the same qualitative descriptors, but they can differ in the quantitative intensity measure, and thus lead to distinct differences between their sensory profiles.

For product optimization related research, it is important to have a flavor profile of the product as well as having consumer panel results for determining the direction of product development. Studies of yogurt by Barnes et al. (1990) and Harper et al. (1990) have demonstrated the use of correlation and principal component analyses for relating two distinct data sets (consumer and descriptive panels) in order to determine the flavor profiles of products which consumers have rated high in liking. Thus, directional information is gained for helping develop product re-formulations for optimization of the sensory characteristics of products.

CORRELATION OF DESCRIPTIVE AND CONSUMER PANEL FLAVOR RATINGS FOR COMMERCIAL PRE-STIRRED STRAWBERRY AND LEMON YOGURTS

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ABSTRACT

Objectives of this study were to determine consumer and trained descriptive panel ratings for strawberry and lemon yogurts and to examine the interrelationship of the panels in order to understand and quantify flavor differences among commercial yogurts. Fourteen brands of strawberry and six lemon pre-stirred yogurts were evaluated by an 11 member trained descriptive panel and a 90 to 182 member consumer panel.

Large sensory differences were found between yogurts by both panels. Correlation and principal component analysis (PCA) of trained panel ratings revealed two distinct groups of descriptors: one associated with fruity and sweet character, and the other related to plain yogurt and sourness attributes. Consumer overall liking was based on fruit flavor, sweetness, and sourness liking, and sweetness/sourness balance in the samples. Nearly one full scale value (on a 9-pt. hedonic scale) differentiated male and female liking ratings. Use of PCA to interrelate the trained and consumer panels revealed that high consumer acceptability corresponded to the principal component comprised of fruity and sweetness characteristics. Samples rated high in plain yogurt characteristics had lower consumer acceptability ratings. To produce a highly acceptable yogurt, processors should strive to provide a balance between sweetness and sourness and provide enough fruit flavor to mask plain yogurt characteristics.

INTRODUCTION

The role of yogurt as a nutritious snack food has been established for some time (Martini et al.1987, Rasic 1987, Savaiano et al. 1984, Shahani et al. 1976). A marketing strategy which has been partially based on stated nutritional benefits has led to increased yogurt sales in the United States over the last few decades (Milk Industry Foundation, 1989). However, an estimated 12% decrease in yogurt consumption for 1989 has ended this yogurt boom (Sandra Wood, Milk Industry Foundation, Personal communication).

Several investigators have reported that the composition of yogurt varies extensively (Kroger et al. 1973, O'Neil et al. 1979, Richmond et al. 1979). These studies discuss possible sensory differences briefly, and mention that varied sources of fruit-flavorings were undoubtedly an important basis for this fairly recent popularity of yogurt. With a range in compositional differences plus the various flavor ingredient sources in yogurt manufacturing, consumers may be somewhat confused about what constitutes the most desirable sensory characteristics of yogurt. There have been relatively few published studies that address consumer acceptability aspects of the sensory attributes of flavored yogurt (Lindsay et al. 1981, McGregor et al. 1986, Harper et al. 1990). Other researchers have focused on specific factors such as sweetness or sourness in relation to their particular effects on flavor quality (Manus 1973, Welker 1986, Barnes et al. 1990).

To understand and quantify some of the flavor differences in commercial yogurts and to evaluate their effect on consumer acceptability, this study was conducted with the following specific objectives: to determine consumer panel responses to commercial brands of strawberry and lemon yogurts, to determine and rate sensory attributes of these flavored yogurts by using a trained descriptive panel, and to examine the possible interrelationships between consumer and descriptive panel results.

METHODS AND MATERIALS

Samples

Fourteen strawberry and six lemon commercial samples of pre-stirred yogurt were obtained from retail stores in the local (Corvallis, OR) marketplace. Because of the relatively high number of samples evaluated, it was impossible to obtain commercial samples that bore the same expiration (sell-by) dates. However, yogurt samples were chosen from the store shelves that exhibited the latest expiration date possible which ranged from a low of seven to a high of 30 days beyond the date of sensory analysis. All containers (purchased as single serving containers where possible) of each yogurt brand were from the same lot. All yogurt samples were obtained no more than three days prior to sensory evaluation. Sample consistency was assured by gently mixing (20 folds) several containers of each sample into one batch. After mixing, the samples were stored in 2.3 kg new polypropylene containers at 1.5 ^{o}C.

Descriptive Panel

Sensory evaluation was conducted within the Sensory Science Laboratory at Oregon State University (Corvallis, OR) in individual booths under red lighting to mask color differences. Spring water was provided for rinsing between samples. The serving temperature was 3.3 °C, and the sample size was 40 ml yogurt served in 60 ml odorless plastic cups. The panelists rated all samples with two replications for strawberry and three for lemon yogurt to complete a randomized balanced complete block design (Cochran and Cox, 1957). A replication for lemon yogurt required only one day of testing while two days were required for the strawberry product. Samples were presented in two sets, each consisting of either three or four samples. Panelists rested between sets to avoid or minimize fatigue.

Eleven students and staff from the Department of Food Science and Technology at Oregon State University (Corvallis, OR) volunteered to be on the trained yogurt panel. Strawberry yogurt descriptors were developed in 14 training sessions through discussion and agreement of terms by the panel with the aid of the panel leader (Table 1). Reference standards were developed (Table 1) according to the definitions set by the panel and panel leader. Panelists rated the flavor descriptors for each yogurt using a 16-pt. intensity scale (0=none, 7=moderate, 15=extreme).

The same 11 panelists were used to evaluate lemon yogurt by a descriptive test; therefore, only six training sessions were necessary to determine descriptors and develop reference standards (Table 1).

Consumer Panel

Testing was conducted at the 1989 Benton County Fair (Corvallis, OR). Commercial brands of strawberry and lemon yogurts were evaluated by 182 and 90 panelists, respectively, to complete a balanced incomplete block design which yielded 26 observations per sample for strawberry and 30 observations per sample for lemon (Cochran and Cox, 1957).

To participate in the evaluation, panelists were required to be a minimum of 10 years old and had to be "consumers" of fruit flavored yogurt (at least once per month). Approximately, an equal number of males and females participated in the yogurt panel. While seated in portable booths, each consumer panelist evaluated two yogurt samples. Serving temperature and sample size were the same as for the descriptive panel test. Panelists evaluated liking of the appearance, overall product, flavor (strawberry or lemon), sweetness, and sourness using a 9-pt. hedonic scale (1= dislike extremely, 5= neither like nor dislike, 9= like extremely). To gain insight on the balance of sweetness and sourness in the samples, panelists rated sweetness and sourness using a 7-pt. "just right" scale (1= way too little, 4= just right, 7= way too much).

Statistical Analysis

For a few panelists the data values for specific attributes were removed either due to poor replication or non-use of terms after the raw data was examined. Analysis of variance (ANOVA), correlation, and principal component analyses were conducted using the SAS statistical package (SAS Institute, Cary, NC). Statistical significance

was accepted if the p-value was less than or equal to .05 for the ANOVA and correlation.

ANOVA was based on a mixed effects model where treatment effects were fixed, and all other effects were random. The F-test for treatment effects was calculated as the treatment Mean Square divided by the panelist by treatment Mean Square. The appropriate degrees of freedom were used to determine significance.

RESULTS AND DISCUSSION

Descriptive Panel

For ANOVA, significant ($p \leq .05$) differences were found between the yogurt brands for all strawberry yogurt descriptors that were evaluated (Table 2). Lemon yogurt descriptors also showed significance except for the fresh lemon and cooked milk descriptors. There were several significant correlations between the descriptors for both strawberry and lemon flavored yogurts.

Correlation analysis revealed that there were two opposing groups of attributes for the commercial strawberry yogurt. Attributes of jammy strawberry, sweetness and cooked milk were significantly ($p<.05$) correlated, and so were the attributes plain yogurt, acetaldehyde, sourness, astringency, and bitterness. These two attribute groups, those associated with sweetness and those associated with plain yogurt, were significantly ($p<.05$) negatively correlated with each other for the majority of attributes (Table 3). A similar pattern of negative correlations was found for the lemon yogurts. Attributes associated with plain yogurt opposed attributes

of sweetness, overall lemon, lemon juice, and artificial lemon flavor (Table 3). These negative correlations seem to indicate that if yogurt sweetness and fruity attributes are present at high levels, then the plain yogurt and associated attributes are likely to be low, or else the sweet and fruity characteristics serve to mask the plain yogurt (base) characteristics (Bills et al., 1972).

PCA was useful for visualizing the relation between attributes and yogurts. For strawberry yogurts, two principal components were involved. Principal component 1 (PC1) was comprised of sourness, astringency, plain yogurt, and overall intensity attributes, and explained 23 percent of the variation. Attributes of fruity, sweetness, jammy strawberry, acetaldehyde, and bitterness contributed to principal component 2 (PC2) which served to explain 16 percent of the variation. Samples 14, 9, and 8 (Figure 1) were especially high in PC2 and showed negative values for PC1; these yogurts were best described by fruity and sweetness attributes while lacking the plain yogurt attributes. These interpretations are consistent with the results found by correlation analysis.

For the lemon yogurts, PC1 explained 23 percent of the variation and was constructed with overall lemon, lemon juice, and sweetness; while PC2 explained 18 percent and included plain yogurt, acetaldehyde, sourness, and astringency attributes. These two components seemed to oppose each other as demonstrated by the correlation analysis. Sample 1 was characterized by high values of PC2 (plain yogurt, acetaldehyde etc.). High PC1 values, which corresponded to attributes of overall lemon, lemon juice, and sweetness, defined samples 5 and 6 (Figure 2). Consequently, these

two samples exhibited low PC2 characteristics (plain yogurt, acetaldehyde, sourness and astringency); this result had previously been indicated by correlation analysis.

Consumer Panel

Large differences were found between yogurt samples (brands) by consumer ratings of both strawberry and lemon flavors. Figure 3 shows the distribution of means for overall liking ratings of yogurt samples. Samples were independent, but lines were added to connect samples for visual clarity. Of the strawberry flavored yogurts, one sample had the highest mean rating (7.89) which corresponded to like very much, while 11 samples had lower mean ratings which fell in the like slightly to like moderately range, and two samples were in the neither like nor dislike category. The majority of lemon yogurts were rated in the like moderately range; however, the least liked yogurt overall was in the category neither like nor dislike. Since there were obvious differences between these flavored yogurts, all flavor attributes (strawberry/lemon flavor, sweetness and sourness liking) and the appearance attribute were compared to determine which were responsible for, or contributed most to the overall liking responses.

Overall liking was highly correlated ($p=.0001$) to the specific fruit (strawberry or lemon) flavor liking for both strawberry and lemon yogurts (Figure 4). This result suggested that strawberry or lemon flavor were the major descriptors which explained consumer overall liking. The purpose in having consumers rate liking of strawberry or lemon flavor was to give them an opportunity to rate

the "quality" of the fruit flavor itself. However, it appeared that a question posed in this form merely resulted in another overall liking response.

Sweetness and sourness liking values were correlated with those for overall liking for both flavors (Figure 4). The strawberry and lemon yogurts had a significant ($p<.01$) correlation with both attributes (Figure 4). It was interesting to observe that the consumers consistently rated sweetness liking higher than sourness liking. Overall liking was not significantly correlated with appearance liking (Figure 4) for either of the two fruit flavored yogurts.

To understand whether the perceived sweetness and sourness levels were just right, too high, or too low for consumers; the attributes of sweetness and sourness were rated on a 7-pt. "just right" scale and were compared with overall liking. For strawberry yogurt, the highest liked samples (10-14) had sweetness and sourness responses closest to the "just right" level (Figure 5). As the liking scores decreased, a group of samples (6-9) rated as too sweet were noted. The lowest liked samples (1-5) were rated as having too much sourness, and, consequently, too little sweetness. The responses for lemon indicated that the least liked sample was too sour. The other lemon yogurts, which were rated close to "just right" for sweetness and sourness, were highest in overall liking. To produce yogurts which would have the highest overall liking ratings, it is clear that a balance between sweetness and sourness is necessary. From a dairy processors point of view, it would seem that the better approach would be to have samples too sweet, rather than too sour, in order to optimize the high overall liking ratings of flavored yogurt.

Because males and females are known to differ in their particular preferences for sweetness liking, classifying the panel by gender seemed appropriate. This difference may be an important factor to consider when planning marketing strategies for flavored yogurts. Males and females did not agree on which samples they liked best for sweetness liking or strawberry flavor liking (Figure 6). In fact, male and female liking ratings were almost one full scale value apart in most cases. The yogurts preferred by the males, samples 7 and 9, for sweetness liking were rated high in sweetness and low in sourness intensity by the trained panel. Yogurts preferred by the females, samples 10 and 12, had higher sourness intensity ratings; consequently, it appeared that males liked high sweetness, and females liked more sourness to balance the sweetness. Simone et al. (1956) also found that males consistently prefer the sweeter of two samples among five entire sets of canned peach samples regardless of how sweet the samples actually were. For the majority of lemon yogurts in our study, sweetness and sourness liking ratings by males and females differed by a full scale value (Figure 6). However, no distinct pattern was discovered for either the males or females liking ratings compared to trained panel results.

Considering that large differences in liking were found between samples evaluated by males and females, it was of interest to determine if males and females used the same part of the scale. A test was constructed to determine whether or not there were significant differences between average attribute liking ratings across all samples by males and females. However, no significant differences were found between the average attribute liking ratings

tested. This indicated that, on the average, the males and females in our study used the same part of the scale. Yogurt processors should be aware of this possible difference in sweetness liking by males and females since large scale value differences were determined for the commercial brands of flavored yogurts.

Interrelationship of Consumer and Descriptive Panels

Spider plots provide a way to visualize the relation between consumer and descriptive panel data. For lemon yogurt, the highest and lowest liked samples were plotted according to the attribute ratings from the descriptive panel. Lemon descriptors and sweetness characteristics were more pronounced in the highest liked sample, while the lowest liked sample had high intensity ratings of plain yogurt, sourness, acetaldehyde, bitterness, and astringency (Figure 7). Similar results were found for the strawberry yogurts with the highest liked sample having high intensity ratings for the fruity and sweetness characteristics and low intensity ratings for the plain yogurt descriptors (Figure 7).

Yogurt samples were overlaid on the PC plots of the descriptive panel descriptors, and these samples appeared widely distributed around the yogurt descriptors. Relating this analysis to overall liking responses from consumers indicated that for strawberry yogurt, the highest liked samples (7-11, 13, 14) were characterized by the PC2 attributes of fruity, jammy strawberry, and cooked milk (Figure 1). Sample 12 had a high overall liking rating, but was also high in PC1 attributes of plain yogurt, sourness, and astringency which was

opposite of the flavor characteristics of the other well liked samples. Sample 12 was also rated as having too much fruit which was the only characteristic that isolated it from other consumer ratings.

Of the lemon yogurts, sample 1 was not liked by consumers and was characterized by the plain yogurt terms responsible for PC2 (Figure 2). The other five samples that received the highest consumer acceptance were characterized by sweetness, lemon juice, and overall lemon attributes (PC1). This finding was consistent with the results of the correlation analysis wherein consumer acceptance was obviously based on the extent of sweetness and fruit flavor characteristics of the product and not based on the plain yogurt base descriptors.

CONCLUSIONS

Consumers were able to distinguish differences between commercial brands of flavored yogurt as expressed by their likes and dislikes. Overall liking was based on the fruit flavor, sweetness, and sourness liking and the sweetness-sourness balance in the samples. Males and females differed in their opinion of the yogurts; thus, when producing a yogurt for a specific market, exploring male and female likes and dislikes may help in the formulation process.

The responses of panelists in this study do not directly enable yogurt processors to readily change formulations; however, use of a trained descriptive panel provides more specific information on the characteristics of yogurt. The trained panel recognized two basic groups of descriptors; those associated with fruity and sweet

character, and those associated with plain yogurt and sourness characteristics. Consumers like samples high in fruity and sweet characters, but dislike samples high in plain yogurt flavor and sourness. If a yogurt processor desires to provide a fruit flavored yogurt that could receive the highest overall liking ratings by consumers, then the yogurt obviously requires an appropriate balance of sweetness and sourness. The flavored yogurt must apparently have sufficient flavor intensity to mask or partially mask the plain yogurt base.

ACKNOWLEDGMENTS

The authors would like to thank all of the hard working and dedicated panelists, and the Western Dairy Foods Research Center for financial support.

PREDICTION OF CONSUMER ACCEPTABILITY OF YOGURT BY SENSORY AND ANALYTICAL MEASURES OF SWEETNESS AND SOURNESS

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ABSTRACT

The objective of this study was to determine if predictions of consumer overall liking for yogurt could be made using trained panel ratings of sweetness and sourness and/or analytical measures of sugars and acids. Fourteen strawberry, 12 raspberry, 6 lemon and 17 plain commercial pre-stirred yogurts were evaluated for sweetness and sourness intensity by a trained panel (11 panelists), and for overall liking by a consumer panel (90 to 182 panelists). Titratable acidity and pH were measured for all samples, while sugars by HPLC were measured only for the flavored yogurts. Consumer overall liking was significantly correlated with sweetness intensity, sweetness:sourness ratio, and the summed impact of sweetness and sourness for strawberry and raspberry yogurt. No correlations between analytical measures and overall liking were found for any of the yogurts. A sweetness:sourness ratio greater than 1.0 for strawberry, and greater than .8 for raspberry and lemon appeared necessary for high consumer acceptance. Generally, it was found that the sweeter the yogurt, the higher the acceptance of fruit flavored yogurt by consumers. No relationships were found for any sensory and analytical measures for predicting the overall liking of plain yogurt. The best predictors of consumer liking of fruit flavored yogurt were the descriptive panel ratings.

INTRODUCTION

Consumption of yogurt in the United States has been increasing over the past number of years (Milk Industry Foundation, 1989). A contribution to this recent product success has been interest in yogurt as a low calorie quick meal or snack as well as an assumption of provided health benefits, including improved intestinal health (Shahani, 1976) and an alternative dairy food for lactose malabsorbers (Martini et al. 1987, Savaiano et al. 1984). For this past year, however, this trend has not held; in fact, consumption has decreased approximately 12% (Sandra Wood, Milk Industry Foundation, Personal communication). To help reverse this sales decline, industry marketers need to seek ways to optimize the market potential for yogurt (Cooke, 1986), or develop programs for expanding the market for cultured dairy foods (Dryer, 1980).

Product quality and consumer satisfaction are paramount for increasing the sales of various types of yogurt products. Some investigators have addressed the question of consumer satisfaction of yogurt by focusing on the effect of specific sensory attributes such as sweetness (McGregor et al., 1986) or texture (Modler 1983, O'Neil 1979). Plain yogurt, by virtue of the lactic acid produced during fermentation, is predominantly sour. For U.S. consumers, the relatively high extent of sourness along with the intensity of acetaldehyde (the key volatile compound of yogurt) have resulted in low consumer acceptance. To enhance acceptance, especially among young people, fruit, flavorings and sweeteners have been added to either improve the flavor balance (Kagen, 1985), or partially mask

the acetaldehyde flavor characteristic (Bills et al., 1972). Currently, many flavored yogurts exhibit marked sweetness with little or no sourness. Previous yogurt studies have reported that consumer acceptance was adversely affected by the products being either too sweet (Greig et al., 1985), or not sweet enough and too sour (Lindsay et al. 1981, Harper et al. 1990, Barnes et al. 1990). Very few studies have addressed the question of consumer acceptance of flavored yogurt as related to sweetness and sourness.

The objectives of this study were: to determine how sensory attributes of sweetness and sourness relate to consumer overall liking, to determine if analytical measures of pH, titratable acidity and/or total sugars by HPLC relate to consumer overall liking, and to determine if sensory characteristics of sweetness and sourness of yogurt can be measured analytically.

METHODS AND MATERIALS

Samples

Plain flavor and three different fruit flavors of commercial yogurt that were readily available in the Corvallis, OR market place were purchased from retail outlets and evaluated. These included 17 plain, 14 strawberry, 12 raspberry, and 6 lemon yogurts which consisted of different brands for each given flavor. Because of the large number of samples tested it was not feasible to obtain samples with the same expiration dates. However, samples were chosen on the basis of the latest expiration date from the various product lots

on the store shelf; ranging from 7 days to 28 days. All container samples of each selected brand were from the same lot. Samples were obtained no more than three days prior to sensory testing. Container contents were blended (20 folds) in a large container to ensure product consistency. After mixing, the samples were stored in 2.3 kg. new polypropylene dairy product containers at 1.5°C.

Consumer Panel

Consumers were screened for age and yogurt consumption. Panelists were all at least 10 years of age and consumed either plain or fruit flavored yogurt at least once a month, depending on which yogurt type was being evaluated.

Testing was conducted at the August, 1989 Benton County (OR) Fair. Consumers evaluated 2 samples while seated in portable booths. The consumer panelists were served 40 ml of sample at 3.3°C in 60 ml odorless plastic cups. By using a 9-pt. hedonic scale (1=dislike extremely, 5=neither like nor dislike, 9=like extremely), consumers rated overall liking, sweetness and sourness liking of the presented yogurts. A randomized, balanced incomplete block design was utilized (Cochran and Cox, 1957) which yielded 16 observations per sample for plain, 26 for strawberry, 24 for raspberry, and 30 for lemon yogurts. A total of 136, 182, 156, and 90 consumers evaluated plain, strawberry, raspberry and lemon yogurts, respectively.

Descriptive Panel

Eleven volunteer students and staff from Oregon State University (Corvallis, OR) participated in training and evaluation of the yogurts (one panelist withdrew during the plain yogurt test). Twenty-six training sessions were conducted throughout a complete descriptive analysis study. Panelists were provided with references for sweetness, 0.5% w/v sucrose (C & H, Concord, CA) in spring water (Aqua-Cool, Portland, OR), and sourness, 0.28% v/v 50% food grade lactic acid (Sterling Chemical Co., Texas City, TX) in spring water. These two reference standards were pre-determined by the panelists to be equivalent to 7 on the 16-pt. intensity scale (0=none, 7=moderate, 15=extreme) used for testing.

Testing was conducted at the Sensory Science Laboratory at Oregon State University (Corvallis, OR) in individual booths under red lighting to mask any color differences. Spring water was provided for rinsing between samples. Serving temperature and sample size were the same as for the consumer panel evaluations.

A randomized balanced complete block design was utilized (Cochran and Cox, 1957) which resulted in three replications for lemon yogurt, and two for plain, strawberry, and raspberry. A replication for lemon required only one day of testing while two days were required for the other yogurt products. Presentation of samples was divided into 2 sets in the case of lemon, strawberry and raspberry, and 3 sets for plain with each set consisting of either 3 or 4 samples. Samples were counterbalanced throughout testing.

A sweetness:sourness (sw:so) ratio (Ennis et al. 1979, Perng 1988) was constructed to provide a measure of the balance of

perceived sweetness and sourness in the tested yogurts. A ratio greater than 1.0 serves to indicate greater perceived sweetness than sourness, while a sw:so ratio less than 1.0 implies more perceived sourness than sweetness.

Analytical Measurements

Titratable acidity and pH were measured at 22°C using the standard methods for the examination of dairy products (Richardson, 1985). The pH meter was a Corning 125 with a Sensorex epoxy body sealed reference combination electrode (S200C). Buffers of pH 3 and 9 (Microessential Laboratory, Brooklyn, NY) were used for calibration of the pH meter, and .10 N Sodium hydroxide (J.T. Baker Inc., Phillipsburg, NJ) was used for the titration analyses.

Analysis of sugars in the fruit flavored yogurts was conducted using a Model 5000 high performance liquid chromatography (HPLC) instrument with a refractive index detector (Varian, Sunnyvale, CA). An Econosphere NH_2 column (Alltech Associates, Deerfield, IL), 4.6 x 250 mm, with 5 μm particles was used, preceded by a CN guard column insert (Millipore Corp., Milford, MA). The mobile phase was 70% acetonitrile in water with a flow rate of 1 ml/min. Injection volume was 50 μl, and run time was 12 minutes at ambient temperature. The chromatogram was recorded and the peak area computed with an LCI-100 computing integrator (Perkin-Elmer Corp., Norwalk, CT).

Sample preparation consisted of accurately weighing ca. 1 g of yogurt into a screw top test tube then diluting the contents with 3 ml distilled water and vortexing. Acetonitrile (8 ml) was added, and the

solution was vortexed a second time and allowed to stand for 10 minutes. This solution was centrifuged for 10 minutes at medium speed on a desktop centrifuge. The supernatant was filtered through a .45 μm filter and placed in sealed autosampler vials.

Individual standards of glucose, fructose, sucrose and lactose were prepared at 1.0000 g/10 ml. distilled water. These were diluted and combined to appropriate concentrations, and made up to a final acetonitrile concentration of 70%.

Studies have indicated that different sweeteners have varying perceived sweetness values (Inglett, 1981). With this in mind, summation of the quantity of each component sugar (sucrose, fructose, lactose, glucose and galactose) multiplied by its relative sweetness value (Inglett, 1981) for each of the flavored yogurt samples was calculated and compared to consumer overall liking. The equation used to determine this value for each sample was:

relative sweetness summation = 1.0(sucrose) + 1.1(fructose) + 0.4(lactose) + 0.7(glucose) + 0.6(galactose)

Statistical Analysis

Correlation analysis was conducted using a SAS statistical package (SAS Institute Inc., Cary, NC). Statistical significance was accepted if the p-value was less than or equal to .05.

RESULTS AND DISCUSSION

Descriptive Analysis Panel vs. Consumer Panel

The first part of this study examined sweetness, sourness, and the sweetness:sourness (sw:so) ratio provided by the trained descriptive panel in comparison to the consumer panel overall liking responses. Fruit flavored yogurt is typically expected to be somewhat sweet; therefore, it was not surprising to find significant ($p \leq .01$) correlations between sweetness and consumer overall liking (Figure 8) for raspberry and strawberry yogurts. As the sweetness intensity of the flavored yogurts increased, consumer overall liking also increased in a linear manner. However, a curvilinear fit, as shown in Figure 8, better describes (at a higher significance level) the relationship of sweetness and overall liking for the raspberry yogurts. An apparent optimal sweetness intensity was observed which corresponded to the highest liked samples for the raspberry flavored yogurts. Moskowitz (1983) graphically described this type of curvilinear relationship which showed an optimal response level. These results also concur with the work of McGregor and White (1986) which indicated that the highest liking scores for flavor in yogurt corresponded with a specific sucrose level, while sucrose concentrations above or below that level decreased liking scores. The

lemon yogurt results, which exhibited a high correlation coefficient for a curvilinear fit, were not significant (p=.07) due to the limited number of samples tested. In the case of plain yogurt, some degree of sweetness was perceived but was not expected to play an important role. This in fact was the case; sweetness intensity showed no significant correlation (r= .18) to overall liking.

There was no significant correlation of overall liking with sourness for plain or fruit flavored yogurt. This was not surprising for the fruit flavored yogurts since they are not usually described as predominantly sour. It was surprising, however, not to find this relationship for plain yogurt with its characteristic sour quality.

For the strawberry and raspberry yogurts, a significant ($p \leq .05$) correlation of the sw:so ratio with overall liking was found (Figure 9). Strawberry yogurts were best described by a linear fit. As the sw:so ratio increased, overall liking also increased showing that the more sweet the yogurt, the higher the consumer acceptability. Strawberry yogurt apparently required a sw:so ratio greater than 1.0 for high consumer acceptance (a liking score of 6.5 or higher corresponding to like slightly-like moderately on the 9-pt. hedonic scale). Raspberry yogurts were best described by a curvilinear fit which is indicative of an optimal sw:so ratio. A sw:so ratio greater than .8 was associated with high consumer acceptance of raspberry yogurt. This lower sw:so ratio (indicating slightly more sour than sweet) may be the result of consumer expectations of raspberry flavor being somewhat more sour. These observations concur with results from a blackberry juice study (Perng, 1988) which indicated that a sw:so ratio slightly less than 1.0 corresponded to the highest

liked juice samples. The curvilinear fit for the raspberry yogurts resulted in an optimal sw:so ratio of 1.6; however, this is probably artificially high due to the uneven distribution of the data along the curve. Plain and lemon yogurts demonstrated no correlation between the sw:so ratio and overall liking.

Sw:so ratios provide some insight into the flavor balance; however, yogurt samples with the same sw:so ratio may vary significantly in overall flavor strength. Two methods were employed in an effort to obtain a measure of overall impact of flavor strength: (1) examining panel ratings of overall intensity, and (2) using a measure of overall impact of sweetness and sourness. Overall intensity did not significantly correlate with consumer overall liking responses; hence, the second method was employed to obtain a measure of overall impact of sweetness and sourness. A summation of sweetness and sourness ratings was established and compared with consumer overall liking. This provided a slightly more significant correlation to overall liking than the sw:so ratio for the flavored yogurts (Figure 10). A linear fit was found to be best for strawberry yogurt within the range of samples tested. The greater the summation of sweetness and sourness ratings, the higher the overall liking by consumers. Raspberry yogurt was best characterized with a highly significant ($p=.0001$) distinctive curvilinear fit, which resulted in an optimal summation value of 16.5 which corresponded to high overall liking ratings. The overall liking for plain and lemon yogurt could not be explained by the summed impact of sweetness and sourness.

A comparison of the sweetness and sourness summation values to the overall intensity ratings did not reveal any significant relationships. This seems to indicate that sweetness and sourness of yogurt, although important to consumer liking, does not furnish a complete explanation of the overall intensity ratings, or the overall flavor intensity rated by the trained panel.

Analytical vs. Consumer Panel

The comparison of consumer overall liking to analytical measures was undertaken to determine if a routine composition measure such as pH or titratable acidity would correlate with liking, and possibly suggest specific yogurt re-formulations to meet certain analytical specifications based on consumer liking observations. However, neither pH nor titratable acidity values significantly correlated with any of the fruit flavored or plain yogurts (Figures 11 & 12). HPLC analysis provided quantitative information on the total sugars in fruit flavored yogurts; however, these results did not correlate significantly with consumers overall liking (Figure 13). Hence, it was not possible to relate the degree of yogurt liking of commercially available samples to the simple analytical measurements tested in this study. This does not imply that on an individual brand basis, a yogurt formulation would not relate to these measures when sugar and acid adjustments are made.

The calculation of the relative sweetness summation indicated that there was no relationship to overall liking in this study. When this relative sweetness summation was correlated with sweetness liking by the consumers, again there was no significant relationship.

Since a calculation of a sw:so ratio generated some valuable information, a calculation of the sugar:acid ratio seemed appropriate. This ratio was constructed by using the total sugars measured by HPLC divided by the titratable acidity value. This ratio, however, did not correlate with overall liking for the fruit flavored yogurts examined in this study.

Analytical vs. Descriptive Panel

The final part of this study was to compare the trained panel responses to the analytical measures. The sw:so ratio provided by the trained panel appeared to be a good measure of consumer overall liking for strawberry and raspberry yogurts; therefore, it was compared with pH, titratable acidity, and the sugar:acid ratio. The sw:so ratio significantly correlated with pH for strawberry, lemon and plain yogurts (Figure 14). For the strawberry yogurt, this basically means that low pH levels, which probably relate to less sweetness, are not desirable, since overall liking correlates positively with the sw:so ratio. This provided a stronger correlation than any of the consumer data/analytical measures comparisons. This was not surprising since trained descriptive panelists normally exhibit less variability in their responses than untrained consumers. The lemon and raspberry yogurts did not exhibit significant correlations in a linear situation; however, lemon was significant ($p=.04$) with a curvilinear fit (Figure 14). Titratable acidity did not correlate with the sw:so ratio for fruit flavored yogurt. Plain yogurt had lower sw:so ratios and a significant ($p=.001$) negative correlation with titratable acidity (Figure 15). High acid levels resulted in lower sw:so ratios.

This relationship seems valid as supported by the sw:so ratios for plain yogurts which were less than 1.0, indicating more sourness than sweetness. In the case of the fruit flavored yogurts, the added fruit flavor base with its fruit and sweeteners increases sweetness intensity and masks sourness, most likely interfering with this relationship. As this ratio decreased, more sourness was perceived and higher acid values were found. The sensory ratio of sw:so compared to the analytical ratio of sugar:acid resulted in a significant ($p \leq .05$) correlation for the fruit flavored yogurts (Figure 16). Yet, the sugar:acid ratio did not relate to overall liking. This analytical measurement of sugars and acids does not appear to directly represent sweetness and sourness as measured by sensory means.

Comparison of sweetness intensity rated by the trained panel to the relative sweetness summation revealed significant correlations for both strawberry and lemon flavored yogurts (Figure 17). Since sweetness intensity was correlated to overall liking in the strawberry yogurt, this model could be used to predict overall liking because of its correlation to sweetness intensity. Relative sweetness summation was not useful for the other yogurts evaluated.

Sourness intensity ratings by the trained panel correlated with titratable acidity and pH. Sourness intensity and titratable acidity correlated for all yogurt flavors (Figure 18) in either a linear or curvilinear response. Sourness intensity was also correlated with pH (Figure 19). Though the best fit is a curvilinear one for strawberry and lemon, usefulness as a predictor is questionable. No apparent practical explanation seems appropriate to the concave nature of these slopes. However, sourness intensity did not correlate to

consumer overall liking; therefore, these analytical measures can only be used to predict the sourness response from the trained panel.

CONCLUSIONS

Consumer panel, trained descriptive panel and analytical measure comparisons for plain yogurt were not significantly correlated except for the relationship of pH and titratable acidity to the sw:so ratio and to sourness intensity. These correlations were not particularly helpful since neither sweetness:sourness ratio nor sourness intensity related to consumer overall liking. Thus, sweetness and sourness relationships cannot be used for predicting consumer preferences for plain yogurt.

In fruit flavored yogurt, overall liking was highly related to sweetness intensity, but not sourness intensity. Consumer overall liking ratings for strawberry, raspberry and lemon flavored yogurt did not relate to any of the analytical measures, but they were correlated either in a linear or curvilinear response with sweetness, the sw:so ratio, and the summed impact of sweetness and sourness. Although the sw:so ratio from sensory and the analytical sugar:acid ratio did relate, this is not useful as an indicator or predictor of consumer liking or a guide for product re-formulations. The only applicable measure of consumer liking seems to be the relationship of the consumer panel responses with the trained descriptive panel ratings.

Since the sweetness in yogurt is derived primarily from the added fruit and flavor base, yogurt producers need to work closely with ingredient suppliers to achieve the most appropriate sweetness for general consumer acceptance. A relatively inexpensive method for determining sweetness and sourness is the use of a small trained descriptive panel. For rating only sweetness and sourness minimal training and testing would be required.

Other flavor factors as well as texture also need to be considered in the delicate balance affecting overall acceptability. Sweetness and sourness are, however, primary factors that influence of consumer overall liking.

ACKNOWLEDGMENTS

The authors would like to thank Bob Durst for analyzing the sugars in yogurt by HPLC, all of the hard working and dedicated panelists for their time, and the Western Dairy Foods Research Center for financial support.

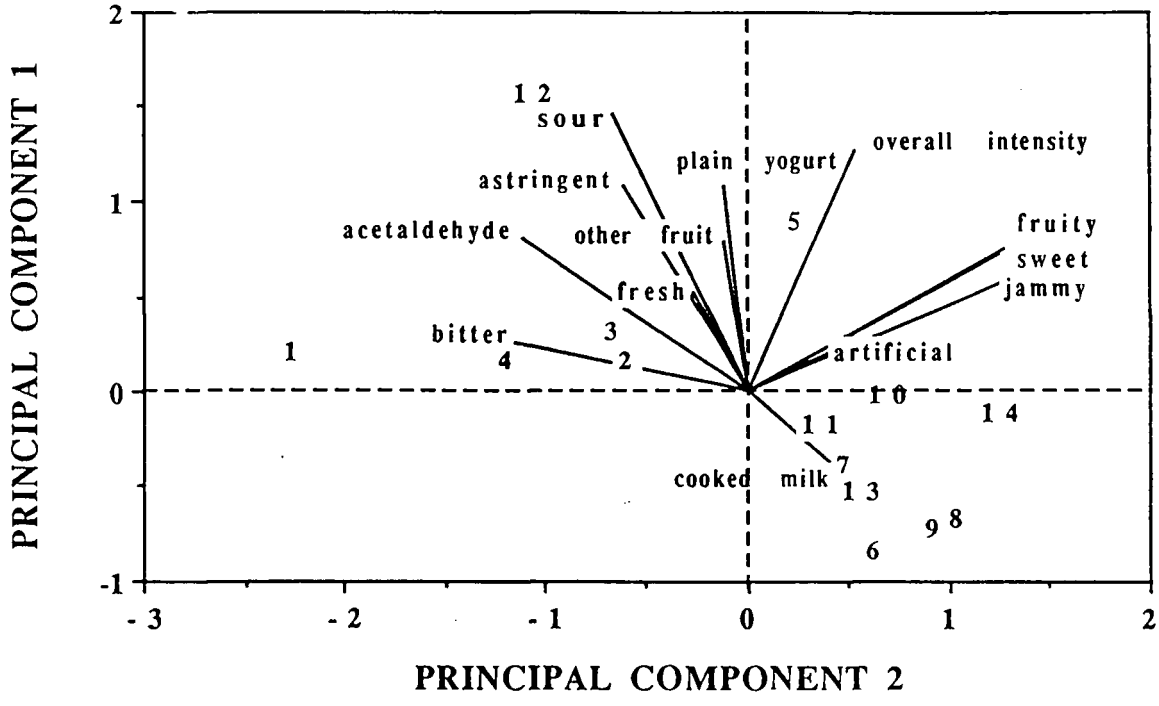

Figure 1. Principal component plot of trained panel descriptors and samples of strawberry yogurt

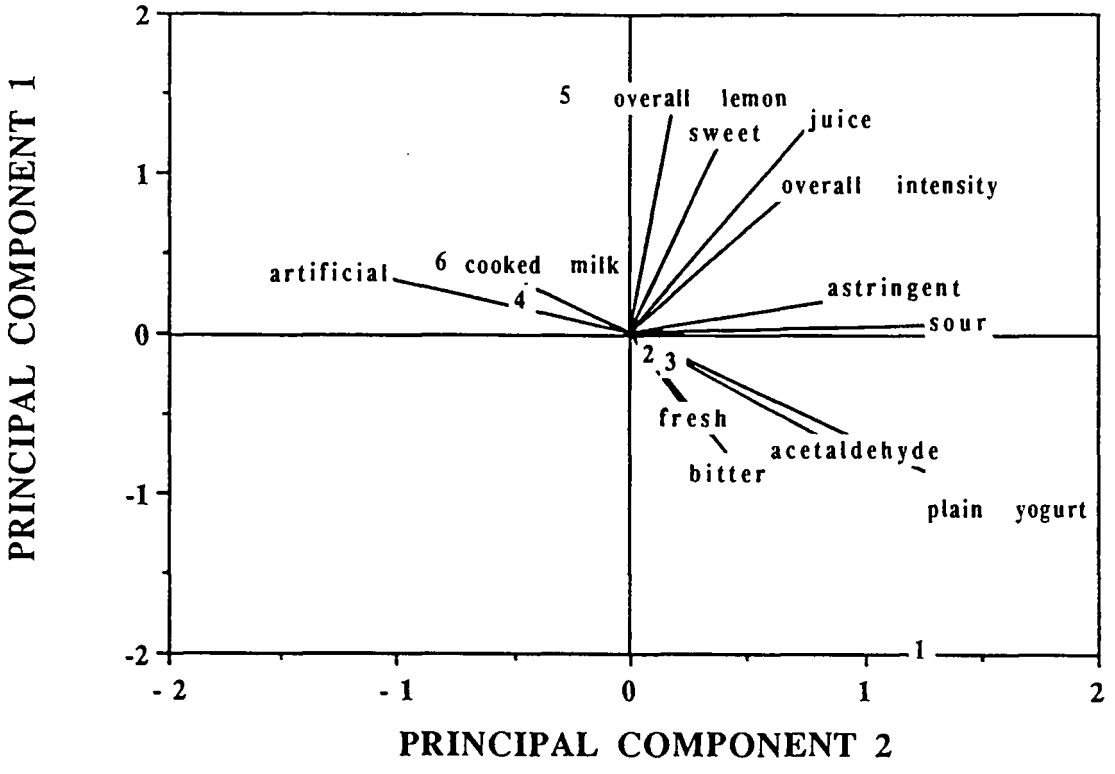

Figure 2. Principal component plot of trained panel descriptors and samples of lemon yogurt

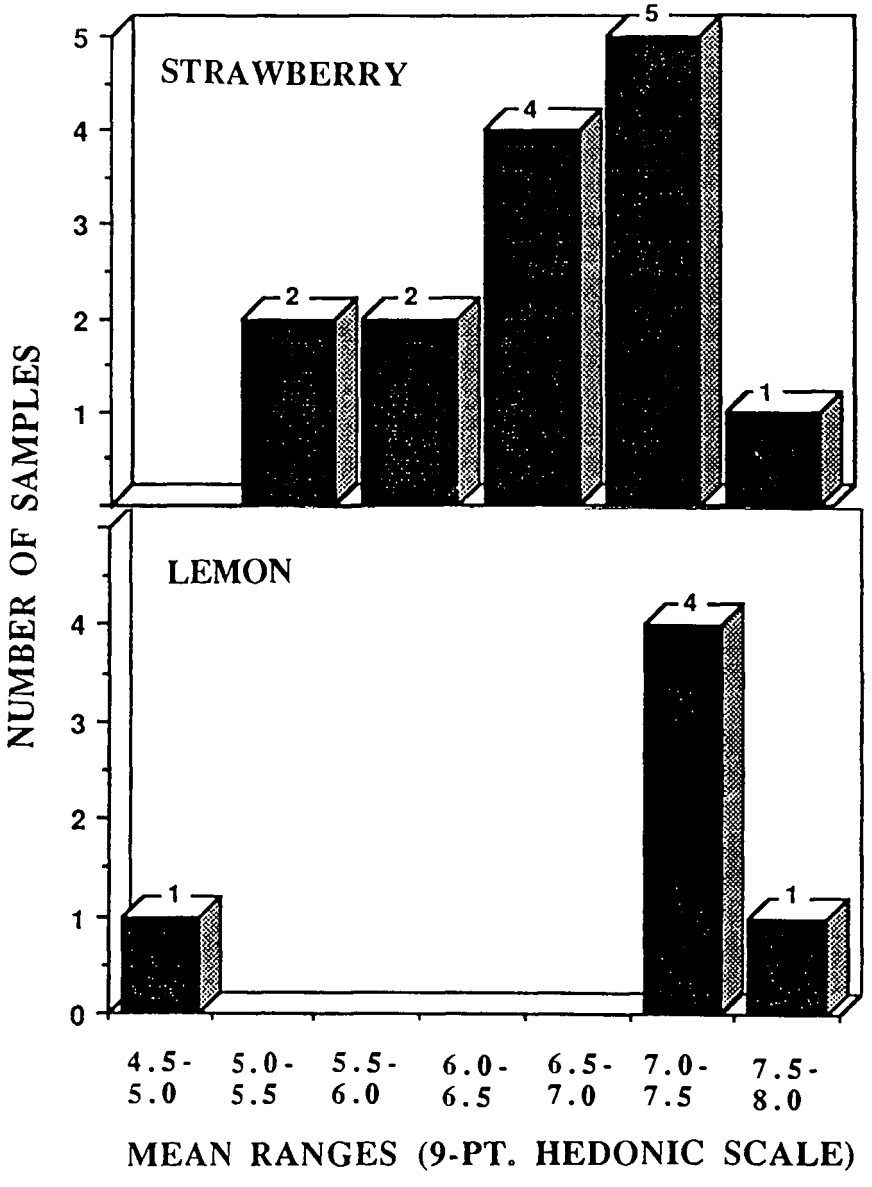

Figure 3. Histograms of mean ranges of overall liking for strawberry and lemon yogurts (9=like extremely, 1=dislike extremely)

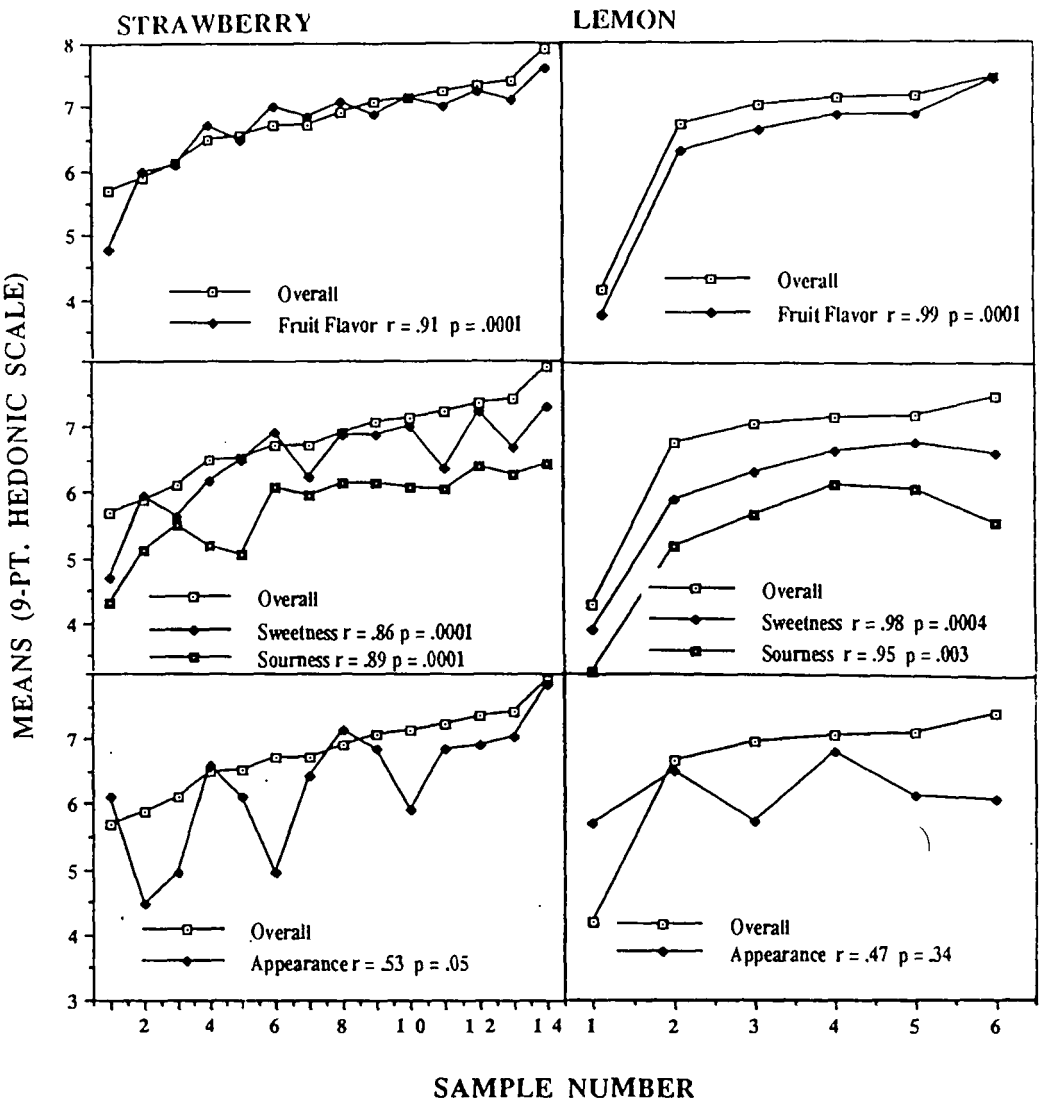

Figure 4. Consumer overall liking ratings compared with fruit flavor, sweetness, sourness and appearance for strawberry and lemon yogurt

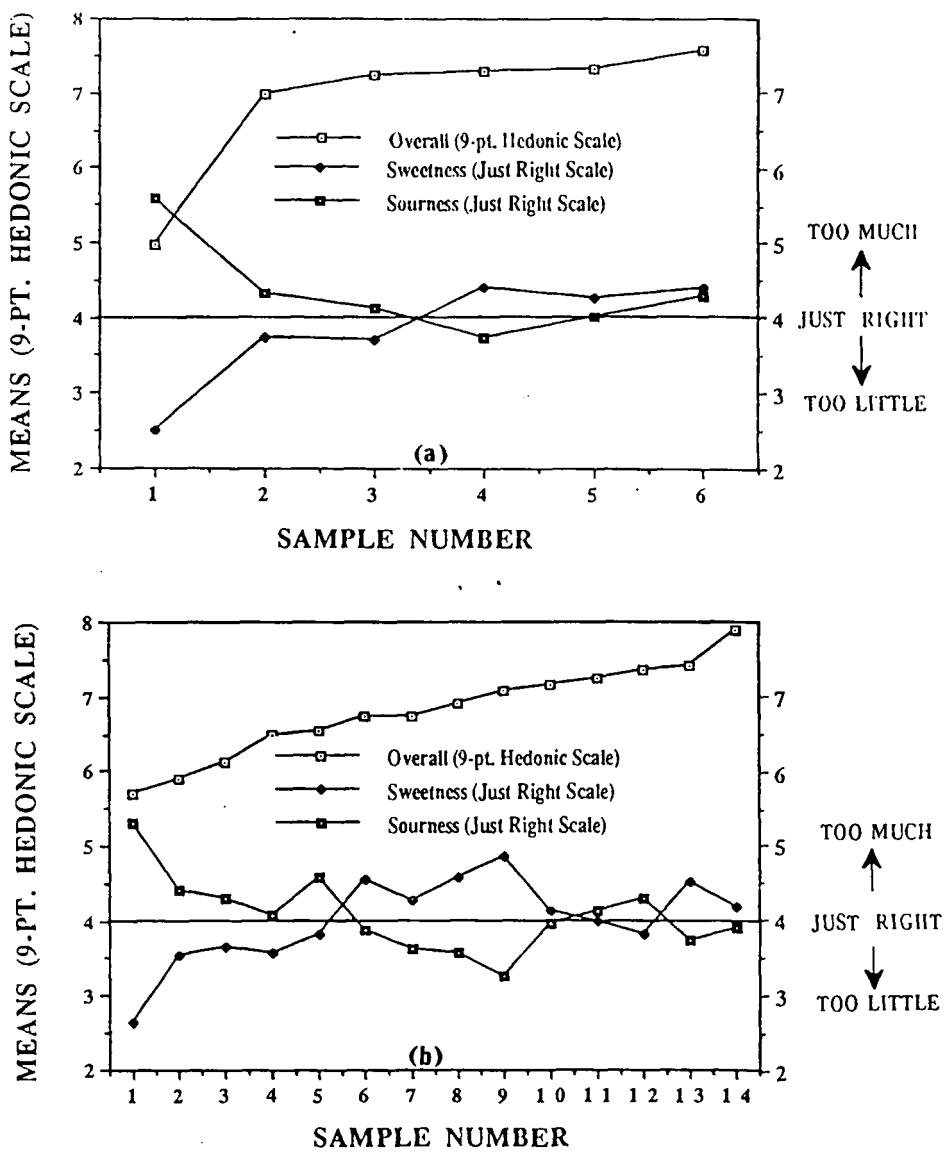

Figure 5. "Just Right" ratings of sweetness and sourness compared with overall liking for a) lemon and b) strawberry yogurts

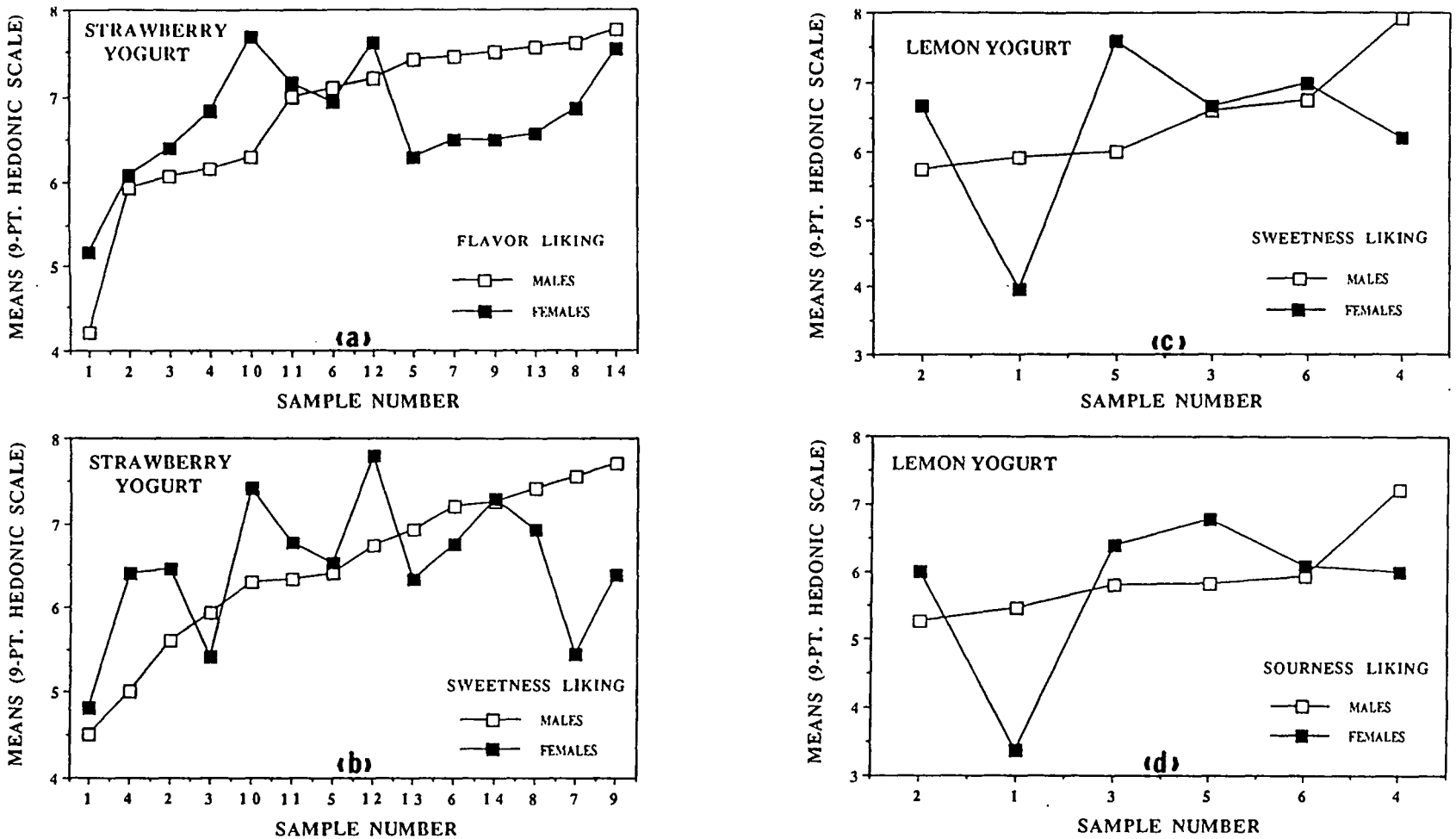

Figure 6. Male and female liking ratings of a) strawberry flavor, b) strawberry yogurt sweetness, c) lemon yogurt sweetness, and d) lemon yogurt sourness

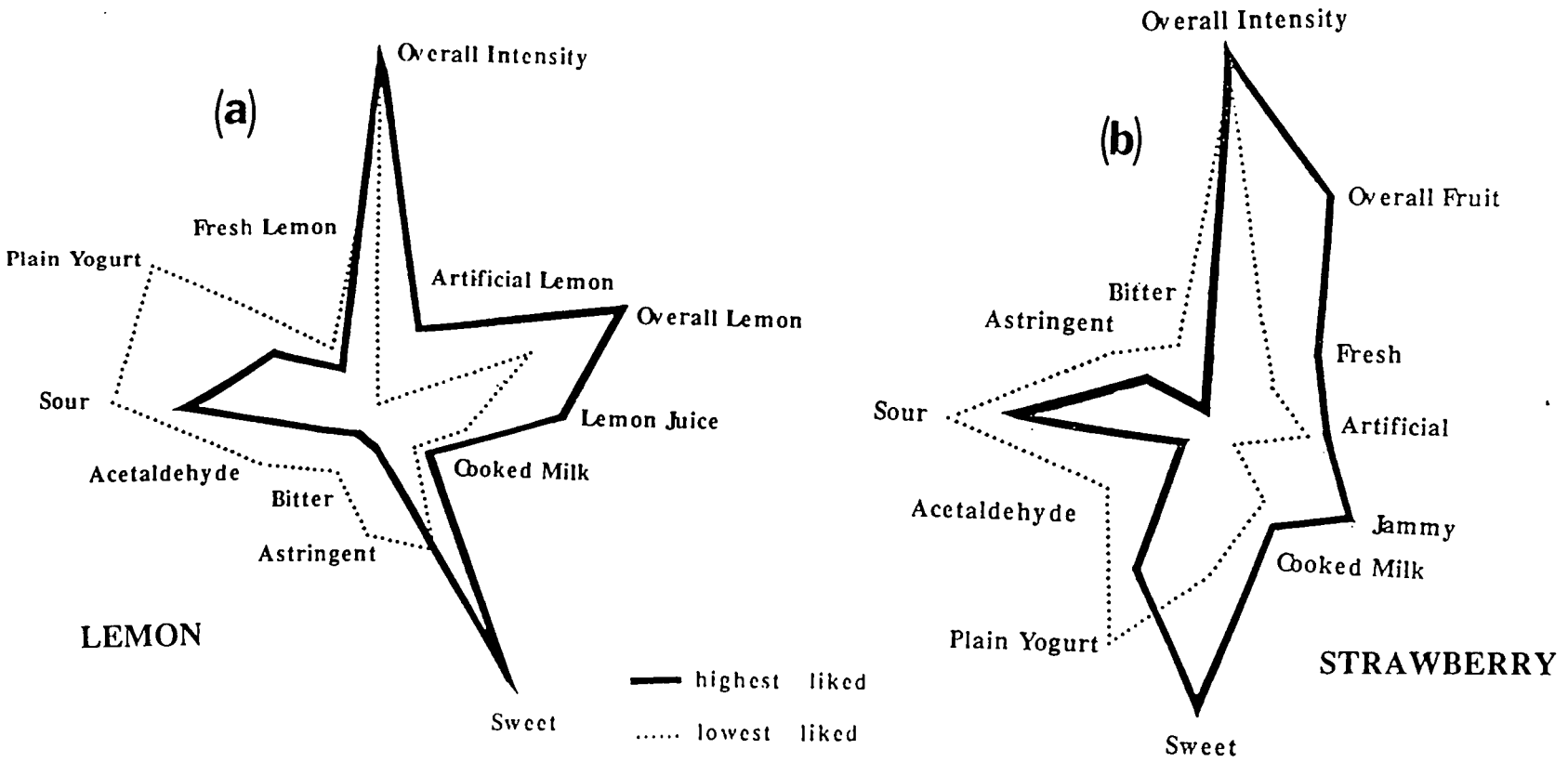

Figure 7. Spider plots of descriptive panel attributes for the highest and lowest liked samples rated by consumers for a) lemon yogurt, and b) strawberry yogurt

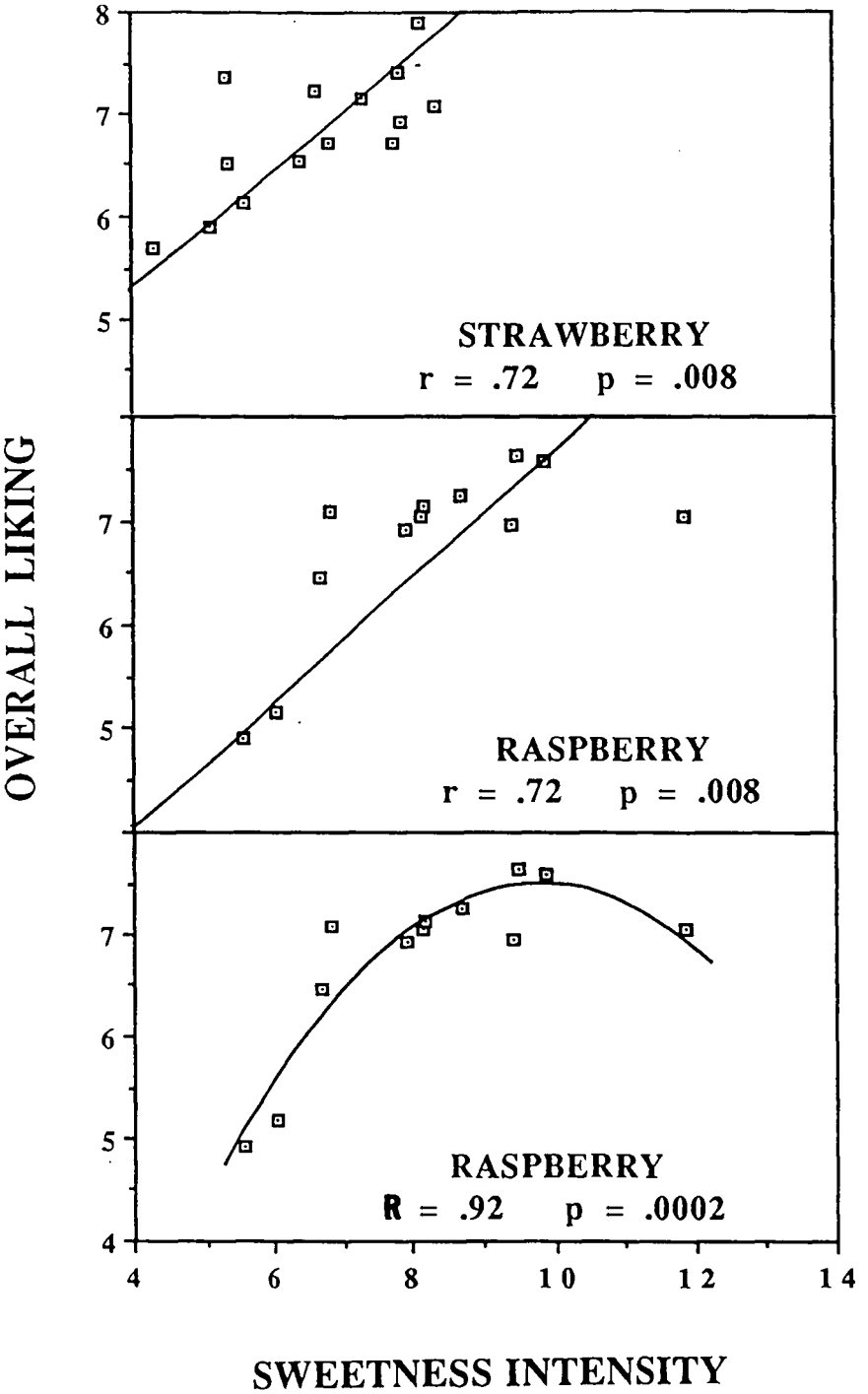

Figure 8. Correlation of consumer overall liking to descriptive panel sweetness intensity for strawberry and raspberry yogurts

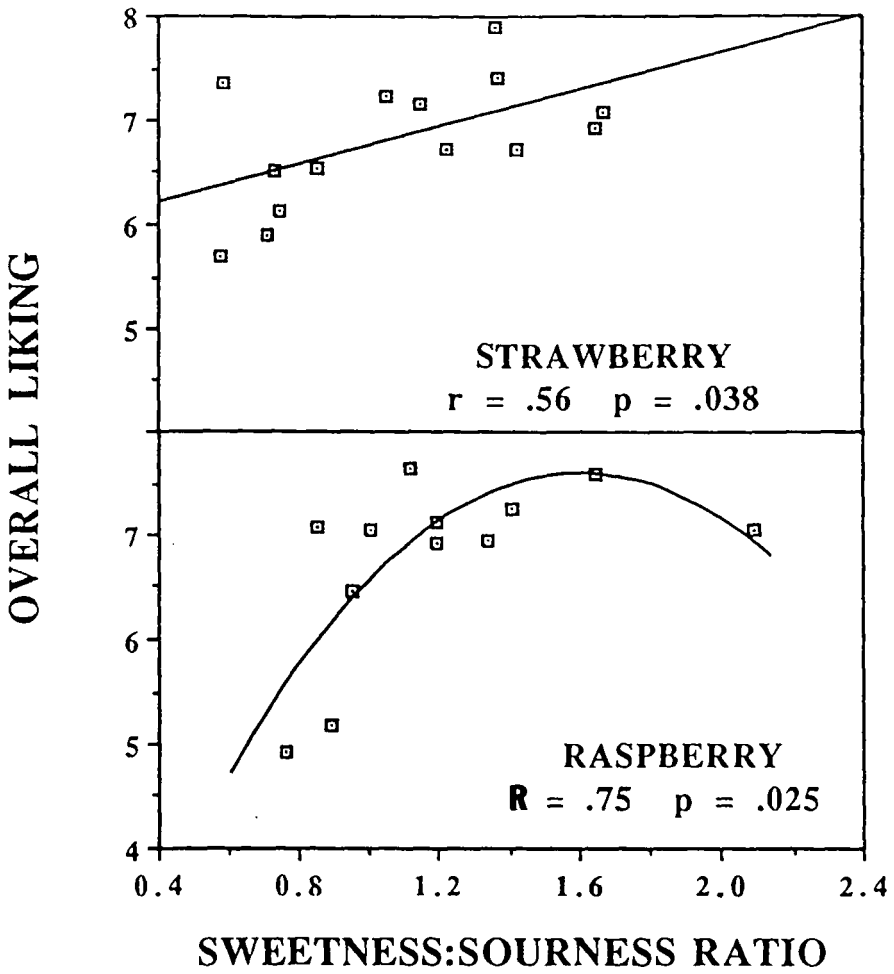

Figure 9. Correlation of consumer overall liking to descriptive panel sweetness:sourness ratio for strawberry and raspberry yogurts

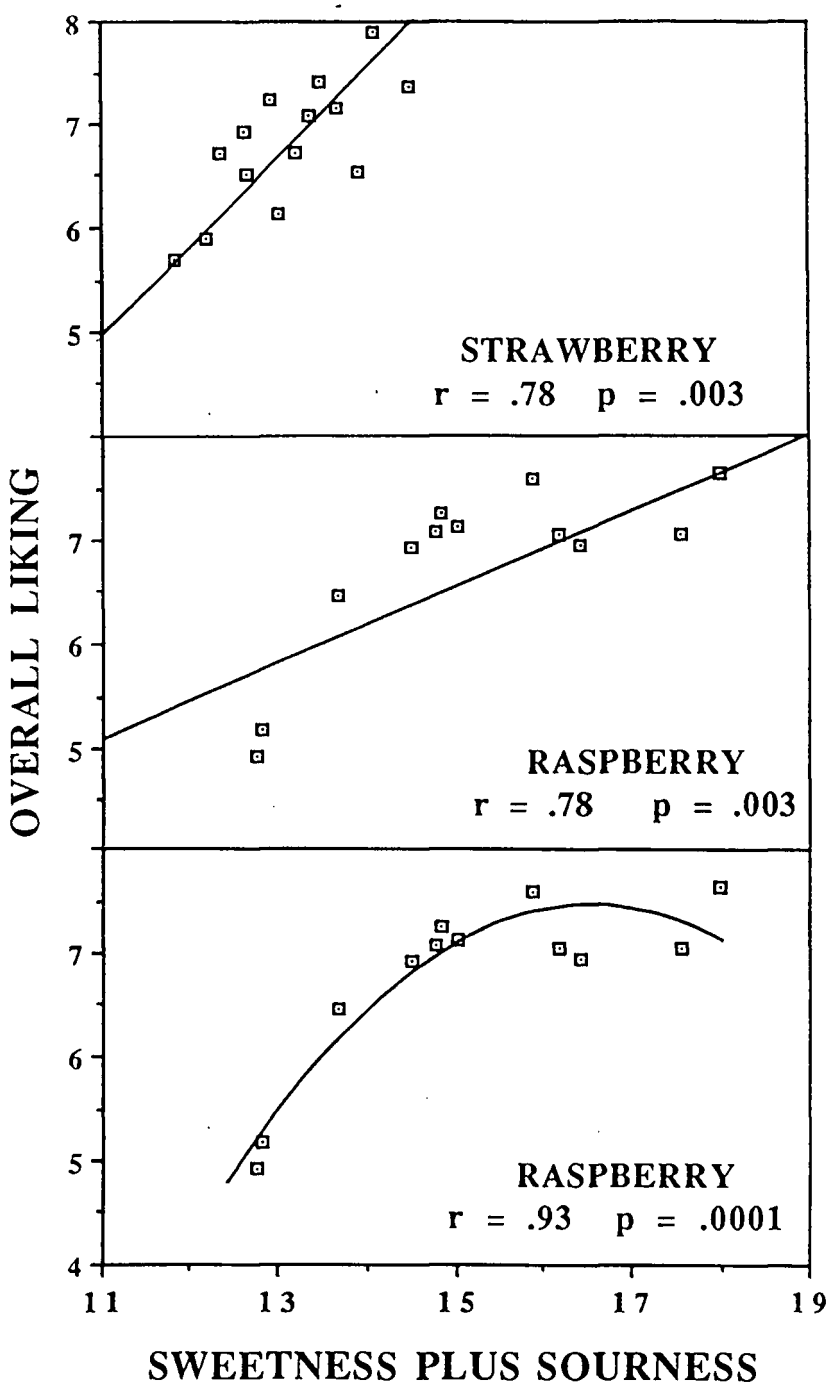

Figure 10. Correlation of consumer overall liking to descriptive panel sweetness plus sourness summation for strawberry and raspberry yogurts

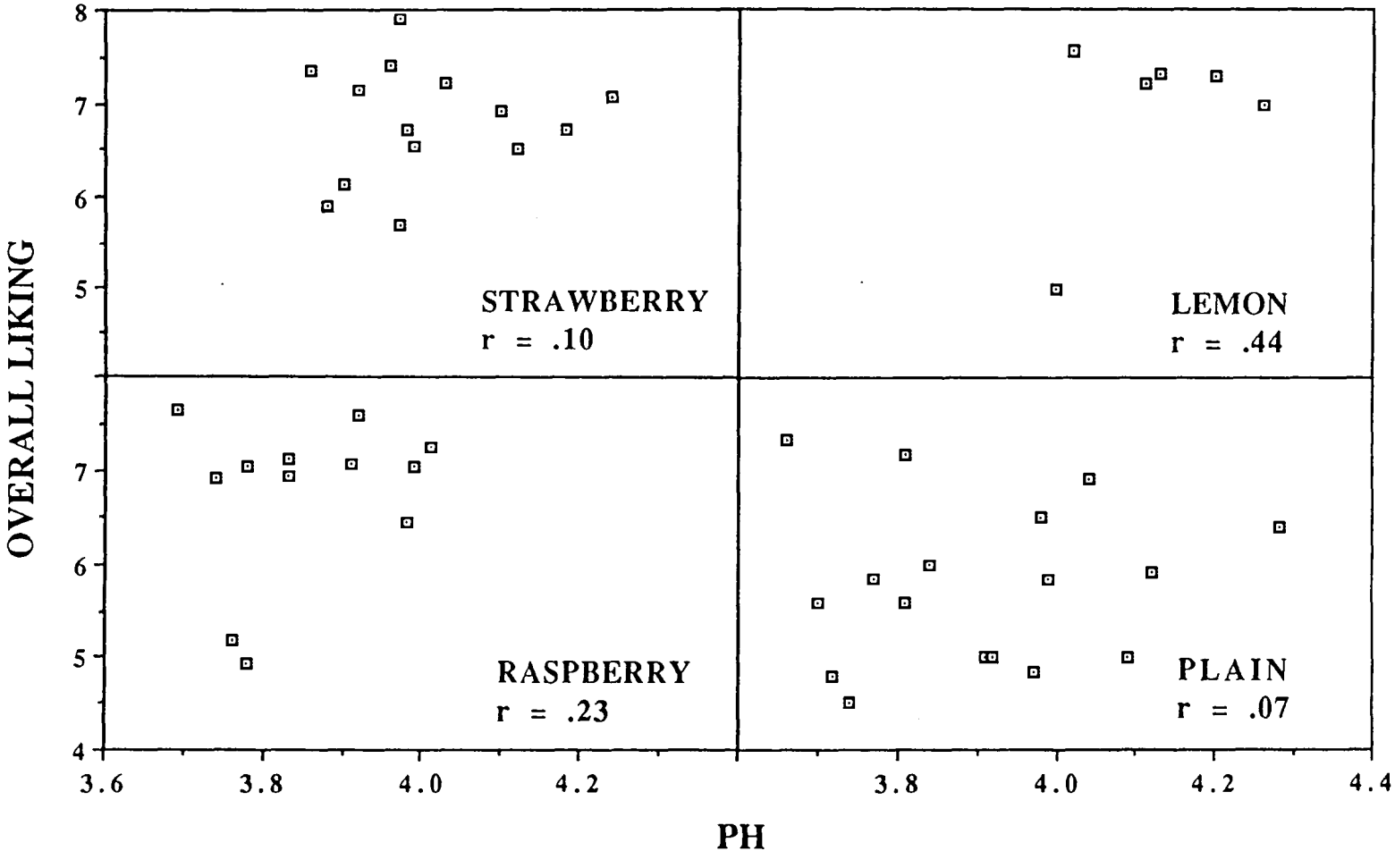

Figure 11. Correlation of consumer overall liking to pH for strawberry, raspberry, lemon, and plain yogurts

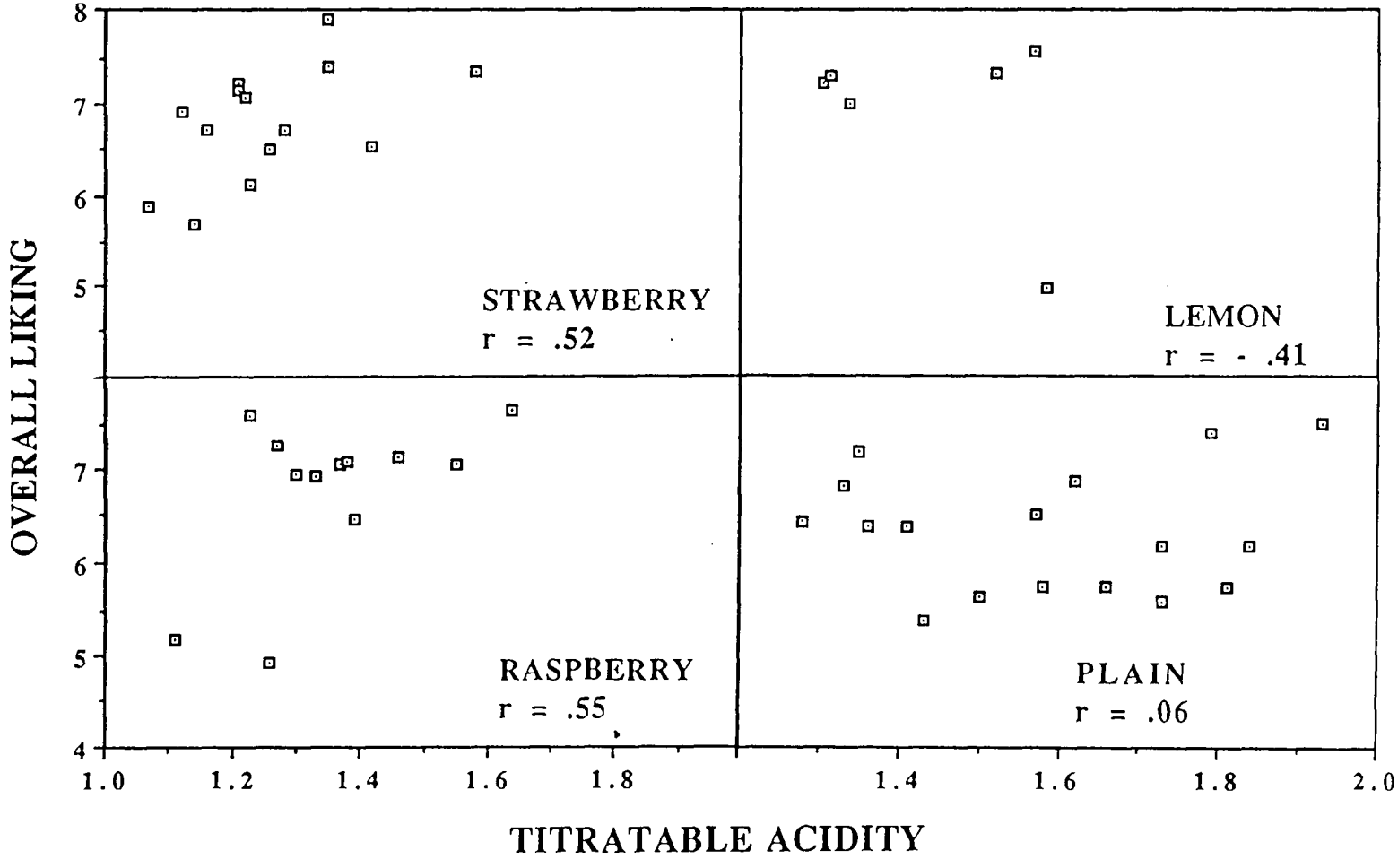

Figure 12. Correlation of consumer overall liking to titratable acidity for strawberry, raspberry, lemon, and plain yogurts

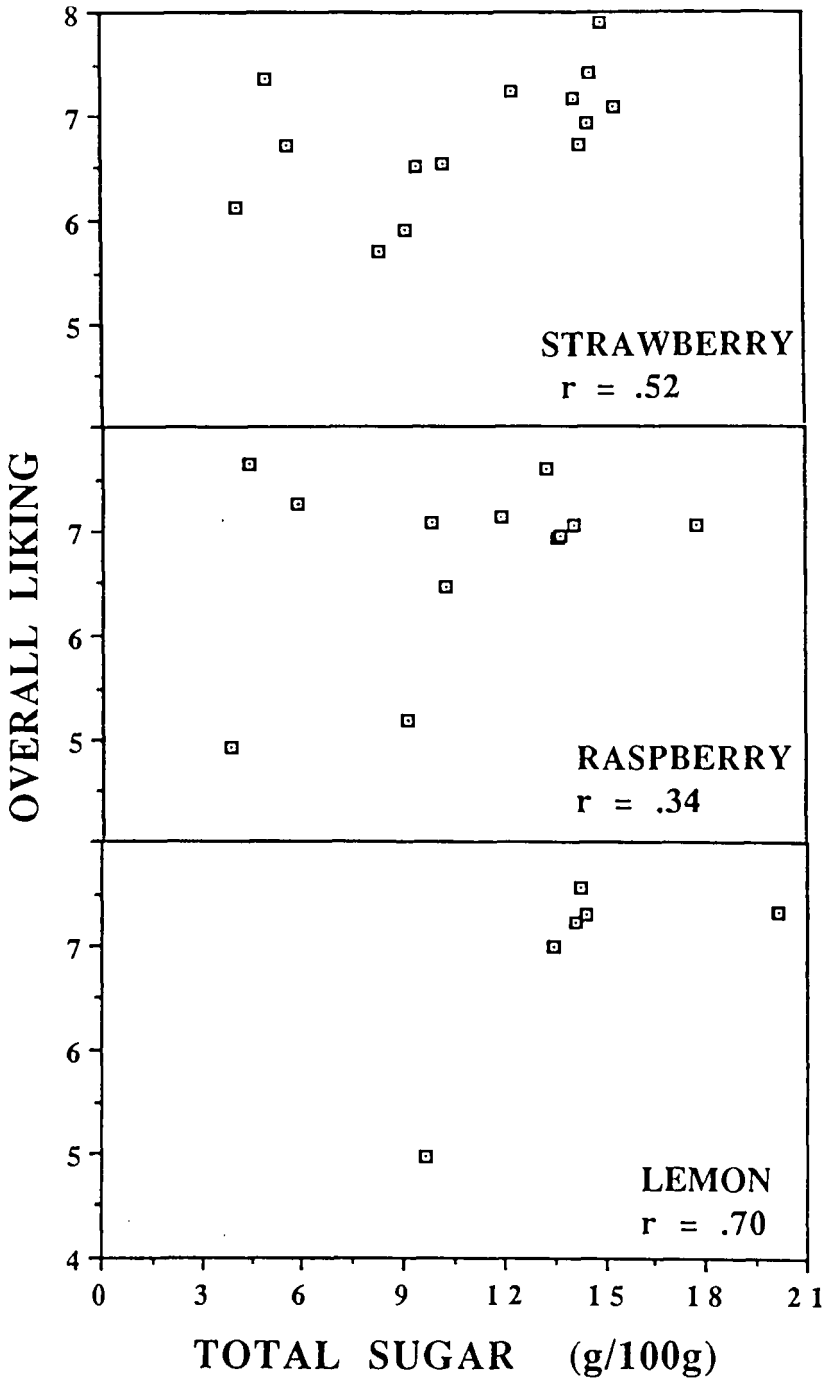

Figure 13. Correlation of consumer overall liking to HPLC sugar analysis of strawberry, raspberry, and lemon yogurts

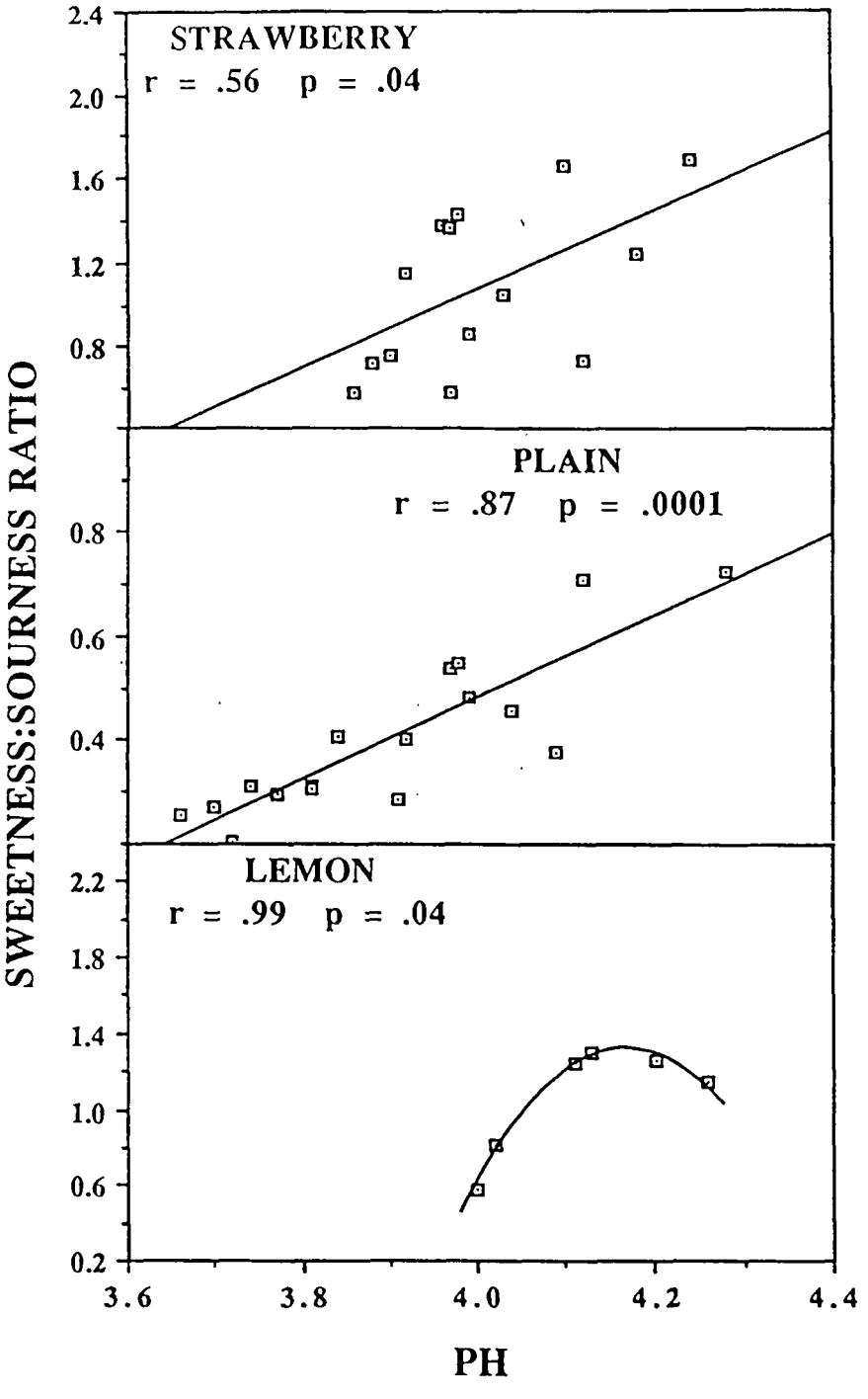

Figure 14. Correlation of descriptive panel sweetness:sourness ratio to pH for strawberry, plain, and lemon yogurts

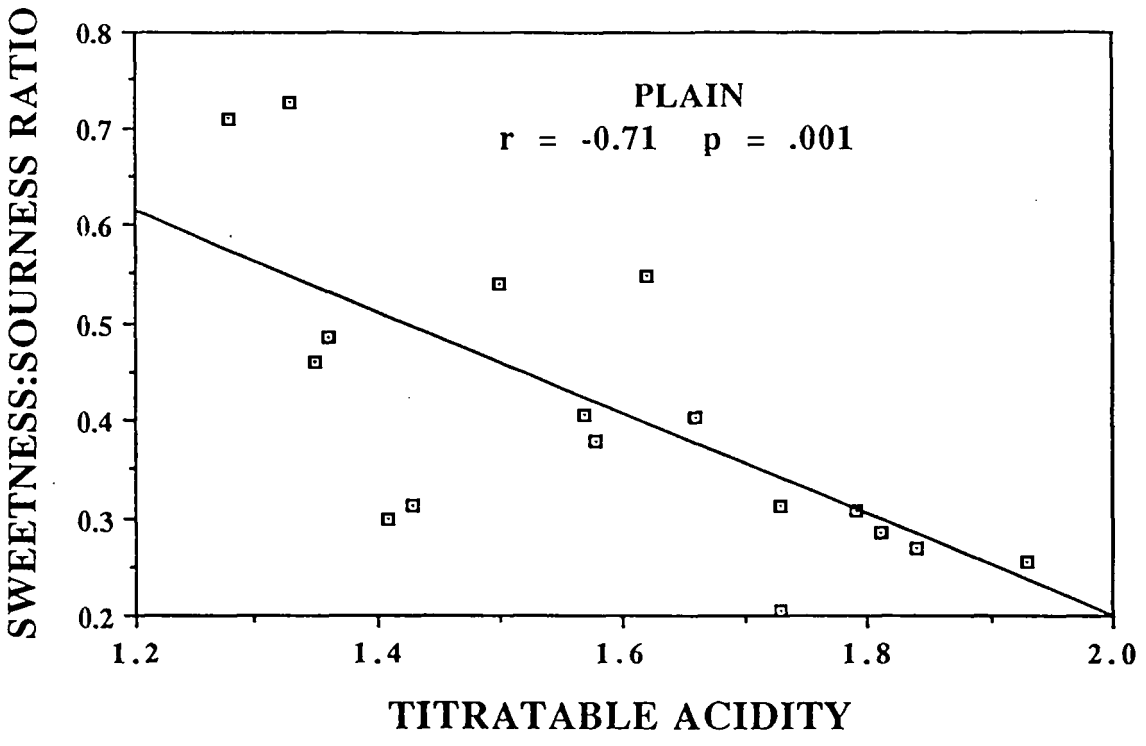

Figure 15. Correlation of descriptive panel sweetness:sourness ratio to titratable acidity for plain yogurt

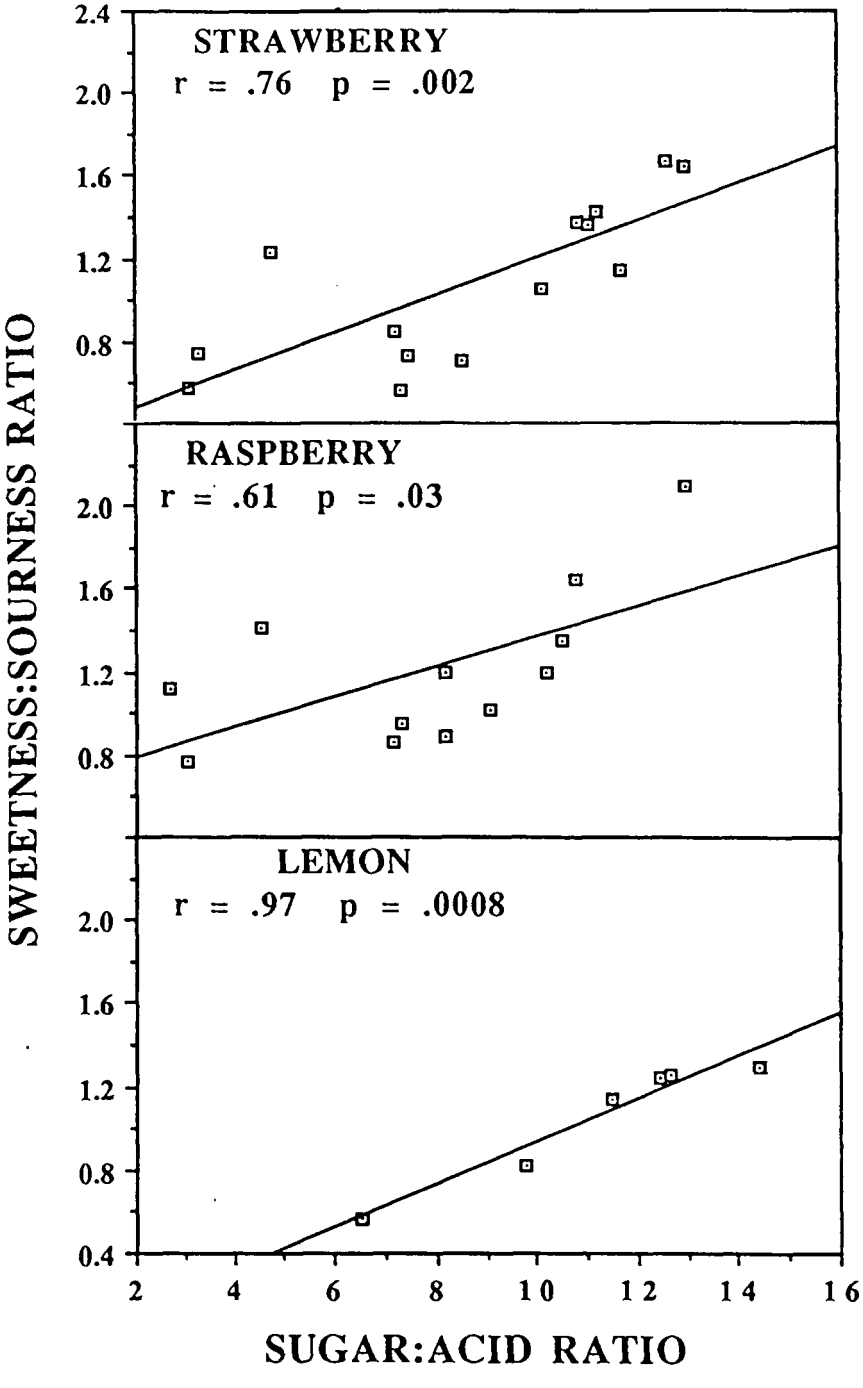

Figure 16. Correlation of descriptive panel sweetness:sourness ratio to analytical sugar:acid ratio for strawberry, raspberry, and lemon yogurts

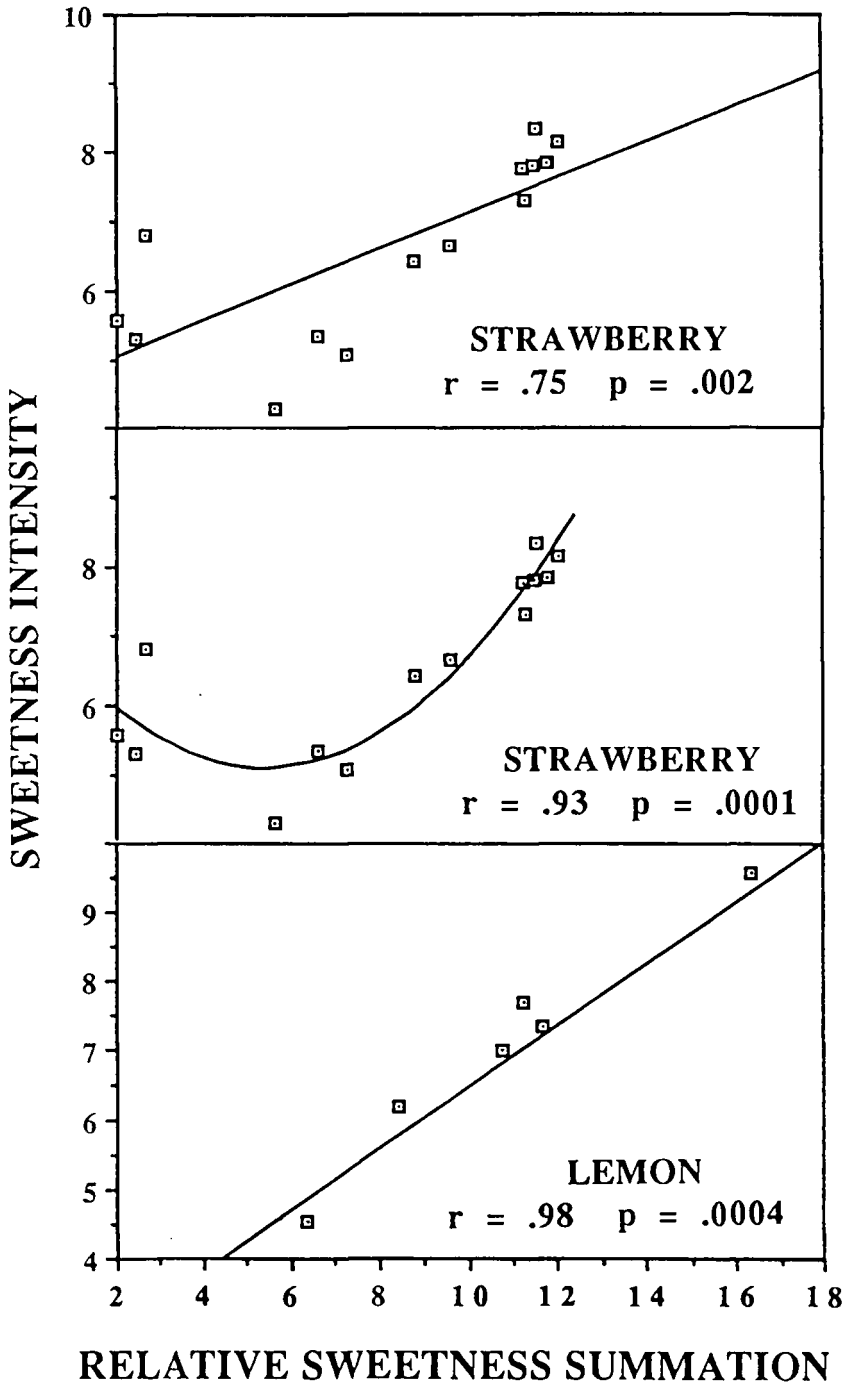

Figure 17. Correlation of descriptive panel sweetness intensity to the relative sweetness summation for strawberry and lemon yogurts

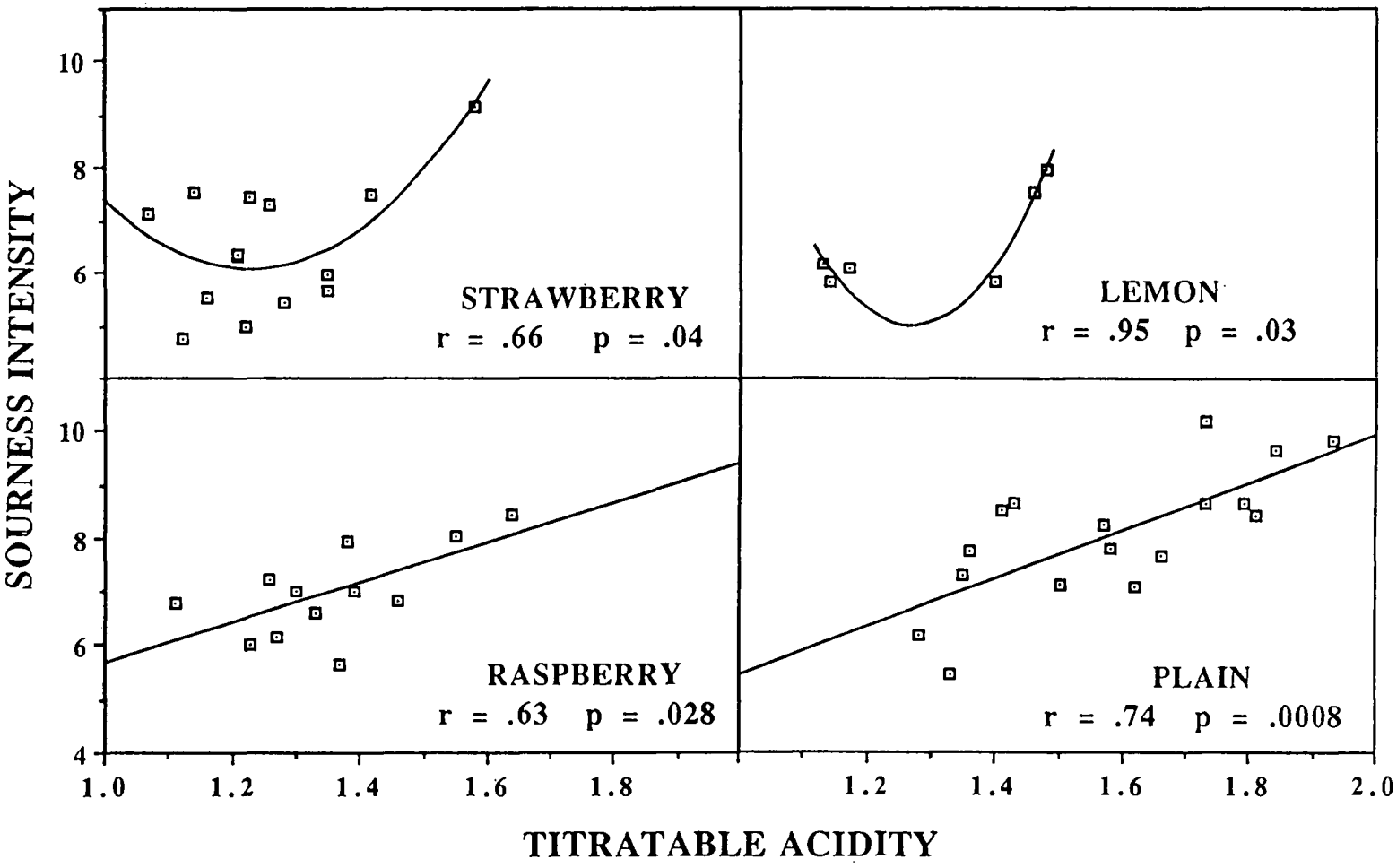

Figure 18. Correlation of descriptive panel sourness intensity to titratable acidity for strawberry, raspberry, lemon, and plain yogurts

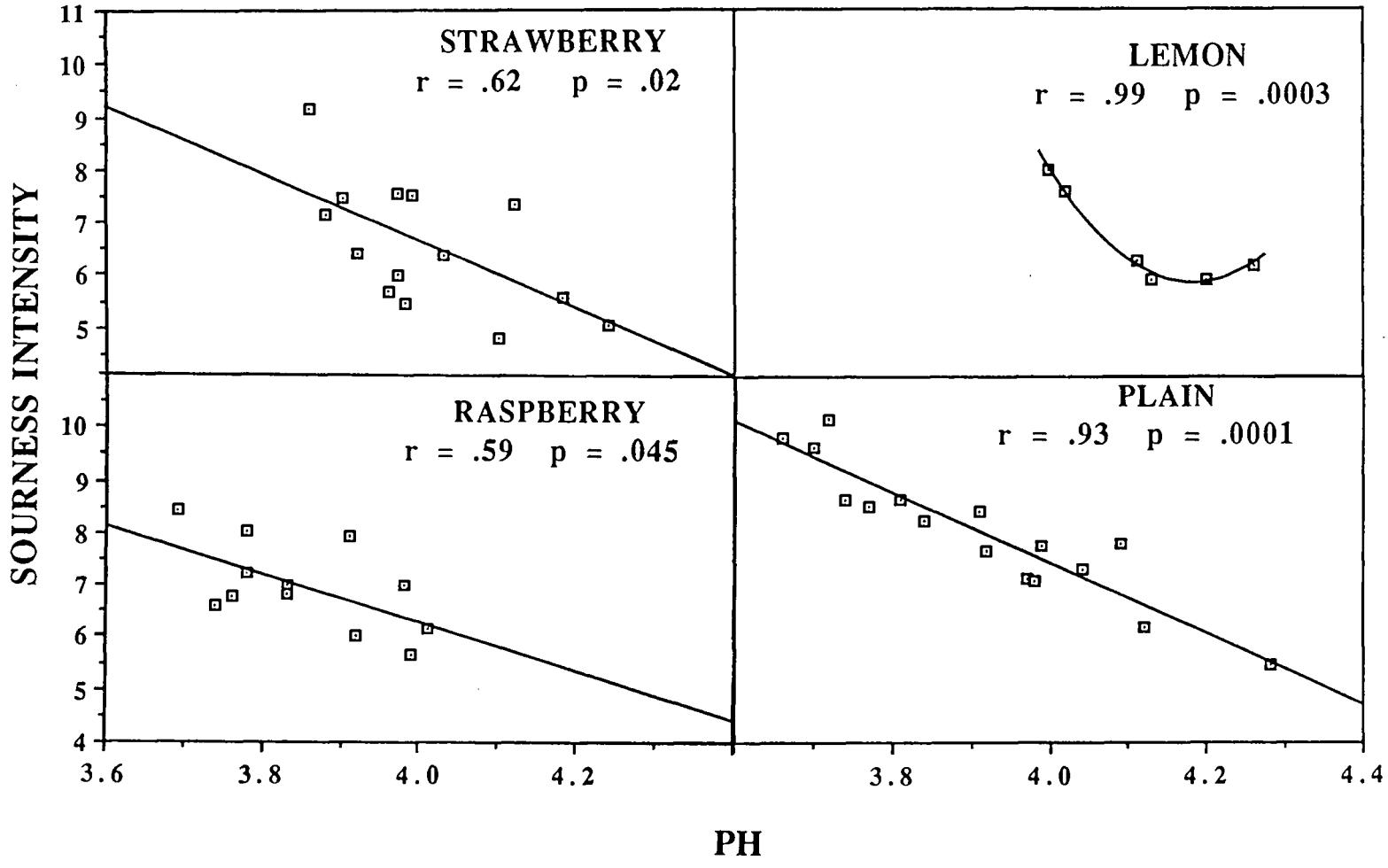

Figure 19. Correlation of descriptive panel sourness intensity to pH for strawberry, raspberry, lemon and plain yogurts

Table 1. Descriptors and reference standards for strawberry and lemon yogurts

	DESCRIPTORS	STANDARDS
	Overall Intensity	
Strawberry descriptors	Overall Fruit	
	Fresh Strawberry	OSU variety #4930 fresh frozen strawberries
	Jammy Strawberry	Strawberry Jam (J.M. Smucker, Orrville, OH)
	Artificial Strawberry	Pre-mixed Strawberry Kool-Aid (Gen. Foods, White Plains, NY)
	Other Fruit	
Lemon descriptors	Overall Lemon	
	Fresh Lemon	Fresh wedge of lemon
	Lemon Juice	Lemon juice (Borden, Columbus, OH)
	Artificial Lemon	Lemon jello (Gen. Foods, White Plains, NY)
Yogurt descriptors	Plain Yogurt	Plain Yogurt (Fred Meyer, Portland, OR)
	Acetaldehyde	.66 ppm acetaldehyde* (IFF, Union Beach, NJ)
	Cooked Milk	2% lowfat milk heated to 92°C then cooled to room temperature
	Sweet	5% solution sucrose*
	Sour	.16% solution Lactic acid* (Sterling Chemical Co., Texas City, TX)
	Astringent	.11% solution alum* (McCormick & Co., Baltimore, MD)
	Bitter	.08% solution caffeine* (Fischer Scientific, Fair Lawn, NJ)

* solution made in spring water (Aqua-Cool, Portland, OR)

Table 2. F-test values and significance for strawberry and lemon yogurt descriptors

Attributes	Strawberry	Lemon
Overall Intensity	2.22*	4.77**
Fruity/Overall Lemon	6.20***	13.85***
Fresh	2.54**	1.00
Jammy/Juice	4.67***	3.26*
Artificial	3.63***	5.05***
Other Fruit	2.11*	NT
Plain Yogurt	7.63***	20.91***
Acetaldehyde	5.05***	7.42***
Cooked Milk	7.27***	1.53
Sweet	18.82***	43.71***
Sour	12.62***	13.39***
Astringent	5.99***	4.17**
Bitter	4.58***	2.73*

*, **, *** indicates significance at the $p \leq .05$, .01, and .001 levels, respectively
NT= not tested

Table 3. Correlation values (and p values) of selected trained panel attributes for lemon and strawberry yogurt

	ATTRIBUTES	plain yogurt	acetaldehyde	astringency	sourness
Lemon Correlations	overall lemon	-.97 (.002)	-.96 (.002)	-.88 (.021)	-.85 (.031)
	lemon juice	-.86 (.027)	-.79 (.056)	-.64 (.171)	-.66 (.141)
	artificial lemon	-.86 (.027)	-.93 (.006)	-.93 (.008)	-.90 (.047)
	sweetness	-.88 (.019)	-.88 (.019)	-.79 (.058)	-.85 (.031)
Strawberry Correlations	jammy	-.69 (.006)	-.81 (.000)	-.46 (.102)	-.56 (.036)
	cooked milk	-.43 (.123)	-.37 (.190)	-.59 (.024)	-.72 (.004)
	sweetness	-.81 (.000)	-.87 (.000)	-.74 (.002)	-.82 (.000)

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