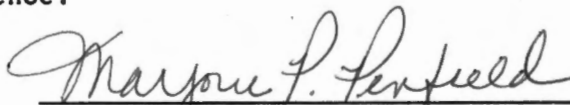
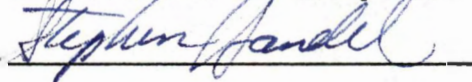


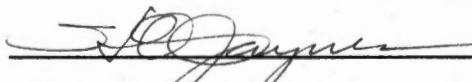
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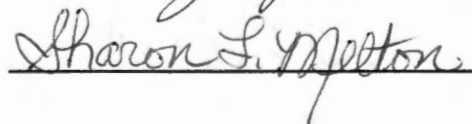
I am submitting herewith a dissertation written by Lisa Yvette Hanger entitled "Solvent and Sample/Rinse Temperature Effects on Sweet and Salty Sensitivity in Sensory Difference Tests." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Food Technology and Science.


Marjorie P. Penfield, Major Professor

We have read this dissertation
and recommend its acceptance:







Accepted for the Council:


Vice Provost
and Dean of The Graduate School

SOLVENT AND SAMPLE/RINSE TEMPERATURE EFFECTS
ON SWEET AND SALTY SENSITIVITY IN
SENSORY DIFFERENCE TESTS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Lisa Yvette Hanger

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Thesis

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DEDICATION

This dissertation is dedicated to Loretta Swanson ("Wanda") .

Fugol, the author's best friend and mother.

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ABSTRACT

The study was undertaken to investigate the effects of sample/rinse temperature combinations and solvent (water or apple juice) on sweet and salty sensitivities of panelists in sensory difference tests. A modified signal detection technique was employed in the experiments. In one experiment apple juice containing sucrose or NaCl was presented at varying sample and water rinse temperature (6° , 24° , 50°C and/or no rinse) combinations. Discrimination abilities of the panelists were measured by R-index values. No temperature effect was found among the sample/rinse temperature combinations in sucrose difference tests. Salty difference tests exhibited a temperature effect. R-index values were higher (greater discrimination) in 24°C samples than in 6° or 50°C ; sample temperature had a greater effect on discrimination than did rinse condition (temperature or no rinse). Panelist variability in both sucrose and NaCl difference tests was attributed to motivation and differential sensitivities to the stimuli.

In the second experiment, panelists' sensitivities to sucrose and NaCl in water and apple juice were monitored across a 200-stimuli test to determine if sensitivity in water indicated sensitivity in a food system. Panelist variability across the 200 stimuli had the greatest effect on the results. Repeated sucrose R-index values indicated equal sensitivity in water and apple juice, although the sucrose concentration was 3 times greater in apple juice than in water. Repeated NaCl R-index values indicated greater sensitivity in water than apple juice; the NaCl concentration was

3.5 times greater in apple juice than in water. Cumulative NaCl R-index values showed 8 of the 10 panelists to have similar sensitivities in water and apple juice, yet variability was greater in apple juice (higher standard deviations) than in water. Cumulative sucrose R-index values showed sensitivity was greater in water than apple juice. It was concluded that sensitivity to sucrose or NaCl in water was not indicative of sensitivity in a food system (apple juice).

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CHAPTER I

INTRODUCTION

Taste perception has intrigued the scientist for some time, yet the sensory analyst is just now entering that world. Much of the work done on the basic tastes has been carried out in water solutions with varied objectives, among which include determination of thresholds, determination of intensity of taste compounds, measuring time/intensity relationships, etc. Investigators in other areas of science may have an entirely different objective for studying taste perception, the sensory analyst must be concerned with taste perception and how it directly relates to sensory evaluation. Very little research in taste perception has been directly related to the work of the sensory analyst in an academic or industrial setting. That is the scope of the study undertaken here, in hopes of "tieving" together past, as well as current, work on taste perception as a direct avenue for improving sensory test sensitivity.

The current study utilized methods that to improve or maximize sensitivity of sensory difference tests. Current work by Michael O'Mahony at California-Davis has focused on sensory test design. He makes use of a modified signal detection technique (Green and Swets, 1974; Brown, 1974; O'Mahony, 1979) to predict sensitivity of triangle and paired comparison tests (O'Mahony and Goldstein, 1986). The majority of O'Mahony's work has centered around salt and water

solutions, but some solid food products have been analyzed by the signal detection technique.

Very little work dealing with the taste primaries has dealt with solvents other than water. It is known that water can take on taste characteristics itself after the taste receptors are exposed to solutions of any of the basic tastes (Price and Desimone, 1977). Thus, it does not seem feasible that results on taste primaries in water solutions would extend to more complex liquid food systems.

Although the water taste occurrence is known, water is currently recommended for use as a rinse in sensory difference tests. It appears that there are no standards for use of water, as tap, once-distilled, double-distilled, or deionized water are often reported for use as mouthrinses in literature. The practice of using a rinse or not using one is also currently questioned by some, and the ones advocating a mouthrinse adopt different policies for use. Mouthrinses have been credited with reducing adaptation of the taste receptors, thus increasing sensory test sensitivity (O'Mahony, 1973a, 1974, 1986a; O'Mahony and Heintz, 1981).

An additional area that currently seems unresolved is the effect of temperature on the perception of taste primaries. Powers et al. (1971) summarized the effect of temperature on sour and bitter thresholds, Moskowitz (1973) addressed temperature and taste intensity, and McBurney et al. (1973) dealt with the temperature dependency of taste responses. Other work with temperature has focused on food acceptability (Cardello and Maller, 1982). The result of past research is that a temperature effect exists, but

exactly "what" that effect is is not known, and it may vary in different situations. The effect of temperature on sensory difference tests utilizing a liquid food system with various rinse conditions has not been previously addressed.

Therefore, the objectives of this study are. . .

Experiment I (Chapter III)

1. To investigate the effect of rinse temperatures on the ability of sensory panelists distinguish between samples of a liquid food system differing in sweetness and saltiness presented at three different temperatures,
2. To compare results of tests in which no rinse was used to those in which a rinse was used for testing of sweet and salty difference tests at three temperatures in a liquid food system, and
3. To determine if one set of test conditions maximizes sensitivity (sample temperature/rinse temperature) for sweet and salty difference tests in a liquid food system.

Experiment II (Chapter IV)

1. To determine if learning takes place across the stimulus set by giving feedback,
2. To determine the sensitivity of sensory panelists to differences of salty or sweet in water solutions across 200 successive stimuli,
3. To determine the sensitivity of sensory panelists to differences of salty or sweet in a liquid food system across 200 successive stimuli, and

4. To determine if sensitivity to salty or sweet in water solutions can indicate sensitivity to those taste differences in a liquid food system.

CHAPTER II

REVIEW OF LITERATURE

I. TASTE MECHANISMS

The mechanisms involved with human taste perception have long intrigued researchers. While many approaches have been taken to answer the questions at hand, no one explanation or conclusion has come forth, and controversies still exist. It appears that every "expert" in the field has formulated a theory and generated some data to support, at least in part, his/her ideas. Much of taste research is carried out on animals, and extrapolation to humans is questionable. Unanswered questions continue to challenge accepted theories of the taste mechanism, but a foundation has been established that forms the basis for current research.

Taste perception begins in the taste bud. Taste buds are found throughout the oral cavity, which may include the fungiform and circumvallate papillae lateral surfaces, fungiform papillae dorsal surfaces, the palate, lips, and epiglottis (Price and Desimone, 1977). The taste buds are located on the papillae and contain the taste receptors (Amerine et al., 1965). Taste stimuli reach the taste buds via the convective processes during tongue movement (Desimone and Heck, 1980; von Békésy, 1966).

The general sequence of events in the mechanism of taste perception begins with stimulation of taste receptor cells by molecules or ions. This initial interaction subsequently sets off a chain reaction that results in a neurotransmitter release from the

receptor synapse and ends with a change in the impulse discharge rate of the taste fibers (Teeter et al., 1987). The taste buds consist of two types of surfaces. Apical surfaces are those in contact with the saliva or mucus layer covering the epithelium and contain the receptive portion of the bud. Basolateral surfaces, also known as innervated surfaces, are bathed by interstitial fluid inside the taste bud (Teeter et al., 1987). Each taste bud is made up of taste cells which are innervated by nerve fibers (Price and Desimone, 1977).

While more taste mechanism theories are based upon the primary tastes, several hypotheses have been proposed that deal with taste cell activation. These include membrane conductance changes, an intracellular second messenger release, and phase boundary potential changes at the apical surfaces (Teeter et al., 1987). Because early work by Beidler (1967) showed that taste cells lacked permeability to saliva and mucus ions, very little focus has been placed on membrane conductance and conformational changes in the proteins present. Recent work has presented evidence to support the idea that apical membranes contain passive cation channels to some sweet stimuli and monovalent salts (Teeter et al., 1987). Once the taste receptor cell has been stimulated, an intracellular second messenger may be generated which could initiate neurotransmitter release. The phase boundary potential hypothesis revolves around changes in ionic diffusion potentials between solutions found on different sides of the apical membrane (Teeter et al., 1987).

The theory behind taste perception of each of the four tastes differs, although some similarities do occur. McBurney (1974) addressed 11 points in favor of the idea of basic taste qualities. Among the most convincing are: 1) taste quality is correlated to some chemical structures; 2) mixtures of primary taste qualities do not produce new taste qualities; 3) different areas of the tongue possess specific sensitivities to different taste qualities; 4) cross-adaptation occurs among the taste qualities, and 5) a water taste exists after adaptation to any of the four basic tastes.

Taste stimuli fall into one of the four primary taste categories of sweet, salty, sour, and bitter, and are primarily low molecular weight compounds (Price and Desimone, 1977). Regarding the four taste categories, several areas have been investigated at great length. The mechanism that triggers the response for each primary taste has received the most attention. Other areas that have been addressed include reaction times, taste sensitivity, and taste adaptation.

Sweet Taste Response

The most widely accepted model of the sweet taste receptor involves a receptor protein. Beidler (1967) postulated that proteins in the receptor cell membrane hydrogen bond to sweet stimuli, resulting in a depolarization of the receptor cells. This in turn creates openings through which ions can pass. The proposed sweet receptor protein has been isolated from rat and cow tongue and shows stereospecificity similar to the sweet taste receptor in vivo

(Price and Desimone, 1977). The basic hypothesis of the sweet taste receptor mechanism is that a protein in the plasma membrane of receptor cells undergoes a conformational change as it forms a complex with a specific sweet stimuli. The conformational change leads to "leaks" in the membrane, resulting in depolarization of the receptor cells (Price and Desimone, 1977). The steps that lead to release of a neurotransmitter following depolarization have not been elucidated. Evidence to further substantiate protein involvement in sweet taste reception includes sweet taste inhibition by sulfhydryl reagents and cycloheximide (a protein synthesis inhibitor) (Faurion et al., 1980).

Boudreau (1986) states that at least two sweet sensations exist for the human. One is active at the front of the tongue by facial nerve innervation and is elicited by amino acids and probably sugars. It is short lived and does not remain following rinsing. The second sweet sensation is innervated by the glossopharyngeal nerve on the portion of the tongue that the nerve serves and persists for a longer periods of time than the other active site. Stimuli that elicit this sensation include furaneol, glycyrrhizin, and neohesperidin dihydrochalcone (Boudreau, 1986).

The theory behind why substances taste sweet is best explained by an AH-B model system involving hydrogen bonding of stimuli to receptors (Shallenberger, 1963; Shallenberger and Acree, 1971). Kier (1972) expanded the theory to include a lipophilic portion to account for the lipophilicity of the taste receptor cell membrane portion. It has been suggested that this lipophilic portion plays a

role in the rate of receptor filling and in the release of molecules from the receptor (Birch et al., 1980).

Because the sweet response is elicited differently among animal species and among human subjects, it has been postulated that the sweet response is a continuum with three modalities (Faurion et al., 1980). They found that sensitivity to one sweet stimuli could not be used to predict sensitivity to other sweet stimuli. They further suggested that each person does not have the same chemoreceptive mechanisms, and that different sweet stimuli trigger the mechanisms present in different patterns. Faurion et al. (1980) accounted for differences in sweet stimulation with the three modality theory. Because subjects disagreed on quantitative measurements of intensity of sweetness, they speculated that only one modality (different for each person) is triggered at low concentrations of sweet stimuli, but all three modalities are triggered at suprathreshold levels. When only one modality is triggered, then a different "sweet", (or maybe no taste at all) would be present in different subjects. When all modalities are triggered, a very similar sweet sensation is elicited among subjects.

Salty Taste Response

The salty sensation is generally attributed to the presence of a cation in the stimulus molecule (Meiselman, 1972; Boudreau, 1986), although ion permeation has been postulated as a mechanism for the salt response (Price and Desimone, 1977). Boudreau (1986) states that salts containing Na^+ or Li^+ are most effective as "salty"

stimuli in humans, while salts containing K^+ or NH_4^+ may also elicit the salty response. He further contends that cations other than these may elicit a bitter sensation rather than a salty one. Smith and McBurney (1968) found that salty stimuli elicited both saltiness and bitterness, with the exception being Na_2SO_4 , which elicited salty and sour. Salts with common cations were found to have similar tastes which led Smith and McBurney (1968) to conclude that only one mechanism coded the salty taste. A further hypothesis for the salty response involves the existence of passive sodium channels in the cell apical membrane (Teeter et al., 1987) that aid in eliciting a salty sensation from Na^+ and Li^+ salts. The fact that amiloride (generally a salty sensation inhibitor) fails to completely suppress the salty sensation of NaCl or other Li^+ or Na^+ salts has been used as a basis to suggest a second mechanism involved in the salty taste sensation (Teeter et al., 1987). This second mechanism entails changes in the surface potential of cell membranes. Desimone and Heck (1980) proposed a model that relied upon the surface pressure of the receptor membrane to be the critical factor in determining a response.

In different animal species in single cell recordings, increasing NaCl concentrations above the concentration of the solution that surrounds the apical cell membrane generally results in large depolarizations of the cell and a decreased membrane resistance. Conversely, decreased NaCl concentrations below the adaptation level result in hyperpolarizations with increased membrane resistance (Teeter et al., 1987). The depolarization of

the cell has been postulated to involve a flow change in cation movement into the cell (Price and Desimone, 1977). The cell depolarization during a salty sensation includes a cation diffusion potential, and anions modify the cation permeability. Cell membrane models have been constructed which can account for the anion/cation inhibition/stimulation of salt taste receptors. Several other models also suggest the role of phospholipids in membranes as salt receptors (Price and Desimone, 1977).

Sour Taste Response

Because acids elicit a sour sensation, the presence of the H^+ ions in the acid is assumed to be the source of sourness (Meiselman, 1972). Boudreau (1986) disagrees with this and postulates that proton donating (Bronsted acids) substances are responsible for the sour sensation. The bulk of literature has dealt with the function of the H^+ ion in the sour sensation. Inorganic acids (HCl, e.g.) appear to exhibit a direct relationship between hydrogen ion concentration and sourness, that is, hydrogen ion increases result in increased sourness. On the other hand, organic acids (acetic acid, e.g.) do not exhibit the same relationship; the concentration of H^+ ions present in a solution does not account for the greater observed sourness that would be expected if a direct relationship existed (Meiselman, 1972).

Although questioned, it is generally accepted that the H^+ ion plays a role in sour taste perception. Beidler (1967, 1971) postulated that the H^+ ion neutralized anionic sites on the cell

membrane, and that the response elicited was related to the number of sites neutralized. The role of the receptor surface pressure has been addressed as a role in the sour response (Teeter et al., 1987; Desimone and Heck, 1980).

Gardner (1980) postulates that the sour receptor lies in the cell membrane, and the ability of an acid to elicit a sour response depends on its ability to penetrate the membrane. The ability of the acid to penetrate the membrane is measured by its lipophilicity. Gardner (1980) contends that a lipophilic portion must be present on the molecule to aid in membrane penetration. Organic acids were found to increase penetration with increasing molecular chain length, but decrease penetration if hydrophilic (hydroxyl) groups were introduced. Gardner (1980) further found that sour thresholds were higher in an oil medium than in water, indicating a role for a lipophilic portion in the sour stimulus. Koyama and Kurihara (1972) suggested that H^+ ions bind to phosphate groups in the phospholipids present in the membrane to induce a sour response.

Bitter Taste Response

The bitter taste response is less researched than the other three tastes. Several theories exist for the types of bitter receptors and the location in the cell (Gardner, 1979). It has been suggested that the bitter receptor site involves an enzyme protein site and a lipid site (Price and Desimone, 1977) and bitter reception consists of two stages. The first stage requires that the stimulus reach the receptor, and the second stage that the stimulus

fit the receptor site. There is evidence that two different types of bitter receptors exist and have different locations (Gardner, 1979).

The lack of structural similarity among bitter stimuli presents difficulty in studying the response, yet suggests that unique receptors may not exist (Teeter et al., 1987). Bitter compounds do show hydrophobicity (Price and Desimone, 1977), and suggestion has been made that bitter compounds interact with lipids in the cell membrane (Gardner, 1979). One mechanism that has been proposed as a portion of the bitter taste response is the reduction of cyclic AMP in the receptor cells (Price and Desimone, 1977). This could occur by stimulation of phosphodiesterase or by any event that reduces cellular ATP levels. A second mechanism mediating the bitter sensation involves membrane lipids (Price and Desimone, 1977) and the lipophilicity of the stimulus (Gardner, 1979). The stimulus must be able to penetrate the cell membrane to reach the site of action, and cell penetration requires lipid solubility of the stimulus. The bitterness of carbohydrates, amino acids and peptides, and phenolic compounds all involve to some extent the lipophilic nature of the molecule (Gardner, 1979). The sequence of events in bitter taste reception is proposed to include penetration of the cell membranes followed by an alteration in cyclic AMP levels (Price and Desimone, 1977).

The hypothesis that two distinct bitter receptors exist having different locations is supported by the insensitivity of some people to phenylthiocarbamide (PTC). At low concentrations PTC elicits no response; yet, at high concentrations, a bitter response develops.

If a receptor is present near the cell surface and another deeper within the cell, then PTC insensitivity at low concentrations could be explained by a deficiency of near surface receptors. At the higher concentrations, PTC would be better able to penetrate the cell to the deeper receptors and elicit a bitter response (Gardner, 1979).

Water Taste

The taste cells respond not only to stimuli representing the four basic tastes, but also to water. The majority of data collected deals primarily with a water taste following adaptation to one of the four basic tastes. Price and Desimone (1977) have reviewed the presence of a water response in species including the human. There is no theory for the water taste in humans, yet studies on animals have produced plausible theories for the water taste mechanism. The water response has been postulated to depend on the anion and cation levels in the adapting solution surrounding taste membranes (Price and Desimone, 1977). Dilution of the adapting solution results in changes in the membrane charge which leads to the water response. Another theory includes the idea that the water response is related to the H^+ ions in water, yet this has not been tested (Price and Desimone, 1977). McBurney (1974) uses the presence of a water taste following adaptation as support for only four primary tastes existing in nature.

Because tap water is not a pure substance, the chemicals in it would be expected to elicit some type of water response. O'Mahony

(1972a) investigated the water taste of tap water, once distilled water and twice distilled water. He found that subjects could easily distinguish once distilled water from twice distilled water and tap water from once distilled water. Descriptive terms associated with tap water were "bitter" or "metallic," and those associated with once distilled water were "tingly," "sweet," "bitter," or "metallic." These results suggest the need to account for a water taste when water of any type is used as a solute for taste stimuli.

II. FACTORS AFFECTING THE BASIC TASTES

Several factors can have an effect on the ability of subjects to respond to the four basic tastes, namely reaction times, solution viscosity and adaptation. The taste system comprises three events in taste reception: 1) the reaction time (latency of nerve discharge), 2) the time to reach maximum sensation (maximum nerve discharge), and 3) the time to complete sensation (adaptation) and recovery time (McBurney, 1974). Reaction times for each of the primary tastes individually and in combinations have been reported (Kuznicki and Turner, 1986). When presented opposite water and informed which taste to look for, reaction times were shortest for salty (0.73 sec), intermediate for sour (0.85 sec) and sweet (0.95 sec), and longest for bitter (1.42 sec). When taste qualities were compared in all possible pairwise comparisons and subjects had to correctly label the taste quality, reaction times increased for all qualities over those in which the subjects knew which quality was

present. Reaction times were also higher when subjects were required to discriminate one taste from the other three: salty (1.44 sec), sour (1.40 sec), sweet (1.44 sec), and bitter (1.89 sec) (Kuzinicki and Turner, 1986).

The time to reach maximum sensation can have an effect on taste detection. Tastes that linger in the mouth (long time to maximum sensation) may affect the ability of a subject to detect other taste qualities (Kuzinicki and Turner, 1986) unless a high concentration of a second stimulus (taste quality) is present. Lawless and Skinner (1979) found that sucrose intensity peaked within 5-10 seconds, but did not completely dissipate for up to 2 minutes. Increasing the concentration of the sucrose solution resulted in increased time to sweet disappearance. Movement of the tongue (as in a sip and spit procedure) increased the time to disappearance of sucrose over that of a dorsal flow procedure, where the tongue is stationary (Lawless and Skinner, 1979). McBurney (1974) reports that the time to reach maximum sensation is on the same order as reaction times, salty < sour <= sweet < bitter.

While tongue movement has an effect on taste reception, the degree of salivary flow does not (Christensen et al., 1983). With up to an 80% reduction in salivary flow rate and using a sip and spit procedure, Christensen et al. (1983) did not find a reduced perceived intensity of suprathreshold taste stimuli. Saliva could play a role in the dilution of a stimulus once in the oral cavity, but when using 10 ml portions, the researchers found no decrease in

perceived intensity of suprathreshold stimuli under normal salivary flow compared with that of reduced salivary flow.

Solution viscosity can have a profound effect on the perceived intensity of the primary tastes. Recognition thresholds of the primary tastes were compared at four different viscosity levels (1, 10, 100, 1000 cP) using four different thickeners (methyl cellulose, guar seed flour, carob seed flour, and tara seed flour) in a recent study (Paulus and Haas, 1980). Sucrose thresholds were increased more when comparing 1 cP and 1000 cP solutions, but varied by the thickener used. Sodium chloride showed variable increases in thresholds from 1 to 10 to 100 cP across thickeners, but increased for every thickener at 1000 cP. Caffeine thresholds showed similar results as NaCl. Citric acid thresholds showed the greatest increase from 1 cP to 1000 cP, and varied by thickener. The only generalities derived from the study were that the least increases in recognition thresholds occurred between 1 and 10 cP, the greatest between 1 and 1000 cP, and guar seed flour almost always induced threshold increases while carob seed flour as a thickening agent was least likely to result in increased thresholds (Paulus and Haas, 1980). It is clear that predictions concerning primary taste intensities using various thickening agents cannot be made on the general theory that "increased viscosity decreases perceived intensity." Specific concentrations and thickeners must be investigated. Stone and Oliver (1966) reported that a decrease in sucrose sensitivity (detection thresholds) resulted from an increase in viscosity of a solution.

III. TASTE ADAPTATION

Perhaps one of the greatest variables capable of affecting the ability to detect the primary tastes is adaptation. In recent years, the term adaptation has been differentiated from the term fatigue (O'Mahony, 1986a), while in the past, the two has been considered synonymous (Laue et al., 1954). In the simplest terms adaptation has been defined as a change in sensitivity (O'Mahony, 1986a). Extended definitions include perceived intensity over time (Halpern, 1980; Gillan, 1984). The ability to achieve complete adaptation has been questioned (O'Mahony, 1986a; Kroeze, 1978; Ganzevles and Kroeze, 1987; Meiselman and Buffington, 1980) and has been referred to as a "laboratory artifact" more than a real world construct (Meiselman and Buffington, 1980). Gillan (1984) contends that adaptation is a psychological phenomena which can be indirectly supported by the definition proposed by Ganzevles and Kroeze (1987) that includes the qualifier "subjective intensity" decline of a stimulus.

Adaptation includes two types, self-adaptation and cross-adaptation. Self-adaptation occurs when the test stimulus and the rinsing (prior inducing) stimulus are the same, e.g. NaCl and NaCl (Ganzevles and Kroeze, 1987). Cross-adaptation occurs when the prior inducing stimulus and the later test stimulus are different from one another. This could involve two substances of one taste quality (two different salts) or substances from two different taste qualities (salty and sweet) (Ganzevles and Kroeze, 1987).

The ability of taste stimuli to cross-adapt one another indicates the likelihood that stimuli compete for the same receptors, and vice versa; the inability of two substances to cross-adapt one another suggests that they compete for different receptors (Lawless and Stevens, 1983; Kroeze, 1978). Ganzevles and Kroeze (1987) found no cross-adaptation between NaCl/sucrose and sucrose/citric acid, and adaptation to all other taste compounds decreased bitterness to di-quinine sulfate. When studying the ability of sucrose and intensive sweeteners to cross-adapt one another, Lawless and Stevens (1983) found that the intensive sweeteners (aspartame, dihydrochalcone, saccharin) were less able to cross-adapt sucrose than vice versa. Cross-adaptation of salts was investigated by Smith and McBurney (1968). They concluded that the "extent of cross-adaptation was dependent upon the qualitative similarity between the adapting and test stimulus." The salt taste was comprised of two components, both salty and bitter qualities. Adaptation to what they term a "pure" salt (NaCl) did not completely cross-adapt salts with a bitter component (CaCl_2 or CaBr_2); similarly, decreases in saltiness after adaptation were associated with bitterness increases in all but the sulphate containing salts (elicited sourness) (Smith and McBurney, 1968).

The generation of adaptation in the taste nervous system is debated. Kroeze (1978) contends that it lies in the taste system periphery. More recently, Gillan (1984) supplied evidence for involvement of both the central and peripheral systems. He states that adaptation occurs in two stages. The initial stage involves

the peripheral processes, and the concluding stage the central processes. The central processes include reductions in the processing of a constant stimulus.

Adaptation in the taste cell receptors may result from a number of causes. O'Mahony (1974) attributes adaptation to inhibition of specific receptor sites, and not to receptor site exhaustion. Meiselman and Buffington (1980) found that increased stimulus concentration increased the time to adaptation by the stimulus. They further found that complete adaptation was more easily elicited when the stimulus concentration was 0.1 M rather than 0.36 M. O'Mahony (1986a) likens the adaptation phenomena to a zero-drift on a laboratory balance. When a stimulus is placed in the mouth, any residuals from that stimulus affect the intensity of subsequent stimuli. Unless the taste receptors are "re-zeroed," increased residues adapt the receptors to the stimulus such that higher concentrations are required to elicit a response. NaCl residues of 5 mM above that of the normal saliva concentration have been found to elicit a salty response in non-adapted subjects (O'Mahony, 1974). O'Mahony (1973a) found that subjects were unable to discern the point when the salt taste disappeared following a 1 M NaCl stimulus. Subjects reported that the salty taste disappeared within 10 minutes, yet NaCl residuals ranged from 4 mM to 134.5 mM above that of the prestimulus saliva concentration. He suggested that the same condition may apply for other taste stimuli capable of remaining in the saliva in large concentrations. Dubose and Meiselman (1979) reported that individual differences in adaptation cannot be

accounted for by the differences in saliva or its sodium content, which is also supported by the fact that salivary sodium content fluctuates constantly and for various reasons (O'Mahony, 1974).

The effects of taste adaptation can have pronounced effects on sensory tests. Without accounting for or attempting to reduce adaptation, the results obtained may be skewed and unreliable. O'Mahony and Goldstein (1987a) found that adaptation affected the ability of subjects to discern the difference between salt and water stimuli. They stated that the salt receptors were less sensitive to subadapting stimuli rather than supra-adapting stimuli. Stimulus residuals can affect the level of the subadapted state (saliva) by continuously altering the concentration. When subjects expected a stimulus response in a self-determined time, they tended to respond incorrectly to subadapting stimuli because they experienced a long latency period (O'Mahony and Goldstein, 1987a). This could result in incorrect responses in sensory difference tests, i.e. that differences are not present when they may actually be present.

Another phenomena commonly associated with adaptation is the water taste. Following adaptation to substances representing the primary tastes, a taste can be elicited by presenting distilled water to a subject. Lawless and Stevens (1983) reported that sucrose adaptation elicited a bitter water taste and dihydrochalcone adaptation elicited a sweet water taste. A more extensive study was conducted on water tastes by McBurney and Shick (1971). They found that bitter, sour, and salty compounds could elicit a sweet water taste, that saccharin and several salts elicited a sour water taste,

that NaCl was the only substance that elicited a bitter water taste, and urea was the only one eliciting a salty water taste. Generally, salts produced sweet and sour water tastes, acids produced sweet water tastes, and bitter compounds produced sweet water tastes. It was further postulated that the taste present in a compound will be absent from its water taste and vice versa (McBurney and Shick, 1971).

Methods to control or reduce sensory adaptation include interstimulus rinses, interstimulus rests, and varied presentation procedures for stimuli. Interstimulus rinses (primarily water) have been reported to lower adaptation (O'Mahony, 1986a; O'Mahony and Heintz, 1981; O'Mahony, 1974; O'Mahony, 1973a). Although not as successful, interstimulus rest periods have also been used. O'Mahony (1986a) reported that 2 min rest intervals were effective in lowering adaptation. A 15 sec mouth rinse was found to be more effective than a 15 sec rest and a 2 min rest intermediate in reducing drift to adaptation (O'Mahony, 1974). Different stimulus presentation procedures have further been shown to affect the adaptation state of taste receptors. Meiselman (1968) reports that one sip held for 5 min produced a greater adapting effect than repeated sips that were expectorated immediately. This is supported by Ganzevles and Kroeze (1987) who found that the sip and expectorate procedure allowed some recovery time to receptor sites which in turn would result in less adaptation. In an attempt to simulate human drinking, Halpern (1980) stated that "pulsatile, alternating stimuli of sufficiently different concentrations

determine the absence of adaptation." His study supports the idea that adaptation is mainly an occurrence in the laboratory rather than in the real world (O'Mahony, 1986a; Meiselman and Buffington, 1980).

Even though adaptation occurs primarily in the laboratory, it must be accounted for in the design of sensory tests and experiments. Because the taste receptor cells cannot be as easily "re-zeroed" as an instrument can be, the investigator must be sure that he is measuring what he intends to measure. Repeated stimuli presentations can result in partial or complete adaptation, yet when accounted for or reduced as much as possible, the sensitivity of the test can be maintained and the results relied upon to be accurate, all other things being equal.

IV. TEMPERATURE EFFECTS ON SENSORY TESTS

Few studies of the effect of temperature on various sensory tests have been reported. The bulk of literature deals primarily with threshold differences at various temperatures (Powers, 1977; Paulus and Reisch, 1980; Stone et al., 1969). Other studies have focused on temperature effects on food acceptability (Cardello and Maller, 1982) and temperature effects on the relative sweetness of sugars (Hyvonen et al., 1977, 1978).

It is accepted that temperature has an influence on threshold values as well as flavor perception (Amerine et al., 1965), but the results are conflicting. Powers (1977) attributes the inconsistencies to heterogeneity of the subjects in response to temperature differences. He explains that each person's taste

receptor system responds unlike that of any other, and these differences can explain some of the variability found. In his work, he grouped subjects into homogeneous groups based on their prior responses and found that temperature did indeed affect the thresholds of ethyl caprylate.

Daget (1977) reports that taste sensitivity is greatest from 20° to 30°C. Paulus and Reisch (1980) compared thresholds of compounds representing the basic tastes in distilled water at four different temperatures (10°, 20°, 40°, 60°C). Generally, stimulus and recognition thresholds were highest for all compounds at 60°C, intermediate at 40°C and lowest at 10° and 20°C. Stone et al. (1969) reported that an increase or a decrease in temperature did not have an effect on the relative sweetness of suprathresholds of dextrose, fructose, or mixtures of the two. When an acidic factor was introduced, the sweetness of the sugars increased with increasing temperatures (5°-50°C) (Stone et al., 1969).

The ability of panelists to distinguish water samples from one another that differed by 5°C temperature differences was investigated by O'Conner et al. (1974). They reported that water temperatures were more easily detected from one another when comparisons of 10° and 15°C, 25° and 30°C, and 30° and 35°C were made. The ease of detectability decreased after 35°C but increased again after 60°C, the temperature at which heat and pain dominate the receptors. O'Conner et al. (1974) equate the temperature sensitivity of the human receptors to the cold/warm fibers in the cat. Cat cold sensors are active at 12°-35°C, inactive from

35°-44°C, and reactivated at 45°C. The subjects detectability in their study showed similar sensitivity to cat temperature sensors (O'Connor et al., 1974).

The effect of temperature on the acceptability of beverages and selected food was investigated by Cardello and Maller (1982). Water acceptability decreased with increasing temperature (38°-120°F), but the addition of flavoring agents to the water improved acceptability at the warmer temperatures. Foods were found to be more acceptable near the temperature at which they are normally consumed. Although maximum sensitivity to taste stimuli is near body temperature, Cardello and Maller (1982) found that the maximum acceptability temperature was not the same as the maximum sensitivity temperature. They also noted that no food or beverage tested had a maximum acceptability at ambient temperature. These findings appear important in light of the testing temperatures currently used in sensory tests. Ambient temperatures are most often used for products in testing. Even though all tests are not acceptability tests, the controversy still exists over which temperature should be used; i.e., the one that achieves maximum acceptability or maximum sensitivity. Even with panel training, learned temperature aversions may result in an uncontrollable variable in testing.

Amerine et al. (1965) report that temperature optimums are 35°-50°C for sucrose and HCl, 18°-35°C for salt, and 10°C for quinine. An increase in response to sweetness and a salty and bitter decrease were observed with increasing temperature (Amerine et al., 1965). Because almost all food or beverages are mixtures of

two or more taste stimuli, a temperature optimum for maximum sensitivity in the mixture may not be possible. A product's textural characteristics at different temperatures must also be considered when determining sample temperatures in testing (Boggs and Hanson, 1949).

Hyvonen et al. (1977) investigated the effect of temperature on the relative sweetness of selected sugars. They found that the sweetness of sucrose at 5°C was less than at 22°C, the sweetness was not different between 22°C and 37°C, and that 50°C samples were more sweet than 22°C or 37°C samples. They postulated that the increased sweetness at higher temperatures could be attributed to severed intermolecular hydrogen bonds. Increasing temperature also had an influence on the relative sweetness of fructose. When an acid was introduced into the sweet solutions, the sweetness of the sugars was similar at 6°C and 23°C, but decreased at 50°C (Hyvonen, 1978). Generally acids had an effect of reducing sweetness in the mixtures.

In order to normalize the effect of temperature in an experiment, Meiselman (1972) proposed that temperatures remain constant within and across experiments if comparisons are to be made. For the most part, samples are presented at like temperatures, yet rinses used between samples are not usually at the same temperature as the samples unless samples are presented at ambient temperature. When animal tongues are preadapted to an experimental temperature, the response to a taste stimulus is greatest at the temperature of the tongue and decreases at temperatures higher or lower (Sato, 1967). The evidence that a

temperature contrast exists for sensory systems (Taylor, 1971) suggests that sample temperatures different from rinse temperatures, with both possibly differing from body temperature may induce variables into sensory tests that have yet to be accounted for in studies reported in literature.

V. SENSORY EVALUATION

Sensory evaluation, as the name implies, is an evaluation of some object that entails use of the senses. The term sensory evaluation has replaced organoleptic evaluation in recent years. Organoleptic is derived from the Greek work "organolepsis" which means a "tool or instrument that is capable of receiving impressions and recording them" (Fritjers, 1975). Sensory evaluation is a psycho-physiological process that draws upon the psychological and physical state of the human or animal during evaluation. In 1975, Fritjers contended that sensory evaluation was still in the pre-scientific stage, and a sound methodology had yet to be set forth. She attributed this to the following: 1) it is a complex phenomena and 2) organizations employing it use it practically. The practical use of sensory evaluation cannot be a reason for not developing a sound methodology. Answers obtained from sensory tests can often be misleading or just wrong if adherence to strict controls are not enforced. The future focus in sensory testing will be directed towards maximizing sensitivity of tests, as well as to set forth exact methodology in hope of alleviating its use primarily as a trouble-shooting technique.

Discrimination (Difference) Tests

An area of sensory evaluation that is used quite often is discrimination testing. As the name implies, these tests are designed to determine whether a difference exists between two or more products, samples, etc. Although the idea is simplistic, the institution of tests is complex because "human perception is relative, not absolute" (McBride, 1982). Numerous reports in literature have pointed out the "relatives" that can influence results of difference tests. Discrimination tests include paired comparison (PC), triangle, duo-trio, dual-standard, A-not A, and two-out-of-five (Meilgaard et al., 1987) with some variations (Peryam, 1958). The tests used most often today are the PC, triangle, and duo-trio, although the A-not A test has regained popularity (O'Mahony, 1979).

Practically speaking, difference tests are easily conducted, rapidly executed, and simply analyzed, yet a disadvantage is the "lack of a functional relationship between the response distribution and the underlying sensory continuum" (Fritjers, 1979). By employing psychometric models, a sensory continua can be related to the observed behavior (Fritjers, 1979). Factors important in determining the type of difference test to institute in a given situation include the intent of the investigator, precision of the test, the number of replications, and the size of the panel (Murphy et al., 1957). Test precision can be maximized by increasing the number of judges or replications, through careful selection and training of judges, by optimizing sample homogeneity, and by

selecting the most efficient statistical design (Kramer and Ditman, 1956). Boggs and Hanson (1949) state that the number of test replications is governed by sample variability, variability of judges' results, the magnitude of sample difference, and the degree of information required. Ennis and Mullen (1985, 1986) address the issue of dimensionality on difference tests. In samples that contain several different dimensions (food system versus water solution with only one taste quality), the ability to differentiate between two samples will depend upon the number of dimensions present as well as the discriminial distances between the samples. To facilitate discrimination, large sample sizes or large discriminial differences are recommended (Ennis and Mullen, 1985). The discrimination methods most suited for multidimensional stimuli are duo-trio and A-not A (Ennis and Mullen, 1985).

Several investigators have set out to determine which of the discrimination tests is more sensitive than the others in detecting differences. Triangle tests were found to be less sensitive than duo-trio tests in detecting sour differences (Spencer, 1979), and Byer and Abrams (1953) reported that triangle tests were less sensitive than two-sample (PC) tests. Advantages given to the duo-trio test included its simplicity (matching to a standard), the declared standard can induce a learning effect, and there is less fatigue from fewer portions assessed (Spencer, 1979). Similar reasoning was applied to triangle tests for being less sensitive than PC tests because more samples are tasted, and the substance tasted could desensitize the taste receptors (increase adaptation)

(Byer and Abrams, 1953). Further studies have shown that the PC test exhibits greater sensitivity to marginal differences than does the triangle (Gridgeman, 1970), and that the two-sample (PC) test is more sensitive in threshold determinations than is the triangle test (Filipello, 1956). Only Dawson et al. (1963) stated that the PC and the triangle test were equal in sensitivity. Paired comparison tests and triangle tests were found to be equally powerful and superior to duo-trio tests, but PC tests have been recommended on the basis of economics (Gridgeman, 1955). Despite these findings, triangle tests continue to be used more often for food quality tests (Harries and Smith, 1982).

In recommendations that support the use of the PC test, Hopkins and Gridgeman (1955) state that fewer comparisons are made in PC tests than in a triangle (e.g.), and this increases the probability of detecting marginal differences. Lockhart (1951) argues that two sample tests cannot be true difference tests unless the answer "no difference" is permitted. Using PC tests to determine sweetness of selected sugars relative to sucrose, Larson-Powers and Pangborn (1978) contend that PC tests might not be appropriate for stimuli that have more than one parameter or that exhibit masking or synergism of components present. The validity of their contention must be questioned on the basis of the data presented.

Sensitivity endurance over several stimuli in difference tests has been addressed. Gridgeman (1956) believes that efficiency decreases with increasing sample numbers evaluated at one session. McBride (1982) argues that small differences are more easily

detected in a number of samples presented simultaneously. Mitchell (1956a) postulates that accuracy increases with increasing judgements as he found that subjects had more correct answers on the last three duo-trio tests than they did on the first two tests in a series of five. Through seven PC tests, Dawson et al. (1963) found that subjects exhibit better taste acuity on the last half of tests than they do on the first half; perhaps learning takes place in the first half of the tests (Mitchell, 1956a). O'Mahony and Goldstein (1986) explain the effectiveness of difference tests in terms of adaptation, stimulus confusion, and differential sensitivity; these three factors must be controlled to maximize sensitivity. When dealing with heterogeneous products (different lots) where small differences are sure to occur, yet may not affect product acceptance, a degree of difference test has been recommended over the triangle test (Aust et al., 1985).

Factors Affecting Difference Test Results

Among factors that can influence difference test results are the instruction set and test design, the test medium, and the use of some type of palate clearer (mouth rinsing most common). Also to be considered are means to increase test sensitivity, namely statistical procedures incorporated into test design.

Test Design and Instruction Set The design of the test has perhaps one of the greatest effects on difference test results. Wasserman and Talley (1969) found that a smoked frankfurter was significantly different from an unsmoked frankfurter when presented

as the odd sample in triangle tests, but not vice versa. Grim and Goldblith (1965) reported that judges receiving an unirradiated "odd" sample (whole egg-magma) in a triangle test were less likely to detect a difference than if the irradiated sample was the odd sample. Current work on sequential sensitivity analysis has given strength to the more sensitive test designs that should be used in difference testing (O'Mahony and Odibert, 1985; O'Mahony and Goldstein, 1986). Mitchell (1956b) found that the weaker sample or the more typical flavor should be used as the pair in duo-trio tests to improve discrimination. In PC preference tests using either simultaneous (at one session) or successive (sessions separated by days) presentations of soups, Schwartz and Pratt (1956) stated that the simultaneous method produced higher preference ratings than did the successive method. This could be attributed to the complete reliance on long term memory.

The instruction set presented along with the test can also affect the results obtained. Raffensperger and Pilgrim (1956) supplied psychological aids for discrimination using triangle tests. They concluded that providing pertinent information increased the discriminating power of the judges, and that supplying the judges with a directional difference (more sweet, e.g.) was no more helpful than simply supplying them with the dimension (sweet) of difference. McBride et al. (1984) found that a "loaded" (Is there a difference? vs. Indicate the difference) question was more likely to induce subjects to find a difference when one actually did not exist. They

proved this using two different food stimuli with two separate panels.

Test Medium Most studies on taste stimuli are carried out in water solutions and not food systems. The ability of a subject to identify basic tastes in water may not indicate his ability to perceive those same stimuli in food. Mackey and Jones (1954) looked at a subject's ability to rank basic taste stimuli in water solutions and in applesauce, pureed pumpkin, and mayonnaise. They found no significant correlation between the ability to rank solutions of water and foods with the same taste quality; that different taste qualities were easier to detect in some foods more than others, and that the ability to detect one taste quality in a food did not predict the ability to detect other taste qualities in the same food. This suggests that caution should be exercised in extrapolating findings from water solutions to complex food systems. More specifically, testing must be conducted using complex food systems as well as the water solutions.

Palate Clearing - Mouth Rinses The interstimulus procedure used in difference testing can have a pronounced effect on the results obtained. The decision between using a mouth rinse or using a rest period (e.g. 60 sec) is controversial. Both are used to decrease adaptation, yet the rest period would stress the short term memory more than the rinse. Some studies support using a mouth rinse (Meiselman, 1972; Boggs and Hanson, 1949; O'Mahony et al., 1979a; O'Mahony and Heintz, 1981; O'Mahony and Godman, 1974; O'Mahony and Wingate, 1974), some do not (Pettit, 1958; McBride and

Laing, 1979), and others suggest a laissez faire approach (McBride and Laing, 1979; Lundgren et al., 1976). When a mouth rinse was used, it tended to lower adaptation, thus increasing discrimination by the subjects (O'Mahony and Godman, 1974). Exact procedures used for mouth-rinsing include variations with tap water rinses (O'Mahony and Godman, 1974; O'Mahony et al., 1979a; O'Mahony, 1972c), purified water rinses (O'Mahony and Heintz, 1981), and distilled water rinses (Lundgren et al., 1976). Boggs and Hanson (1949) state that it is necessary to allow the effect of the rinse to disappear before moving on to subsequent samples. Pettit (1958) claims that rinsing is not necessary except after taste clinging substances have been tested. The majority of studies in which the effect of rinsing has been a main effect have dealt primarily with NaCl test solutions (O'Mahony and Godman, 1974; O'Mahony and Wingate, 1974; O'Mahony and Heintz, 1981), yet O'Mahony and Godman (1974) contend that the positive effect of mouthrinsing would be general for any stimulus that would persist in the mouth having the ability to adapt taste receptors. This has not been confirmed for test solutions or food stimuli.

Recommendations for the water rinse state that it should be of neutral character (Peryam and Swartz, 1950). Various rinse temperatures have been proposed: lukewarm (Peryam and Swartz, 1950), body temperature (Boggs and Hanson, 1949), same temperature as the sample temperature if the sample is at ambient temperature, or slightly above body temperature for heated samples (Peryam and Swartz, 1950). Although these have been set forth, no study has

determined these as optimum. Meiselman (1972) cautions against the use of water because even it has a taste, which is further supported by O'Mahony (1972a). The idea of using a long interstimulus wait to allow the saliva to coat the taste buds in a normal way (Boggs and Hanson, 1949) has been questioned on the basis of stressing the short term memory and thus decreasing test sensitivity (McBride and Laing, 1979). The optimum rinses and temperatures have yet to be investigated.

Increasing Sensitivity In Difference Tests

Attempts to increase sensitivity in difference tests have been made by means of statistical procedures and by altering test designs. Changes in statistical procedures have focused on 1) allowing ties in PC tests (Powers and Ware, 1980) because in reality, indecisiveness does occur, 2) using calibrated triangle tests (Holland, 1979), and 3) giving weight to responses of nondiscriminators in the two-stage triangle test (Gridgeman, 1970). Basker (1980a) has used polygonal and polyhedral tests to increase test sensitivity while reducing the number of assessments required. Stone and Sidel (1978) discuss the importance of computing exact probabilities for difference tests rather than relying on tables that could be incorrect or inconsistent.

In applying the binomial distribution for statistical analysis of difference tests, it is assumed that the probability of a correct selection does not differ among assessors. Harries and Smith (1982) state that only when no real discrimination exists can "x" assessors

at one judgement be interchanged for one assessor "y" number of judgements. This leads to the type errors that can be committed in analysis of the data. A Type I error (α level) takes place when the null hypothesis (no difference) is rejected when it is actually true. A Type II error (β level) occurs upon acceptance of the null hypothesis when it is false (Radkins, 1957). Although both type errors are costly, it is much worse to commit a Type II error than a Type I error. Type I errors can result in a product being reworked into the system, yet a Type II error would affect the consumer, as this is where it would probably be realized. Radkins (1957) addresses the importance of considering Type II errors in the statistical design of the test. If the two-sample (PC) tests make it easier to detect differences, then the possibility of committing a Type II error would be decreased, thus the test is more sensitive. Basker (1980b) warns that a statistically significant difference can be detected between any two samples if a sufficiently large number of assessments are made. When millions of dollars can depend on a "simple" difference test in the food industry, it is important that differences be detected if they exist, and so noted if they do not.

The newest approach in test design that attempts to increase sensitivity is an adaptation of signal detection measures (Green and Swets, 1974). O'Mahony (1986b) employs the use of the R-index in ascertaining whether differences exist. The R-index is a calculated value, the probability of a judge distinguishing correctly between two samples. As the R-index increases, the greater the degree of difference between two samples. The method is a forced choice

method, but allows for psuedo-ties. When presented with a sample, the judge can respond A - positively, A? - perhaps A, not sure, B - positively, and B? - perhaps B, not sure. A matrix is set up and the R-index calculated using the formula (Brown, 1974; O'Mahony, 1986b).

Sample	Response				
	A	A?	B?	B	
A	a	b	c	d	Total = nA
B	e	f	g	h	Total = nB

$$R = \frac{a(f+g+h) + b(g+h) + ch + 1/2(ae+bf+cg+dh)}{nA \ nB} * 100$$

The chance level of distinguishing a signal (difference) from noise (background) is 50%. Always distinguishable samples would receive an R-index of 100%. O'Mahony (1979) likens the noise (anything other than what the difference is based on, i.e. the stimulus background) to random neural firing or as the general sensory background. Unlike binomial distributions commonly used for difference tests (PC, duo-trio, triangle), the R-index can be subjected to parametric statistics (O'Mahony, 1986b). O'Mahony (1974) reports that this method can be used with as little as 20 judgements (10 A and 10 B). The R-index (signal detection measure) also overcomes response bias and is not criterion specific (i.e., each judge chooses his/her own criteria for difference) free. The A-not A difference test outlined by Peryam (1958) and Meilgaard et al. (1987) may be considered a distant cousin to signal detection

measures. The signal detection measure has been used for difference tests of NaCl solutions vs water (O'Mahony et al., 1979a, 1980; O'Mahony, 1972b; O'Mahony and Odbert, 1985), for milk off-flavors (O'Mahony et al., 1979b), for difference tests with flavored water and wine (O'Mahony and Goldstein, 1986), for color, firmness, appearance, and odor of canned peaches (O'Mahony et al., 1983), and for surface appearance of oranges (O'Mahony and Goldstein, 1987b). An added procedure included in the design is the warm-up procedure (O'Mahony and Odbert, 1985). The warm-up procedure allows judges to familiarize themselves with the samples in order to avoid stimulus confusion. The judge is presented with 3-10 pairs of the samples prior to the test and requested to sample until he/she can distinguish between the two (O'Mahony and Goldstein, 1986). The positive effect of a warm-up has been reported by several investigators (Peryam and Swartz, 1951; Boggs and Hanson, 1949; Peryam, 1958; O'Mahony and Odbert, 1985; O'Mahony and Goldstein, 1986). If a difference exists between samples, it is important that it be detected. By presenting a warm-up sample, stimulus confusion can be decreased, thereby increasing test sensitivity. As previously stated, difference test effectiveness can be influenced by adaptation, stimulus confusion, and differential sensitivity. Adaptation may be controllable with interstimulus rinses and stimulus confusion by warm-up procedures. Differential sensitivity among judges may be controllable only by selecting similarly sensitive judges. The criteria on which to base this sensitivity is controversial (Mackey and Jones, 1954) because no two persons have

the same sensitivity. Trant and Pangborn (1983) support this by concluding that sensitivity at threshold levels is not predictive of a person's sensitivity at suprathreshold concentrations across a range.

CHAPTER III

SAMPLE/RINSE TEMPERATURE EFFECT ON SWEET AND SALTY
SENSITIVITY IN A FOOD SYSTEM

I. INTRODUCTION

The effect of temperature on taste perception has not been clearly defined. Lawless (1986) stated that ". . . taste responses are more robust between room temperature and body temperature." The influence of temperature on threshold values has been variable (Paulus and Reisch, 1980; Powers et al., 1971; Pangborn et al., 1970). Sweetness perception of different sugars at varying solution temperatures showed intensity in the order $5^{\circ} < 22^{\circ} < 50^{\circ}\text{C}$ (Hyvonen et al., 1977). Varying combinations of sugars and acids at 6° , 23° , and 50°C , Hyvonen et al. (1978) found a temperature effect that was dependent upon the specific sugar/acid combination.

When considering sample temperature, Gridgeman (1958) found that judges associated hot (37°C) and cold (7°C) samples with a decrease in taste intensity. Stone et al. (1969) stated that in general sweetness intensity increases at higher temperatures in the range of 5° - 50°C . Sample temperature had a greater effect on taste intensity than did the adapting temperature or stimulus concentration employed (McBurney et al., 1973). Moskowitz (1973) also found the temperature effect on taste intensity to be independent of stimulus concentration except for glucose and NaCl.

The effect of temperature on taste thresholds, taste intensity, or thermal perception may also vary with judges. Powers et al.

(1971) found a different optimum temperature for each judge when determining thresholds of different acids. Powers (1977) stated the need for singularity among judges because each person has different oral fluids that may affect sensitivity. He further suggested that temperatures at 6° or 43°C could result in judge stress and not entirely a temperature effect. Subjects were found to exhibit greater discrimination between sample temperatures that ranged from 10°-35°C (O'Connor et al., 1974). Cardello and Maller (1982) addressed food acceptability as a function of temperature.

Peryam and Swartz (1950) recommended that the optimum rinse for palate clearing in sensory testing should be of neutral character and presented at room temperature for room temperature samples and slightly above body temperature for heated samples. The volume of the rinse and the time held in the mouth should also be controlled (McBurney and Pfaffmann, 1963). One advantage of rinsing during sensory testing has been effectiveness in lowering adaptation (O'Mahony and Godman, 1974; O'Mahony and Heintz, 1981). A disadvantage of using water rinses is that water itself exhibits a taste after stimulation by any of the basic tastes (O'Mahony, 1973b; McBurney and Schick, 1971) which may interfere with subsequent tastings. Some have questioned the need for a rinse in sensory testing (McBride and Laing, 1979).

This experiment was designed to study the effect of sample and rinse temperature variations on panelist sensitivity to sweet and salty differences. In order to determine the sensitivity of panelist's to sweet and salty differences in the sample/rinse

temperature variations, an R-index approach to signal detection measurements was employed (O'Mahony, 1979; Brown, 1974). The R-index is a probability value. It reflects the ability of a panelist to distinguish between a pair of samples differing in one component. The R-index value has a range of 50% (chance) to 100% (always distinguishable) (O'Mahony, 1979, 1986b).

II. MATERIALS AND METHODS

Part I. Sweetness Difference Tests

Ten panelists (6 male, 4 female) were chosen on the basis of their ability to identify all four of the basic tastes in water solutions (Jellinek, 1985). The concentrations of the basic taste components used are shown in Appendix A.

Following panelist selection, triangle tests were employed to determine the levels of sucrose to be used in the experiment. Five concentrations of sucrose (Mallinckrodt, Paris, KY) (0.9, 0.8, 0.7, 0.6, and 0.1 g/100 ml) in apple juice (Kroger unsweetened) were used. The four stronger concentrations (0.6, 0.7, 0.8, and 0.9 g/100 ml) were each paired with the weakest concentration (0.1 g/100 ml sucrose) in triangles such that the stronger concentration was presented as the odd sample in one triangle and as the pair in another triangle (e.g., 0.1, 0.1, 0.6 and 0.1, 0.6, 0.6) (Appendix B). This resulted in eight triangle tests with two triangles of each of the four highest concentrations. Samples were presented at ambient temperatures in covered 1-oz white plastic souffle cups (Solo, Chicago, IL) coded with 3-digit random numbers. Orders of

presentation of samples within triangles and among triangles were randomized. All testing took place under white light in individual booths. The sucrose level chosen for subsequent testing was always the lowest concentration that was identified at least 60% of the time (panel composite) as the odd sample in the triangles. This value was 0.9g/100 ml.

Since the objective of this experiment was to compare sample and rinse temperature combinations, samples and rinses were presented in selected combinations of three sample temperatures, 6^o, 24^o, and 50^oC with no rinse or rinses at 6^o, 24^o, and 50^oC (Table 1). Samples (0.1 g/100 ml and 0.9 g/100 ml sucrose in apple juice) were prepared the day prior to testing, pipeted (Lab Industries Repipet Dispenser, Berkeley, CA) into 1-oz white plastic souffle cups and covered with lids. The water used for rinsing was glass-bottled spring water (Mountain Valley, Hot Springs, AR). Samples and rinses were held at ambient temperature for the 24^oC presentations and at 6^oC in a compact refrigerator (Kenmore, model no.564.8963630, Sears, Chicago, IL) for the 6^oC presentations. For 50^oC presentations, the samples were held at ambient temperature until 1.5 hr before testing, at which time they were placed in an incubator at 50^oC (Thelco, Chicago, IL) and allowed to equilibrate. During testing, these samples were held in a steamer or warming tray to maintain temperature.

Prior to testing, panelists were given five pairs of the samples (15 ml) labeled A (0.1 g/100 ml) and B (0.9 g/100 ml) in a warm-up procedure to practice detecting the difference. The

Table 1--Sample/rinse temperature combinations used for sweet and salty difference tests of Experiment I

Sample temperature	Rinse temperature
6°C - Cold (CS)	6°C - Cold (CR)
6°C - Cold (CS)	24°C - Room temperature (RTR)
6°C - Cold (CS)	No rinse (NR)
24°C - Room temperature (RTR)	24°C - Room temperature (RTR)
24°C - Room temperature (RTR)	6°C - Cold (CR)
24°C - Room temperature (RTR)	No rinse (NR)
50°C - Warm (WS)	50°C - Warm (WR)
50°C - Warm (WS)	24°C - Room temperature (RTR)
50°C - Warm (WS)	No rinse (NR)

temperature of the warm-up samples was the same as the sample presentation temperature for the session. This was used to help avoid stimulus confusion. Immediately following the warm-up procedure panelists proceeded to testing. Panelists were presented with 15 ml samples. Fifteen milliliter rinses were presented between samples in the sample/rinse temperature combinations that utilized a rinse. Throughout the test, a sip and expectorate procedure was used. Panelists met for three sessions. In session one and two, they received 10 samples, and in session three they received 20 samples. Data for sessions one and two were combined for one replication. Each replication thus contained 20 samples. Two replications per sample/rinse temperature combination were collected, at which time panelists were divided into groups based on discrimination capabilities. Those who performed significantly greater than chance for all sample/rinse temperature combinations were classified as consistent discriminators (2 panelists); those rarely different from chance for any of the sample/rinse temperature combinations as non-discriminators (3 panelists), and those different from chance most of the time as fluctuating discriminators (5 panelists). Z-scores ($p \leq 0.05$) were calculated to determine if R-index values differed from chance to confirm separation of panelists into these categories. A Z-score of .7559 (R-index value of .60) with a 20 sample test was required to achieve significance from chance. The consistent discriminators and the non-discriminators were not asked to return for the third replication. The fluctuating panelists participated in all three replications for

each of the nine sample/rinse temperature combinations, and the three replications of the fluctuating panelists were used to determine if an optimum (sweet or salty sensitivity) sample/rinse temperature combination existed. The investigator presented all samples and recorded all answers during the test sessions.

After sipping the sample, swishing for up to 5 sec, and expectorating, panelists were asked to respond to a four-point category rating scale:

A - definitely A, (always lower concentration)

A? - perhaps A, not sure,

B - definitely B, and (always higher concentration)

B? - perhaps B, not sure.

This procedure is a modification of signal detection measures (Green and Swets, 1974). From the rating scale, an R-index value can be calculated. The R-index is a probability value. It represents the ability of a panelist to distinguish between two samples. Chance is defined as 50% and R-index values closer to 100% indicate greater distinguishability than those nearer 50% (O'Mahony, 1979, 1986b). The R-index approach to signal detection measures has been outlined completely in Brown (1974) and O'Mahony (1972b, 1979, 1986b).

Part II. Salty Difference Tests

The same procedure as was used for sweetness difference tests (Part I) was used in this part of the experiment, except that NaCl (Mallinckrodt, Paris, KY) (0.05 and 0.14 g/100 ml) was added to the apple juice in levels determined by triangle tests as described in

Part I. NaCl concentrations used in triangle tests were 0.05, 0.12, 0.14, 0.16, and 0.18 g/100 ml. The NaCl concentration labeled A in the experiment was 0.05 g/100 ml and that labeled B was 0.14 g/100 ml. Twenty samples (one replication) per test session were presented throughout the experiment. Non-discriminators (1 panelist) and consistent discriminators (1 panelist) were identified after the second replication of each sample/rinse temperature combination. As in Part I, only the fluctuating panelists (7) were asked to return for the third replication of each sample/rinse temperature combination. Only 9 of the 10 panelists from Part I participated in this part of the experiment.

Data Analysis

Following data collection for each part, responses were tallied, and R-index values were calculated for each panelist for each block of 20 observations (replication) and each sample/rinse temperature combination; means were calculated across blocks for each panelist for each combination. Analyses of variance ($p \leq 0.05$) (SAS Institute Inc., 1985) of mean R-index values of sample/rinse temperature combinations for all panelists were performed using only panelist and treatment as main effects. Conditions were grouped to make logical comparisons where sample temperatures and/or rinse temperatures were alike (Table 2). ANOVA's of R-index values (groups in Table 2) of the fluctuating panelists were performed using effects attributable to treatment (sample/rinse temperature combination), panelist, replication, panelist X replication,

Table 2--Sample/rinse temperature combination groups used in analyses of variance for Experiment I

Group	Sample/rinse temperature combination ^a
I	CS/CR RTS/RTR WS/WR
II	CS/NR RTS/NR WS/NR
III	CS/RTR RTS/RTR WS/RTR
IV	CS/CR CS/RTR CS/NR
V	RTS/RTR RTS/CR RTS/NR
VI	WS/WR WS/RTR WS/NR

^aCS, RTS, WS = cold, room temperature, warm samples;
CR, RTR, WR, NR = cold, room temperature, warm, no
rinse(s).

treatment X replication, and panelist X treatment in the model. The purpose of this was to determine if the fluctuating panelists exhibited greater sensitivity in any one of the sample/rinse temperature combinations. All non-significant interactions ($p > 0.05$) were dropped from the model and means were separated using Tukey's test at a P value of 0.05.

III. RESULTS AND DISCUSSIONS

Part I. Sweetness Difference Tests

This experiment was designed to identify differential sensitivity of panelists to sweetness differences in a food system presented at varying sample/rinse temperature combinations. ANOVA results for group analyses (Table 2) using all panelists are listed in Table 3. Because all panelists (consistent discriminators, fluctuating, and non-discriminators) were used in the analyses, panelist differences would be expected. The results show panelist differences for all analysis groups of sample/rinse temperature combinations. Sample/rinse temperature combination means for the group analyses for all panelists are shown in Table 4. Powers et al. (1971) found that panelists exhibited different temperature optimums when they determined threshold values of different acids at varying temperatures. To eliminate the source of variation of panelists, only those panelists who fluctuated in performance across the nine sample/rinse temperature combinations were used in additional ANOVA's. The consistent discriminators were not used because they performed appreciably better than other panelists

Table 3--Mean squares and significance of F-ratios for all panelists for varying sample/rinse temperature combinations in sweet and salty difference tests

Group Sample/ rinse temperature ^a	Source	Sweet		Salty	
		df	Mean square	df	Mean square
I					
CS/CR	Panelist	9	.0323***	8	.0322**
RTS/RTR	Treatment	2	.0068	2	.0261*
WS/WR	Error	18	.0030	16	.0061
II					
CS/NR	Panelist	9	.0256*	8	.0691***
RTS/NR	Treatment	2	.0005	2	.0285
WS/NR	Error	18	.0072	16	.0108
III					
CS/RTR	Panelist	9	.0327***	8	.0393***
RTS/RTR	Treatment	2	.0002	2	.0318*
WS/RTR	Error	18	.0048	16	.0049
IV					
CS/CR	Panelist	9	.0293**	8	.0407***
CS/RTR	Treatment	2	.0017	2	.0041
CS/NR	Error	18	.0066	16	.0064
V					
RTS/RTR	Panelist	9	.0373***	8	.0682***
RTS/CR	Treatment	2	.0023	2	.0042
RTS/NR	Error	18	.0051	16	.0083
VI					
WS/WR	Panelist	9	.0186***	8	.0506***
WS/RTR	Treatment	2	.0037	2	.0032
WS/NR	Error	18	.0032	16	.0040

^aCS, RTS, WS = cold, room temperature, warm samples; CR, RTR, WR, NR = cold, room temperature, warm, no rinse(s).

*** P < 0.001, ** P < 0.01, * P < 0.05.

Table 4--R-index means^{ab} for sweet and salty difference tests for varying sample/rinse temperature combinations from analyses of all panelists and fluctuating panelists

Group Sample/ rinse temperature ^c	All panelists		Fluctuating panelists	
	Sweet (n=30)	Salty (n=27)	Sweet (n=15)	Salty (n=21)
I				
CS/CR	.60 ± .11x	.68 ± .10xy	.64 ± .13x	.65 ± .12y
RTS/RTR	.62 ± .13x	.74 ± .10x	.65 ± .13x	.76 ± .14x
WS/WR	.65 ± .09x	.64 ± .13y	.68 ± .08x	.60 ± .13y
II				
CS/NR	.62 ± .10x	.64 ± .17x	.63 ± .11x	.62 ± .18y
RTS/NR	.63 ± .14x	.75 ± .20x	.62 ± .13x	.74 ± .22x
WS/NR	.62 ± .09x	.66 ± .15x	.61 ± .10x	.62 ± .13y
III				
CS/RTR	.62 ± .14x	.67 ± .12xy	.61 ± .13x	.68 ± .16xy
RTS/RTR	.62 ± .13x	.74 ± .13x	.65 ± .13x	.76 ± .14x
WS/RTR	.61 ± .09x	.63 ± .14y	.63 ± .11x	.65 ± .12y
IV				
CS/CR	.60 ± .11x	.68 ± .10x	.64 ± .13x	.65 ± .12x
CS/RTR	.62 ± .14x	.67 ± .12x	.60 ± .13x	.68 ± .16x
CS/NR	.62 ± .10x	.64 ± .17x	.63 ± .11x	.62 ± .18x
V				
RTS/RTR	.62 ± .13x	.74 ± .13x	.65 ± .13x	.76 ± .14x
RTS/CR	.65 ± .10x	.71 ± .17x	.69 ± .09x	.72 ± .16x
RTS/NR	.63 ± .14x	.75 ± .20x	.62 ± .13x	.74 ± .22x
VI				
WS/WR	.65 ± .10x	.64 ± .13x	.68 ± .08x	.60 ± .13x
WS/RTR	.61 ± .09x	.63 ± .14x	.63 ± .11x	.65 ± .12x
WS/NR	.62 ± .09x	.66 ± .15x	.61 ± .10x	.62 ± .13x

^aMeans ± SD.

^bR-index means followed by different letters within a grouping for all or fluctuating panelists for sweet or salty tests differ $P < 0.05$.

^cCS, RTS, WS = cold, room temperature, warm samples; CR, RTR, WR, NR = cold, room temperature, warm, no rinse(s).

regardless of the temperature used, and so they would be able to discriminate differences in any sample/rinse temperature combination that prevailed as optimally better than the others. Pangborn and Trabue (1964) stated that panelists should be separated on the basis of discrimination capabilities because all panelists are not equivalent.

The ANOVA results for sweetness difference tests of different sample/rinse temperature combinations for fluctuating panelists are shown in Table 5. Differences among panelists were not found. No treatment differences were found either; only replication was significant for the group of room temperature samples and varying rinse conditions (Group V - RTS/RTR, RTS/CR, and RTS/NR). This is attributed to the lack of consistency of judges' performances from day to day, which may be a motivational error. The investigator's subjective observation was that panelists performed better (higher R-index values) on days in which they were in "good moods" than on days in which they appeared to be "under stress." Sample/rinse temperature combination R-index means for fluctuating panelists are shown in Table 4. The fact that no differences occur among the treatments indicates that panelists were no better at discriminating differences in sweetness at one temperature of sample and rinse combination than any other. Hyvonen et al. (1977), however, found sweetness intensity in the order $5^{\circ} < 22^{\circ} < 50^{\circ}\text{C}$. Stone et al. (1969) found no temperature effect on relative sweetness of sugars. Because all R-index values (means from all panelists - Table 4) were significantly different from chance (Z scores, $p < 0.05$), it would

Table 5--Mean squares and significance of F-ratios for sweet and salty difference tests of fluctuating panelists for varying sample/rinse temperature combinations

Group Sample/ rinse temperature ^a	Source	Sweet		Salty	
		df	Mean square	df	Mean square
I					
CS/CR	Panelist (P)	4	.0191	6	.0339
RTS/RTR	Treatment (T)	2	.0063	2	.1399***
WS/WR	Replication (R)	2	.0343	2	.0104
	Error	36	.0120	52	.0155
II					
	Panelist	4	.0105	6	.1233***
CS/NR	Treatment	2	.0019	2	.1069**
RTS/NR	Replication	2	.0079	2	.0210
WS/NR	P X T	-		12	.0351*
	P X R	-		12	.0278*
	Error	36	.0144	28	.0124
III					
	Panelist	4	.0063	6	.0525**
CS/RTR	Treatment	2	.0088	2	.0627*
RTS/RTR	Replication	2	.0317	2	.0202
WS/RTR	T X R	-		4	.0502**
	Error	36	.0159	48	.0128
IV					
	Panelist	4	.0095	6	.0793***
CS/CR	Treatment	2	.0052	2	.0172
CS/RTR	Replication	2	.0100	2	.0495
CS/NR	Error	36	.0164	52	.0160
V					
	Panelist	4	.0165	6	.0105***
RTS/RTR	Treatment	2	.0163	2	.0084
RTS/CR	Replication	2	.0634**	2	.0081
RTS/NR	P X T	-		12	.0298*
	P X R	-		12	.0365**
	T X R	-		4	.0502**
	Error	36	.0116	24	.0100
VI					
	Panelist	4	.0056	6	.0332*
WS/WR	Treatment	2	.0185	2	.0167
WS/RTR	Replication	2	.0110	2	.0029
WS/NR	Error	36	.0103	52	.0146

^aCS, RTS, WS = cold, room temperature, warm samples; CR, RTR, WR, NR = cold, room temperature, warm, no rinse(s).

*** P < 0.001, ** P < 0.01, * P < 0.05.

seem that any of the temperatures tested in this study (6°, 24°, 50°C) would give similar results in sweetness difference tests using the R-index approach to signal detection measurements. The validity of the results in revealing a difference could be questioned on the basis of the standard deviations of the means. At least a .6 R-index is required to be significantly different from chance with at least 20 samples in the test. If the R-index values lie in the .6-.7 range and large standard deviations are present, it means that even within fluctuating panelists, some would be more sensitive than others to the differences present (as in this study). Whether these results would apply to a larger population must be questioned. On the basis of the data presented, no conclusion can be drawn as to one sample/rinse temperature combination resulting in an optimum for sweetness sensitivity.

Part II. Salty Difference Tests

ANOVA results across the nine sample/rinse temperature combinations for all panelists are shown in Table 3. As expected, panelist differences were found in all ANOVA groups. Treatment differences were found when comparing combinations with identical sample and rinse temperatures (Group I - CS/CR, RTS/RTR, WS/WR) and the combinations with varying sample temperatures and room temperature rinses (Group III - CS/RTR, RTS/RTR, WS/RTR). ANOVA results of only fluctuating panelists are shown in Table 5, and results of fluctuating panelists will be referred to from now on in the discussion. R-index sample/rinse temperature combination

(treatment) means are shown in Table 4. When comparing sample/rinse temperature combinations with like sample and rinse temperatures (Group I), the R-index value for RTS/RTR was significantly different ($p < 0.05$) from those for CS/CR and WS/WR. This indicates a greater sensitivity to salty differences in apple juice at room temperature (24°C) than either cold (6°C) or warm (50°C) temperatures. Powers (1977) suggested that temperatures at cold (6°C) or warm (43°C) settings could introduce thermal stress and not represent a sensory difference attributable to a temperature difference. Moskowitz (1973) found that NaCl taste intensity was affected by temperature.

Within the no rinse sample/rinse temperature combination (Group II), RTS resulted in a significantly higher ($p < 0.05$) R-index mean than either CS or WS temperatures. Without a rinse present, when adaptation would be more likely to occur, salty differences were more detectable in room temperature samples ($\text{R-index} = .74 \pm .22$). Significant differences within this comparison were also noted for panelists, panelist X treatment, and panelist X replication. Panelist X treatment R-index means are shown in Table 6. Panelist performances were similar in CS/NR and RTS/NR, than CS/NR and WS/NR or RTS/NR and WS/NR ($r_s = .78, .45, \text{ and } .49$, respectively). The variation among panelists within the combinations CS/NR and RTS/NR were probably attributable to a number of high R-index values (.8 and above). The panelist X replication interaction indicates lack of panelist consistency over test days, which may be attributed in part to panelist motivation as previously discussed. When

Table 6--R-index means^{ab} for panelist X treatment interaction for salty difference tests of varying sample temperatures without a rinse

Panelist	Sample/rinse temperature combination		
	CS/NR ^c	RTS/NR ^c	WS/NR ^c
	-----R-index-----		
2	.45 ± .13z	.47 ± .12yz	.63 ± .03vwxyz
4	.65 ± .09vwxyz	.52 ± .21xyz	.57 ± .21wxyz
5	.55 ± .23xyz	.80 ± .30vwxy	.47 ± .10yz
6	.57 ± .06wxyz	.84 ± .10vw	.57 ± .12wxyz
7	.73 ± .10vwxyz	.90 ± .01vw	.68 ± .06vwxyz
9	.50 ± .09xyz	.73 ± .10vwxyz	.65 ± .05vwxyz
10	.90 ± .05vw	.93 ± .06v	.75 ± .09vwxyz

^aMeans ± SD; means of R-index values across 3 replications.

^bR-index means followed by different letters differ $P < 0.05$; LSD = .35.

^cCS, RTR, WS = cold, room temperature, warm samples; NR = no rinse.

different sample temperatures with room temperature rinses were compared (Group III), panelist, treatment, and treatment X replication were significant in the model (Table 5). Differences in treatment R-index means (Table 4) show that RTS/RTR was different from WS/RTR, but not from CS/RTR. Again, it appears that differences in salty sensitivities are attributed more to sample temperature than rinse temperature. McBurney et al. (1973) stated that sample temperature affected taste intensity more than an adapting stimulus or stimulus concentration. Treatment X replication R-index means (Group III) are shown in Table 7. Within CS/RTR combination, differences occurred between replication 1 and 2, but 1 and 3 and 2 and 3 were not significantly different ($p > 0.05$). No trends are evident, and treatment X replication differences are attributed to variability among judges' motivation on the days of testing. This suggests the need for replication of the R-index test when cold samples are used. When only one replication is completed, the panelist may perform poorly and differences not be noted if they exist.

The ANOVA results for all three sample/rinse temperature combinations where a cold sample with varying rinse temperatures (Group IV) was tested show a panelist difference (Table 5). Treatment R-index means ranged from .62 to .68 (Table 4), which indicates that the rinse temperature or no rinse did not affect discrimination abilities of the panelists when cold samples were used. Panelist means ranged from .53 to .83 and the differences

Table 7--R-index means^{ab} for treatment (sample/rinse temperature combination) X replication interaction for salty difference tests of sample temperature variations with room temperature rinses (III) and room temperature samples with rinse variation (V)

Group Sample/rinse ^c	Replication		
	1	2	3
-----R-index-----			
III			
CS/RTR	.76 ± .13x	.56 ± .18y	.71 ± .06xy
RTS/RTR	.67 ± .16xy	.80 ± .12x	.79 ± .12x
WS/RTR	.67 ± .13xy	.63 ± .12xy	.66 ± .13xy
V			
RTS/RTR	.67 ± .16x	.80 ± .12x	.79 ± .12x
RTS/CR	.79 ± .14x	.70 ± .21x	.65 ± .11x
RTS/NR	.81 ± .14x	.67 ± .22x	.74 ± .28x

^aMeans ± SD; mean R-index values across 7 panelists.

^bR-index means followed by different letters within a group differ P < 0.05; LSD for Group III = .20, for Group V = .18.

^cCS, RTS, WS = cold, room temperature, warm samples; CR, RTR, WR, NR = cold, room temperature, warm, no rinse(s).

were attributed to differential salt sensitivities for each panelist at cold sample temperatures.

The ANOVA results for all three sample/rinse temperature combinations (treatment) that compared RT samples with varying rinse conditions (Group V) showed that panelist, panelist X treatment, panelist X replication, and treatment X replication were significant. Treatment means (fluctuating panelists) ranged from .72 to .76 (Table 4), indicating a high level of sensitivity to salty differences at room temperature regardless of the rinse temperature. Panelist X treatment R-index means are shown in Table 8. Panelist performances were more alike for RTS/CR and RTS/NR (r_s .74) than for RTS/RTR and RTS/NR (r_s .41) or RTS/RTR and RTS/CR (r_s .48). Panelist X replication differences are an indication of panelist variability (lack of individual consistency) within the replications. This could be a result of panelist motivation changes on different days (as discussed previously) of testing because a panelist was unable to replicate his/her performance within the same sample/rinse temperature combination. The treatment X replication interaction R-index means are shown in Table 7. No significant differences are identifiable among the means.

The ANOVA results for warm sample temperatures with different rinse conditions (Group VI) are shown in Table 5. Only panelist differences were present. This again points to the different sensitivities of panelists to salt at warm temperatures. Sample/rinse temperature combination R-index means ranged from .60 to .65. Because no differences were noted among the treatments, it

Table 8--R-index means^{ab} for panelist X treatment interaction for salty difference tests of room temperature samples with variations in the rinse

Panelist	Sample/rinse temperature combination		
	RTS/RTR ^c	RTS/CR ^c	RTS/NR ^c
	-----R-index-----		
2	.66 ± .20xyz	.52 ± .23yz	.47 ± .12z
4	.83 ± .02xy	.74 ± .17xyz	.52 ± .21yz
5	.67 ± .10xyz	.77 ± .21xyz	.80 ± .30xy
6	.74 ± .11xyz	.61 ± .04xyz	.84 ± .10xy
7	.74 ± .19xyz	.83 ± .04xy	.90 ± .01x
9	.75 ± .17xyz	.72 ± .13xyz	.73 ± .10xyz
10	.91 ± .03x	.83 ± .06xy	.93 ± .06x

^aMeans ± SD; mean of three R-index values.

^bR-index means followed by different letters differ $P < 0.05$; LSD = .33.

^cRTS = room temperature samples; CR, RTR, NR = cold, room temperature, no rinse(s).

can be concluded that the rinse temperature had no effect on panelist sensitivity to salt for warm temperature samples.

General trends to be noted from the analyses of R-index values of salty difference tests for fluctuating panelists are: 1) When sample and rinse temperatures were the same, room temperature samples resulted in greater discrimination to salty differences than either cold or warm samples; 2) When samples at different temperatures were presented without a rinse, salty discrimination by panelists was greater with room temperature samples than with cold or warm samples; 3) When sample temperatures varied and only room temperature rinses were used, discrimination in room temperature samples was greater than or equal to cold samples which was equal to warm; 4) No differences were found among cold samples, warm samples, or room temperature samples in combination with varying rinse temperatures; 5) The sample temperature tends to have more effect on salt discrimination than does the rinse temperature; 6) Interactions involving panelist X treatment and panelist X replication indicate different sensitivities to salty by panelists at varying temperatures and lack of panelist consistency across a sample/rinse temperature combination, respectively, and 7) Treatment X replication interactions indicate lack of consistent performance across replications within a temperature condition for the panelists.

The greater sensitivity of panelists to salt (in a food system) at 24°C is also supported by Pangborn et al. (1970). They found that sensitivity to NaCl was greater at 22° or 37°C than at 0° or

55°C in water solutions. The lack of a rinse temperature effect on salty differences presently does not support the suggestion by Peryam and Swartz (1950) that room temperature rinses be presented with room temperature samples and that warm samples have slightly above body temperature rinses.

IV. SUMMARY

From the results of this experiment, it is concluded that sensitivity to sweetness differences is not affected by the sample or rinse temperature variations tested in this study. Salty differences are, however, affected by temperature variations. The sample temperature appears to have a greater effect on sensitivity to salt than does the rinse temperature, with room temperature samples resulting in greater salt sensitivity (higher R-index values). Because the levels of NaCl used in this experiment are in line with those considered to be low levels in food (0.05%-0.8%) (Pangborn and Chrisp, 1964; Pangborn and Trabue, 1964), it would be reasonable to expect sweetness enhancement in the apple juice by the salt. If the sweetness was then the overriding basic taste in the solution, then one would have to consider the temperature optimum for sweet and salty to be able to optimize sensitivity to these taste compounds. Paulus and Reisch (1980) found sweet thresholds at different temperatures in the order $60^{\circ} > 10^{\circ} > 20^{\circ} = 40^{\circ}\text{C}$ and salty thresholds in the order $40^{\circ} > 20^{\circ} = 10^{\circ}\text{C}$. These data indicate a temperature optimum for sweet in the $20^{\circ}\text{--}40^{\circ}\text{C}$ range and for salty in the $10^{\circ}\text{--}20^{\circ}\text{C}$ range. Both these are near to or encompass the room

temperature optimum which was found in the present study for salty differences in a sweet (apple juice) food system.

CHAPTER IV

SOLVENT EFFECTS ON SWEET AND SALTY

SENSITIVITY IN A LARGE

STIMULUS SET

I. INTRODUCTION

Several researchers have pointed out that sensitivity to basic tastes in water solutions does not extend to complex food systems where two or more of the basic tastes are present (Mackey and Jones, 1954; Trant and Pangborn, 1983). Taste interactions have been reported in studies in which water solutions (Pangborn, 1960), tomato juice (Pangborn and Chrisp, 1964) and lima bean puree (Pangborn and Trabue, 1964) have been the solvents. Generally, the addition of a second taste quality to a singular solution results in altered perception of the taste quality initially present. One could expect a decrease in or enhancement of the primary taste quality upon addition of a second taste quality. The interaction of sucrose and NaCl in tomato juice has been reported (Pangborn and Chrisp, 1964). The addition of low levels of NaCl (0.05%-0.8%) to different sweetness levels in juice enhanced the sweetness; high levels (1.6%) of NaCl decreased apparent sweetness. The addition of increasing levels of sucrose to salty tomato juice decreased "greatly" the perceived saltiness at high levels of NaCl (0.8 and 1.6%) and only slightly decreased perceived saltiness at low NaCl levels (0.2 and 0.4%). In lima bean puree, sweetness was enhanced by low NaCl levels and depressed at high NaCl levels (Pangborn and

Trabue, 1964). The authors reported that the interactions in the food systems were similar to those found in water solutions (Pangborn, 1962). These interactions were noted for suprathreshold concentrations of taste substances. Reaction times for salty or sweet vs. water have been reported as .73 sec and .95 sec, respectively. When subjects had to discriminate between these tastes in combinations, the reaction times increased to 1.44 sec for both tastes (Kuznicki and Turner, 1986). Ennis and Mullen (1985) stated that discrimination ability in complex systems would depend on the "discriminal distances between stimuli and the number of dimensions present." In a multidimensional stimulus with only one dimension in difference, a large difference or large sample sizes would be required to note differences if they existed.

Studies involving taste interactions in water solutions have shown that all four basic taste substances (sucrose, citric acid, NaCl, caffeine) decreased the intensity of the others when two substances were combined in sub-threshold, threshold, and supra-threshold concentrations (Pangborn, 1960). Trant and Pangborn (1983) stated that sensitivity to a taste compound at threshold levels was not an indication of sensitivity at supra-threshold levels. Evidence of a water taste (O'Mahony, 1972a; McBurney, 1974) further supports the impracticality of using sensitivity in water solutions to indicate similar sensitivity in complex food systems.

Taste adaptation has been defined as the "subjective intensity decline of a stimulus" (Ganzevles and Kroeze, 1987). Gillan (1984) extended that definition to include "a decrease in attention to or

processing of a persistent stimulus." Taste residuals in the mouth from prior stimuli could be expected to produce adaptation to the taste substance over a large stimulus set. Because sucrose and NaCl failed to cross-adapt one another (Ganzevles and Kroeze, 1987), it was suggested that they compete for different taste receptors (Lawless and Stevens, 1983; Kroeze, 1978).

In order to determine the sensitivity of panelists to sweet and salty differences in water and apple juice, an R-index approach to signal detection measurements was employed (O'Mahony, 1979; Brown, 1974) in this experiment. The R-index is a probability value. It reflects the ability of a panelist to distinguish between a pair of stimuli. The R-index value has a range of 50% (chance) to 100% (always distinguishable) (O'Mahony, 1979, 1986b). R-index values calculated across a large stimulus set can be used to indicate a panelist's level of sensitivity to a taste substance in a solvent. The increase or decrease in R-index values across a stimulus set can also be an indication of any occurrence of adaptation.

II. MATERIALS AND METHODS

Part I. Sweetness Difference Tests

Ten panelists (6 female, 4 male) participated in the experiment. On the day of testing, sucrose (0.35 g/100 ml) (Mallinckrodt, Paris, KY) was mixed with glass-bottled spring water (Mountain Valley, Hot Springs, AR) and held at ambient temperature for not longer than 1 hr. Prior to presentation, 10-ml samples (water or sucrose solution) were dispensed (Lab Industries Repipet

Dispenser, Berkeley, CA) into 1-oz white plastic souffle cups. Panelists received 5 15-ml samples of water (labeled "A") and 5 15-ml samples of the sucrose solution (labeled "B") for a warm-up session before testing each day in order to avoid stimulus confusion (O'Mahony and Odibert, 1985) and to aid in differentiation between the samples. When difficulty arose in difference detection, panelists were offered two additional pairs of warm-up samples. Panelists were required to verbalize the difference between the samples before testing proceeded. Following warm-up, panelists were allowed a 100-ml mouthrinse of bottled water during a 2-min wait before testing began. All warm-up samples and the rinse were expectorated.

Panelists then proceeded to the test which consisted of tasting 100 10-ml water samples and 100 10-ml sucrose samples at ambient temperature (24°C) in random orders. Stipulations of ordering required that 10 of each sample be presented in every block of 20, but no more than 6 consecutive samples of either A or B occurred in a sequence of 200 samples. Panelists were instructed to sip the entire sample, swish for up to 5 sec, expectorate, and respond with one of four possible alternatives:

A - definitely A (water),

A? - perhaps A, but not sure,

B - definitely B (sucrose),

B? - perhaps B, but not sure (O'Mahony, 1979).

Testing continued without pausing between samples or using interstimulus rinses until the 200 samples were tasted. All samples

were presented consecutively and all responses recorded by the investigator. Sessions lasted 20-35 min.

To determine the panelists' sensitivities to sucrose in a liquid food system, sucrose was added to apple juice (Kroger unsweetened) in two levels determined with triangle tests as explained in Experiment I (Chapter III). The concentrations used were 0.1 g/100 ml and 0.8, 0.9, 1.0, and 1.1 g/100 ml sucrose. The concentrations chosen for use in the experiment were 0.1 and 1.0 g/100 ml sucrose, using the 60% requirement of odd sample identification as in Experiment I (Chapter III). The same test procedure as was used with the water solutions was used in this portion of the experiment. Panelists participated first in the water solution test before the food system test, and panelists only participated in one test session per day.

To determine the effect of learning during the test session, five of the panelists were given feedback (correct, incorrect) after each sample through the first 100 samples of the water and apple juice solutions. The other five panelists received no feedback during this part of the experiment.

Part II. Salty Difference Tests

The same panelists that participated in Part I of this experiment also participated in this part. Samples were prepared by adding NaCl (Mallinckrodt, Paris, KY) to bottled water to obtain a 0.029 g/100 ml concentration (O'Mahony et al., 1979b). The water sample was labeled A and the salt sample was labeled B for the

warm-up session. The same procedure that was used in Part I was also used in this test. The liquid food system portion of the experiment consisted of apple juice (Kroger unsweetened) to which two levels of NaCl (0.05 and 0.18 g/100 ml) were added. The levels were determined with triangle tests in which 0.05 g/100 ml NaCl was tested against 0.16, 0.18, 0.20, 0.22 g/100 ml NaCl in the same procedure outlined in Experiment I (Chapter III).

The five panelists that received no feedback in Part I (sweetness) received feedback in this part; the remaining five received no feedback.

Data Analysis

Following data collection, R-index values (Brown, 1974; O'Mahony, 1979) were calculated for each panelist for each experiment as outlined in Table 9. To determine the effect of learning (feedback), an analysis of variance was performed using the cumulative R-index values for samples 1-100 and 101-200 for each panelist. Salt and sucrose test data were analyzed separately in ANOVA (SAS Institute, Inc., 1985). The model included the main effects of solvent (water, apple juice), panelist/feedback, block (1-100, 101-200), and feedback, and the interactions panelist/feedback X solvent, panelist/feedback X block, block X feedback, solvent X feedback, solvent X block, and solvent X block X feedback. All non-significant ($p > 0.05$) interactions were dropped from the model.

Table 9--Summary of R-index values calculated across a 200 sample test

Repeated	Cumulative	Feedback
1-20	1-20	
21-40	1-40	
41-60	1-60	1-100
61-80	1-80	
81-100	1-100	
101-120	1-120	
121-140	1-140	
141-160	1-160	101-200
161-180	1-180	
181-200	1-200	

An analysis of variance was performed on repeated and cumulative R-index values for salt and sucrose (both water and apple juice) each. The model included as factors: panelist, treatment (water-salt, water-sucrose, apple juice-salt, and apple juice-sucrose), blocks (number of samples, e.g. 20, 40,... 200 etc.), panelist X treatment, treatment X blocks, and panelist X blocks. All non-significant ($p > 0.05$) interactions were dropped from the model, and mean separations were carried out using Tukey's test at a P value of 0.05. The repeated R-index values were used to determine if differences occurred among the blocks (of 20); an indication of performance consistency among the panelists. The cumulative R-index values were used to determine if adaptation took place across the stimulus set. Both repeated and cumulative R-index values were used to determine if performance (sensitivity) in water was related to one's sensitivity in a liquid food system (apple juice).

An analysis of variance was also performed to determine differences in panelist performance between sucrose (or salt) in water solutions vs. a liquid food system. Cumulative R-index values for panelists were compared to individual R-index values (every block of 20) for differences in performance across the 200 samples.

III. RESULTS AND DISCUSSION

This experiment was designed to investigate the effect of feedback and solvent (water or apple juice) on panelist sensitivity to sucrose or NaCl across a large stimulus set. Because the

stimulus set contained 200 stimuli, the occurrence of adaptation would also be important and was considered. Learning during the test session was determined by comparing R-index values of groups of panelists who received feedback during the test with those who did not receive feedback. To determine if feedback had an effect on learning, analyses of variance were performed on salt and sucrose data. The analysis of variance tables for the final models are shown in Table 10. The results revealed that feedback was not significant in either the salt or the sucrose tests. Panelists receiving feedback performed no better than those that did not receive feedback, indicating that learning did not take place. Figures 1-4 show the variability encountered among panelists receiving feedback and those who did not receive feedback in all four tests. No clear patterns of learning developed between the two groups in any of the four tests.

Because no differences were found for feedback, the repeated and cumulative R-index values were then analyzed for the salt and sucrose tests. Repeated data (Appendix C) were analyzed primarily to determine if panelists performed significantly better in one block of 20 samples than the other blocks or if sensitivity varied (increasing or decreasing R-index values) across the stimulus set of 200. Cumulative data (Appendix C) were analyzed to determine if adaptation (decreasing R-index values) occurred across the stimulus set. Both sets of data were examined for differences between panelist sensitivity in water and apple juice, as one of the objectives of the experiment was to determine if one's sensitivity

Table 10--Mean squares and significance of F-ratios for the effect of feedback on sucrose and salt tests

Source	df	Mean square	
		Sucrose	Salt
Feedback (FB)	1	.0002	.0410
Panelist/Feedback (P/FB) ^a	8	.0379***	.0242***
Solvent (S)	1	.0010	.0168
Block (B)	1	.00004	.0004
P/FB X S	9	.0141***	.0481***
Error	19	.0012	.0040

^aError term for feedback.

*** P < 0.001.

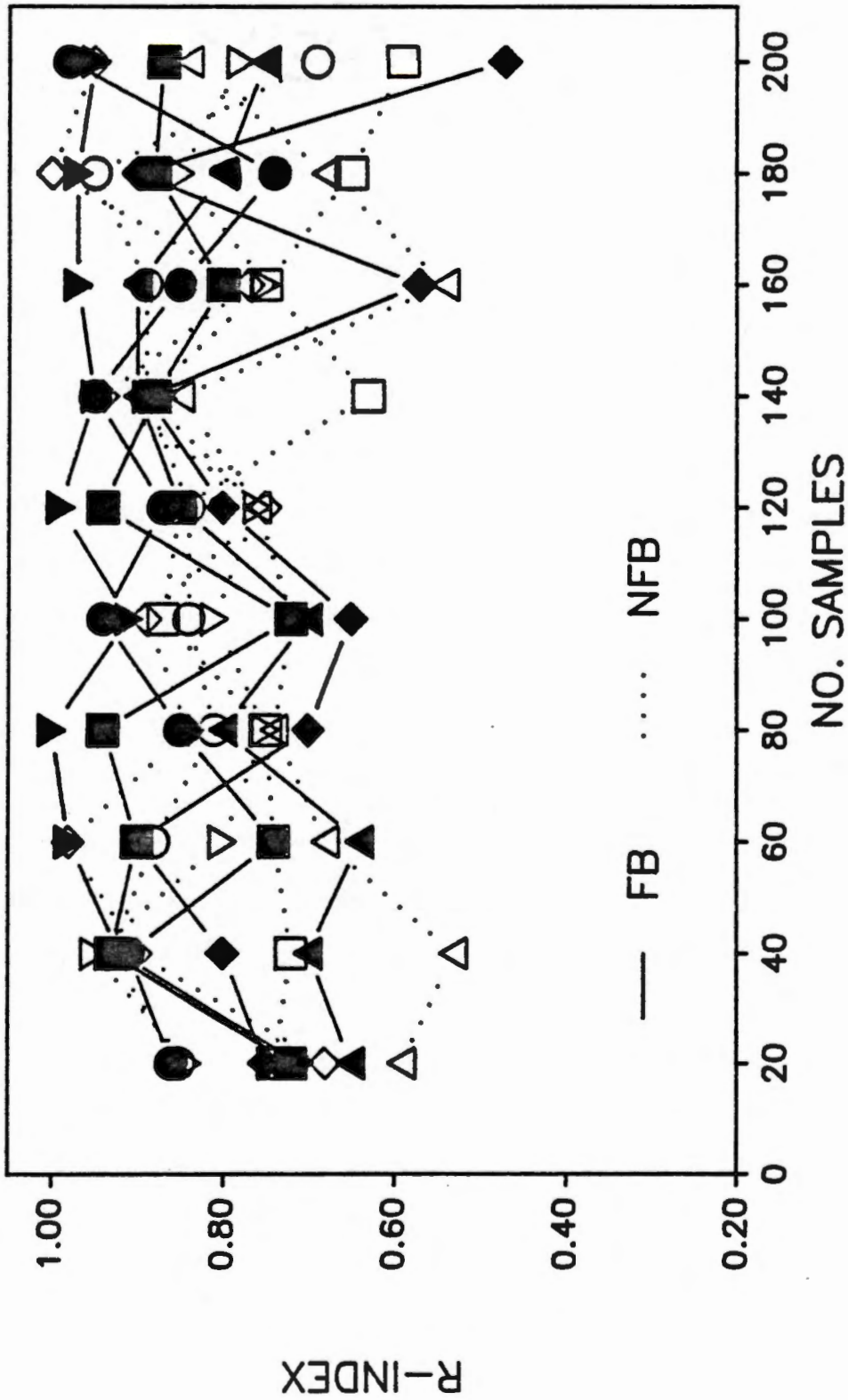


Figure 1--Effect of feedback (FB) and nonfeedback (NFB) on R-index values of panelists across a 200 sample test of salt-water.

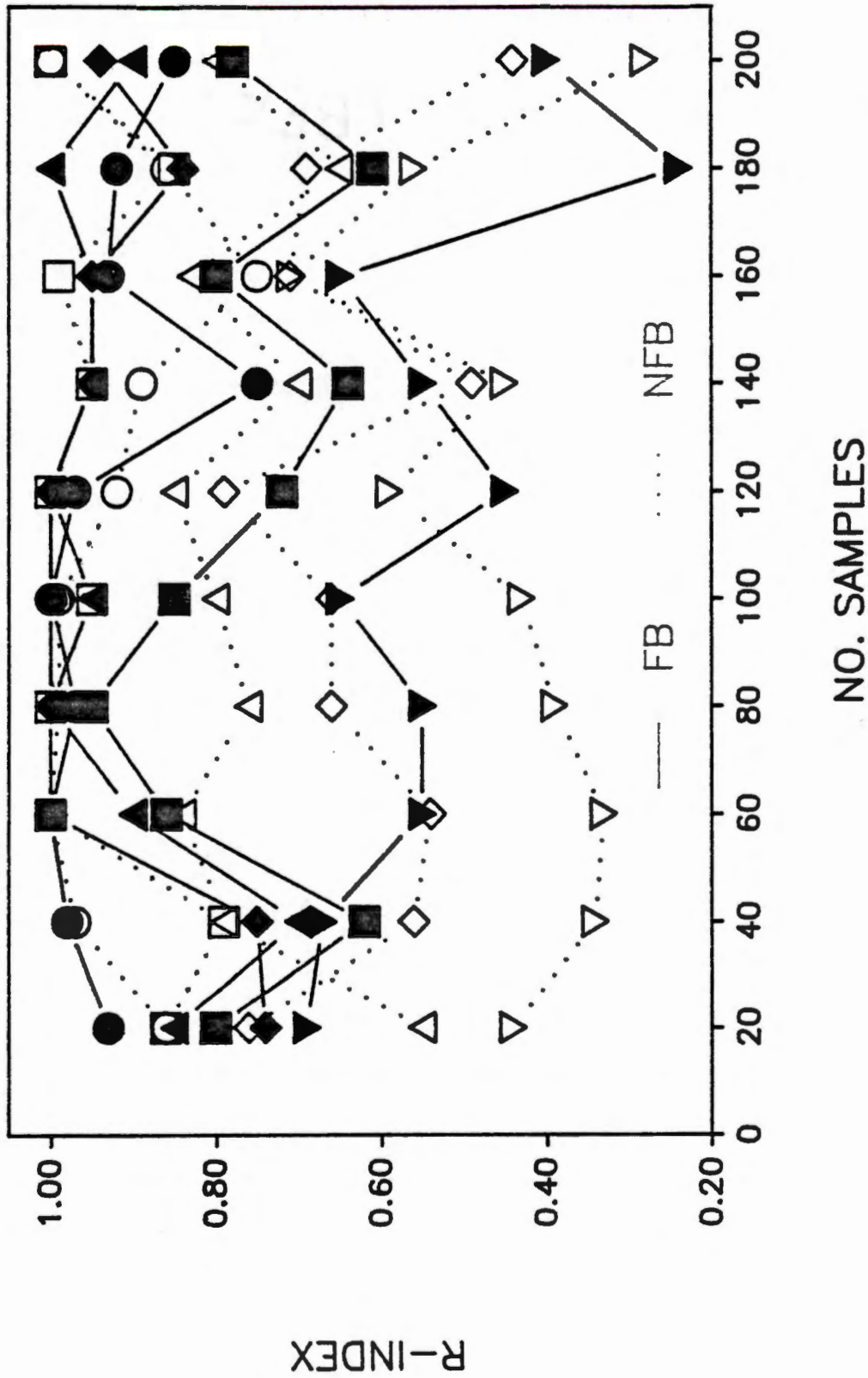


Figure 2--Effect of feedback (FB) and nonfeedback (NFB) on R-index values of panelists across a 200 sample test of salt-apple juice.

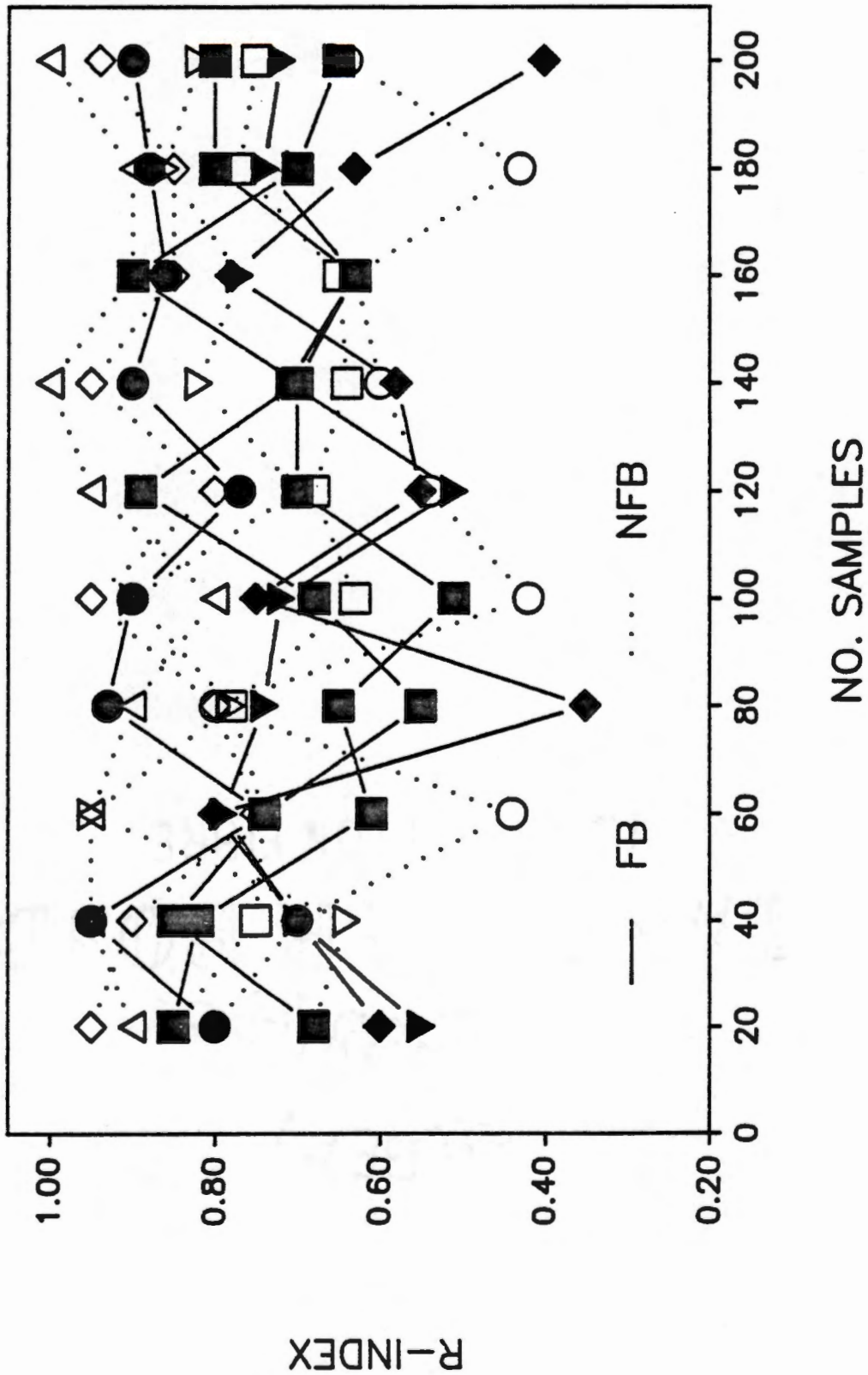


Figure 3--Effect of feedback (FB) and nonfeedback (NFB) on R-index values of panelists across a 200 sample test of sucrose-water.

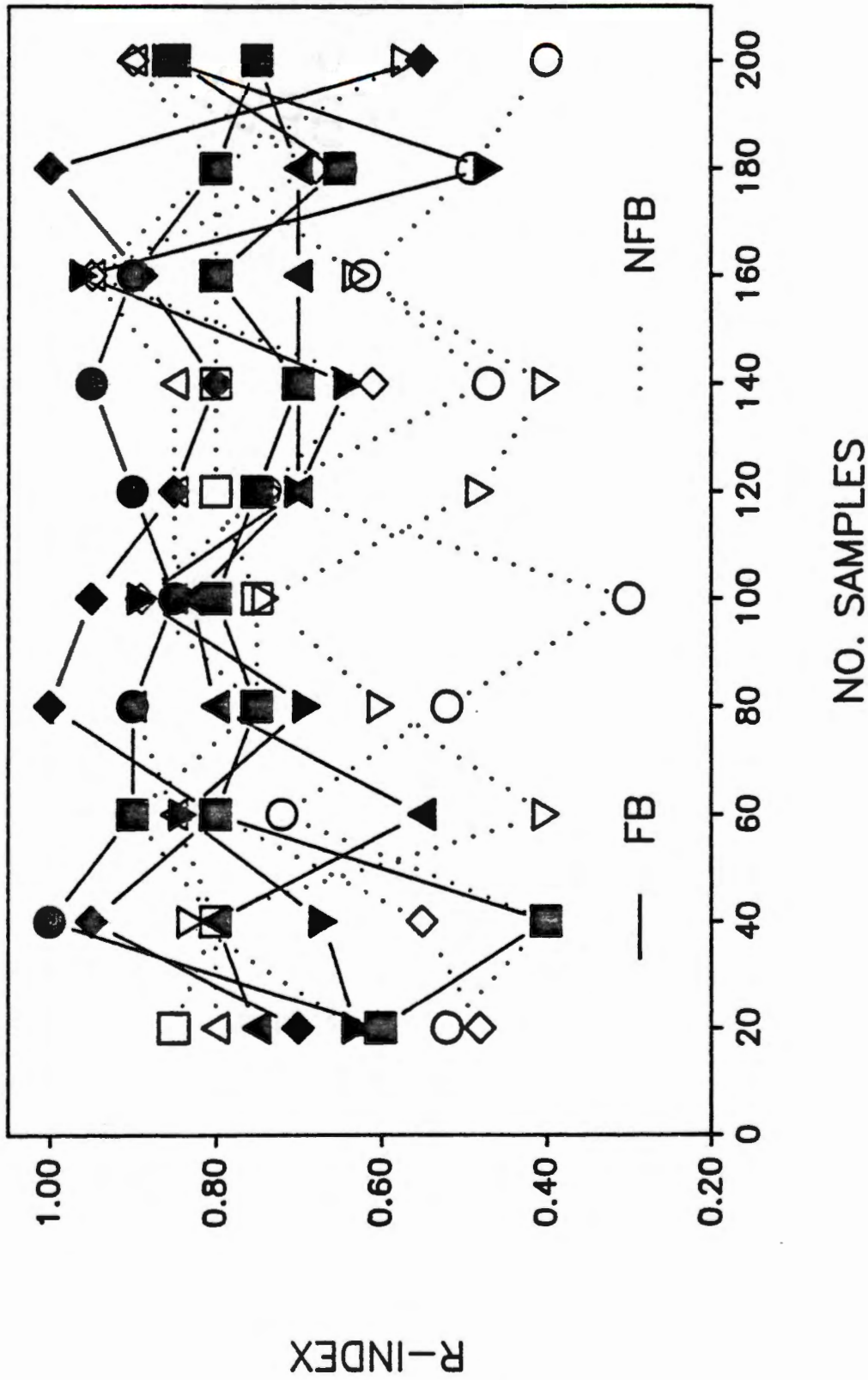


Figure 4--Effect of feedback (FB) and nonfeedback (NFB) on R-Index values of panelists across a 200 sample test of sucrose-apple juice.

to salt or sucrose in a water solution could indicate one's sensitivity in a food system (apple juice).

Repeated R-index ANOVA tables for the final models of salt and sucrose tests are shown in Table 11. For the sucrose tests only panelist and treatment (water and apple juice) X panelist were significant ($p < 0.05$). For the salt tests, treatment, panelist, samples (number of), panelist X treatment and treatment X samples were significant ($p < 0.05$). Table 12 shows panelist X treatment means for the sucrose tests. For 8 of the 10 panelists, there was no significant difference between sensitivity in water (R-index values) and sensitivity in apple juice. One panelist had lower R-index values (less sensitive) in apple juice than in water, and one panelist performed better with apple juice than with water. Because the majority of the panelists (eight) performed no better in water than apple juice for sucrose difference tests, it means that one's sensitivity in water could indicate one's sensitivity in a liquid food system (apple juice). Yet, in this study the concentration of sucrose in apple juice (1.0 g/100 ml) was almost three times that of sucrose in water (0.35 g/100 ml). The rank correlation coefficient for sucrose-water and sucrose-apple juice was not significant ($r_s = .45$, $p > 0.05$). Mackey and Jones (1954) found no significant correlation between panelists' abilities to rank water solutions of taste qualities and rank foods with the same taste qualities present. Ennis and Mullen (1985) stated that large differences would have to be present in multidimensional systems for significant differences to be found.

Table 11--Mean squares and significance of F-ratios for sucrose and salt repeated and cumulative R-index values

Data analyzed	Source	Sucrose		Salt	
		df	Mean square	df	Mean square
Repeated R-index values	Panelist (P)	9	.1722***	9	.1392***
	Treatment (T)	1	.0073	1	.0662*
	Samples (S)	9	.0093	9	.0175*
	T X P	9	.0707***	9	.2482***
	T X S	-		9	.0220**
	Error	171	.0130	162	.0091
Cumulative R-index values	Panelist	9	.1453***	9	.1508***
	Treatment	1	.0512***	1	.0733***
	Samples	9	.0011	9	.0098***
	T X P	9	.0775***	9	.1769***
	T X S	9	.0059**	-	
	Error	162	.0017	171	.0023

*** P < 0.001, ** P < 0.01, * P < 0.05.

Table 12--Repeated R-index means^{ab} for panelist X treatment interaction for sucrose and salt tests

Panelist	Sucrose		Salt	
	Water	Apple juice	Water	Apple juice
	-----R-index-----			
0	.60 ± .14yz	.52 ± .14z	.87 ± .08uv	.93 ± .08u
1	.93 ± .06v	.86 ± .05vw	.77 ± .10vwx	.92 ± .09u
2	.72 ± .07wxy	.80 ± .05vwx	.86 ± .08uv	.76 ± .11vwx
3	.79 ± .10vwx	.61 ± .15yz	.94 ± .08u	.54 ± .14yz
4	.87 ± .07vw	.74 ± .16wxy	.74 ± .15vwx	.92 ± .10u
5	.86 ± .07vw	.86 ± .11vw	.86 ± .07uv	.92 ± .08u
6	.73 ± .11wxy	.73 ± .08wxy	.69 ± .11wx	.76 ± .10vwx
7	.71 ± .11wxy	.71 ± .13wxy	.73 ± .09vwx	.94 ± .08u
8	.68 ± .09xyz	.74 ± .15wxy	.81 ± .06uvw	.45 ± .13z
9	.61 ± .15yz	.85 ± .14vwx	.87 ± .11uv	.63 ± .12xy

^aMeans ± SD; mean R-index values across 10 blocks.

^bR-index means within sucrose or salty followed by different letters differ $P < 0.05$; LSD for sucrose tests = .18, for salt tests .15.

Means for salt tests of panelist X treatment and treatment X samples are shown in Tables 12 and 13, respectively. For panelist X treatment means, R-index values for water and apple juice were not significantly different ($p > 0.05$) for four of the panelists. Mean R-index values increased significantly for three panelists, indicating greater salt sensitivity in apple juice than in water. Mean R-index values decreased significantly ($p < 0.05$) for three panelists, indicating greater salt sensitivity in water than in apple juice. Individual differences among panelists were not consistent across the tests. Rank correlation coefficients were less than .5. The treatment X samples salt R-index (Table 13) means show that the water test generally resulted in lower standard deviations than did the apple juice test. The average standard deviation for water was 0.10 and for apple juice 0.20. This indicates greater panelist variability across the 200 stimuli for apple juice than for water. Figure 5 shows individual panelist performance curves for all four tests (salt-water, salt-apple juice, sucrose-water, sucrose-apple juice). The general trend that results from all panelists is the lack of constant steady increases or decreases across the 200 stimuli. What is actually found is an oscillating pattern from block to block. This is probably more attributable to panelist motivation and/or task difficulty than to adaptation and recovery. Only for panelist 0 (Figure 5a) was sensitivity to salt clearly separate and greater than sensitivity to sucrose. Panelist 3 (Figure 5d) performed clearly better in water tasks than in the apple juice tasks. Figure 6 shows repeated

Table 13--Repeated R-index means^{ab} for treatment X samples interaction for sucrose and salt tests

Samples	Sucrose		Salt	
	Water	Apple juice	Water	Apple juice
-----R-index-----				
1-20	.77 ± .13x	.66 ± .12x	.74 ± .09yz	.75 ± .15yz
21-40	.80 ± .11x	.72 ± .21x	.83 ± .14yz	.72 ± .19yz
41-60	.75 ± .15x	.76 ± .16x	.82 ± .12yz	.80 ± .24yz
61-80	.73 ± .17x	.77 ± .14x	.82 ± .09yz	.83 ± .22yz
81-100	.73 ± .17x	.79 ± .18x	.81 ± .10yz	.83 ± .19yz
101-120	.71 ± .15x	.75 ± .12x	.84 ± .08yz	.83 ± .19yz
121-140	.76 ± .15x	.69 ± .17x	.87 ± .09y	.73 ± .20yz
141-160	.76 ± .12x	.82 ± .13x	.78 ± .14yz	.83 ± .12yz
161-180	.76 ± .14x	.72 ± .16x	.84 ± .12yz	.72 ± .22z
181-200	.76 ± .17x	.73 ± .17x	.79 ± .17yz	.74 ± .27yz

^aMeans ± SD; mean R-index values across 10 panelists.

^bR-index means within sucrose or salt followed by different letters differ $P < 0.05$; LSD for salt tests = .15.

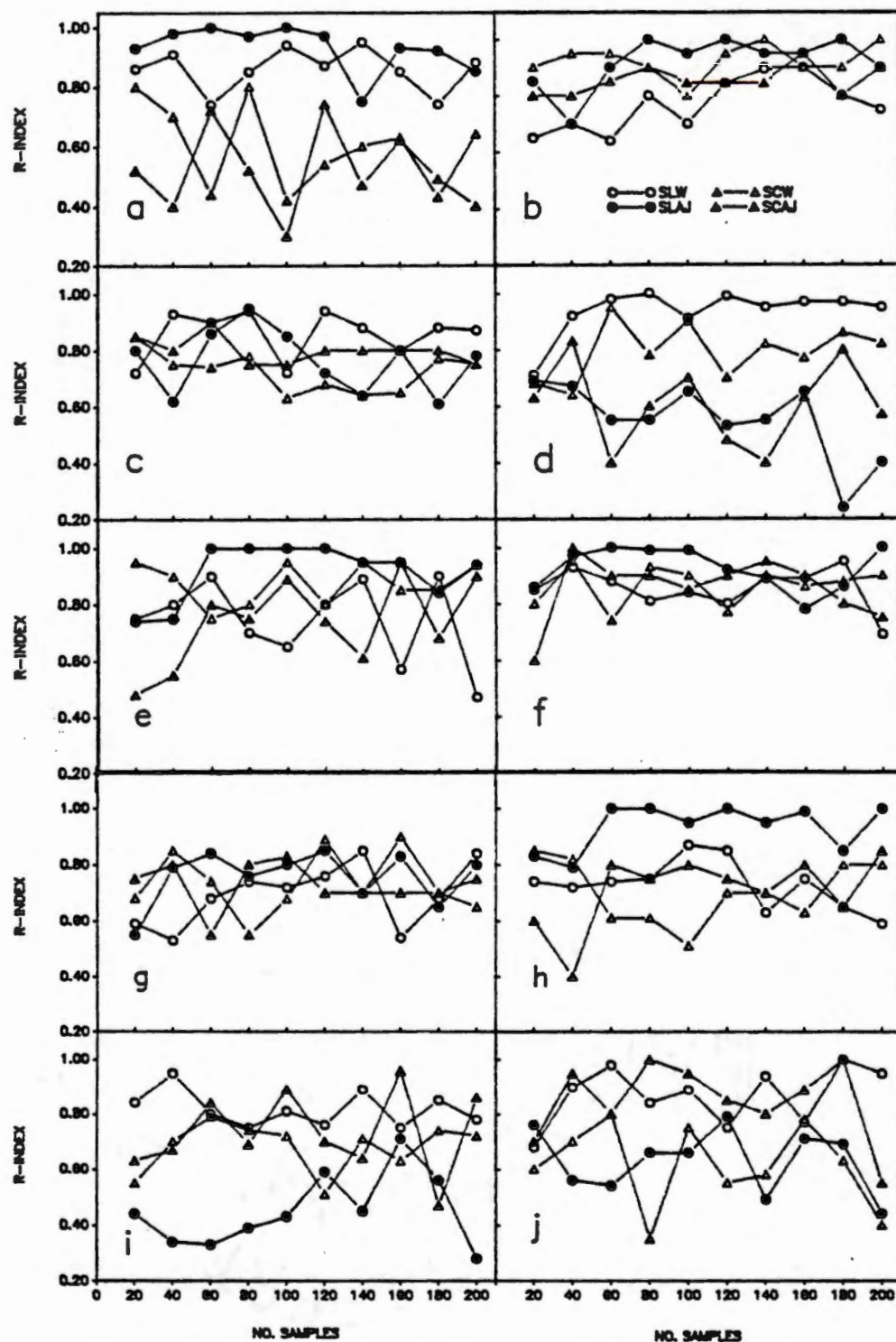


Figure 5--Repeated R-index values for individual panelists' performances across 200 sample tests of salt-water (SLW), salt-apple juice (SLAJ), sucrose-water (SCW), and sucrose-apple juice (SCAJ).

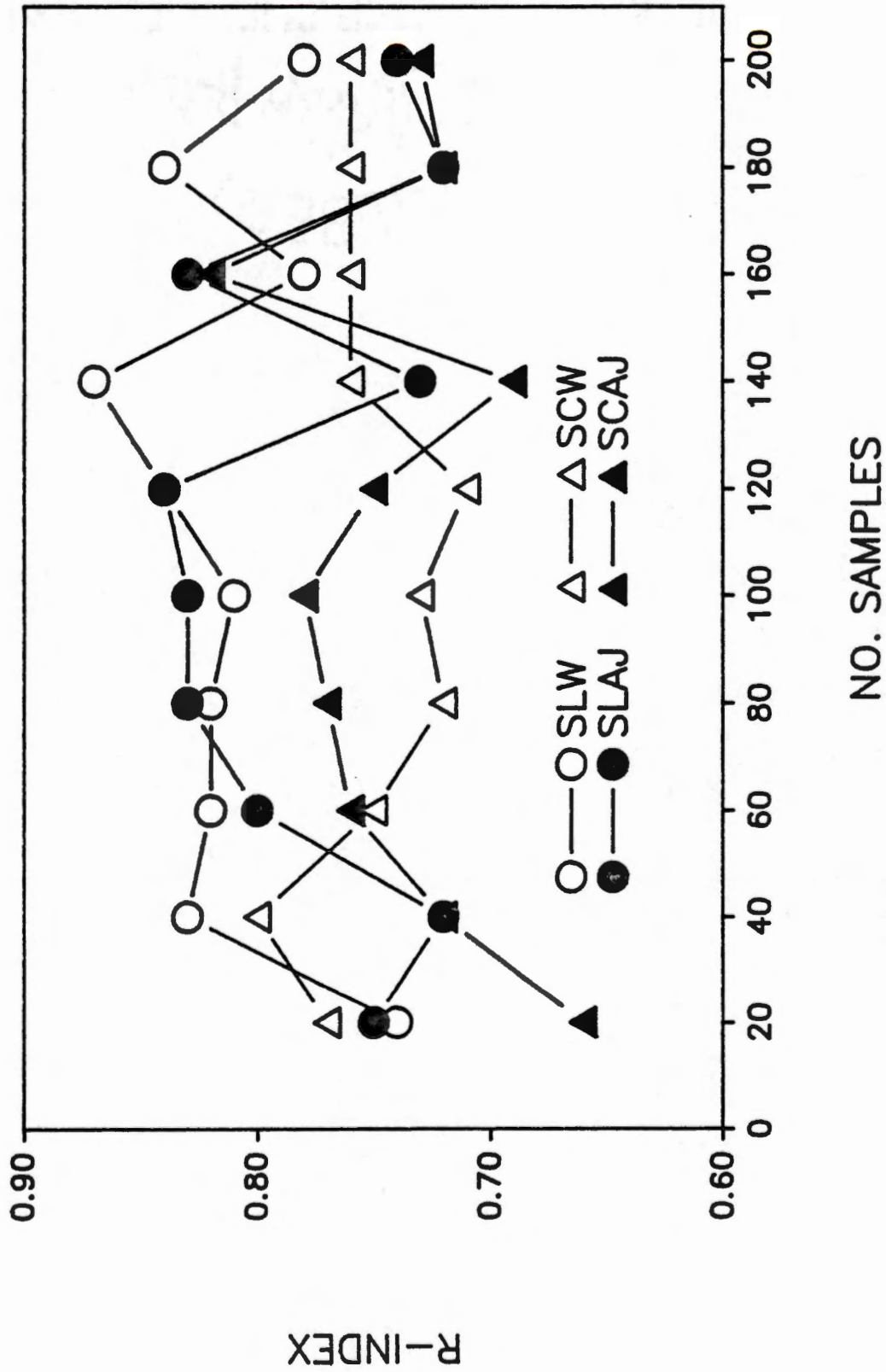


Figure 6--Repeated R-Index means of panelist performance across 200 sample tests of salt-water (SLW), salt-apple juice (SLAJ), sucrose-water (SCW), and sucrose-apple juice (SCAJ).

R-index means of all four test conditions plotted across the stimulus set. The salt-apple juice and sucrose-apple juice curves follow similar patterns and this appears to be the only trend present. All these data clearly show the great variability among panelists and across the stimulus set. Trant and Pangborn (1983) among others (Pangborn and Chrisp, 1964; Pangborn and Trabue, 1964) found panelist variability to be a significant factor when studying discrimination of taste qualities. They attributed this variability to panelist motivation as well as differential sensitivities.

ANOVA tables for the final models for salt and sucrose cumulative R-index data are shown in Table 11. For salt tests, panelist, treatment (water or apple juice), samples, and panelist X treatment were significant ($p < 0.05$). Mean R-index values for salt panelist X treatment are shown in Table 14. For four panelists, no difference was found for sensitivity in water versus apple juice; three panelists performed better (higher R-index values) and three worse (lower R-index values) in water than in apple juice. The salt concentration in apple juice (0.18 g/100 ml) was three and one-half times greater than in water (0.05 g/100 ml). For salt cumulative R-index values, the number of samples was also significant. Table 15 shows mean R-index values for the number of samples for sucrose and salt tests. A trend in increasing R-index values for salt indicates that 20 or 40 samples were not enough to reach a maximum R-index, even though it was significantly different from chance (Z score, $p < 0.05$). From samples 61-200, the cumulative R-index values were not significantly different from one another, which

Table 14--Cumulative R-index means^{ab} for panelist X treatment interaction for sucrose and salt tests

Panellist	Sucrose		Salt	
	Water	Apple juice	Water	Apple juice
-----R-index-----				
0	.65 ± .07xy	.53 ± .03z	.86 ± .02qrs	.95 ± .02p
1	.92 ± .01t	.84 ± .02u	.72 ± .05wx	.88 ± .05pqr
2	.76 ± .04vw	.82 ± .02uv	.84 ± .04rst	.78 ± .04tuvw
3	.75 ± .05w	.62 ± .04y	.89 ± .07pqr	.62 ± .05y
4	.88 ± .03tu	.65 ± .09xy	.77 ± .02uvw	.87 ± .07pq
5	.84 ± .02u	.85 ± .02u	.86 ± .02qrs	.93 ± .04pq
6	.73 ± .03w	.74 ± .02w	.65 ± .05xy	.72 ± .07wx
7	.74 ± .06w	.65 ± .07xy	.75 ± .02vw	.79 ± .13stuv
8	.66 ± .04xy	.71 ± .04wx	.83 ± .02rstu	.42 ± .04z
9	.63 ± .03y	.84 ± .05u	.83 ± .06rstu	.66 ± .04xy

^aMeans ± SD; mean R-index values across 10 blocks.

^bR-index values followed by different letters within sucrose or salt differ $P < 0.05$; LSD for sucrose tests = .07, for salt tests .08.

Table 15--Cumulative R-index means^{ab} for sucrose and salt tests

Samples	Sucrose	Salt
-----R-index-----		
1-20	.72 ± .13x	.74 ± .12y
1-40	.74 ± .14x	.74 ± .15y
1-60	.74 ± .10x	.77 ± .14yz
1-80	.74 ± .10x	.78 ± .14yz
1-100	.74 ± .10x	.79 ± .14yz
1-120	.74 ± .10x	.80 ± .13z
1-140	.74 ± .11x	.80 ± .13z
1-160	.75 ± .11x	.79 ± .12z
1-180	.75 ± .11x	.80 ± .13z
1-200	.75 ± .11x	.79 ± .13z

^aMeans ± SD; mean R-index values across 10 Judges and two treatments.

^bR-index values within sucrose or salt followed by different letters differ $P < 0.05$; LSD for sucrose = .04, for salt .05.

means that a maximum R-index was reached after 60 samples. Cumulative R-index values across the stimulus set of 200 show that adaptation to salt is probably not taking place because there is no decrease in values. No differences across the samples were found for the sucrose tests. Treatment means for the salts tests were significantly different from one another. The mean salt-water R-index value was .81 ($\pm .08$) and salt-apple juice was .76 ($\pm .16$). There was greater variation (standard deviation) within the salt-apple juice test than in the salt-water test. The lower R-index mean for the salt-apple juice test shows that it was more difficult for panelists to detect salty differences in a food system than it was in water solutions. This further shows that sensitivity to salt in water does not indicate sensitivity to salt in apple juice. The rank correlation coefficient for salt-water and salt-apple juice was not significant ($r_s = -.34, p > 0.05$).

Table 16 shows salt cumulative treatment X samples R-index means across the stimulus set for water and apple juice. Although no differences occurred within the treatments across the stimulus set, the standard deviation was higher across the set for apple juice than for water.

Analyses of cumulative R-index values (Table 11) for sucrose showed that treatment, samples, panelist X treatment and treatment X samples were significant. Treatment R-index means showed that the water test had a significantly higher mean R-index ($.75 \pm .11$) than did the apple juice test ($.72 \pm .12$). Table 14 shows mean sucrose R-index values for panelist X treatment interaction. Mean R-index

Table 16--Cumulative R-index means^{ab} for treatment (water or apple juice) X samples interactions for sucrose and salt tests

Samples	Sucrose		Salt	
	Water	Apple juice	Water	Apple juice
	-----R-index-----			
1-20	.77 ± .13x	.68 ± .12z	.74 ± .09x	.75 ± .15x
1-40	.78 ± .11x	.69 ± .15yz	.79 ± .10x	.70 ± .17x
1-60	.77 ± .09x	.72 ± .11xyz	.80 ± .10x	.74 ± .17x
1-80	.76 ± .10x	.73 ± .11xyz	.80 ± .09x	.76 ± .18x
1-100	.75 ± .10xy	.74 ± .12xyz	.80 ± .08x	.78 ± .18x
1-120	.74 ± .10xyz	.74 ± .11xyz	.81 ± .08x	.78 ± .18x
1-140	.75 ± .11xy	.73 ± .12xyz	.82 ± .07x	.78 ± .18x
1-160	.75 ± .10xy	.75 ± .12xy	.81 ± .07x	.78 ± .16x
1-180	.75 ± .11xy	.74 ± .11xyz	.82 ± .08x	.78 ± .17x
1-200	.75 ± .11xy	.74 ± .11xyz	.81 ± .08x	.77 ± .18x

^aMeans ± SD; mean R-index values across 10 panelists.

^bR-index means within sucrose or salt followed by different letters differ P < 0.05; LSD for sucrose tests = .07.

values were lower in apple juice than water for five panelists; higher in apple juice than water for one panelist, and not different from one another for four panelists. Across all four test conditions, trends in panelists' sensitivities to salty or sweet differences in the solvents was the same for four panelists, meaning that those four (2, 3, 5, 6) performed no differently in water or apple juice tasks. Four panelists (0, 1, 4, 9) exhibited opposite sensitivities when comparing trends from sucrose to salt, i.e. when lower R-index values in apple juice for sucrose were obtained, higher R-index values in apple juice for salt were obtained. Two panelists (7, 8) had changing sensitivities in the tasks, i.e. not different in one solute, but different sensitivity in the other tests. These results point to the variability among the 10 panelists used in the tests. The lack of agreement among the panelists could be attributed to any number of reasons. The task could be more difficult, threshold values may differ, interactions of taste primaries may take place, or panelist motivation could be affecting performance. Table 16 shows cumulative sucrose mean R-index values for water and apple juice across the stimulus set. Through samples 20 and 40, R-index values were significantly lower ($p < 0.05$) for apple juice than for water. All other R-index values were not different between water or apple juice through the 200 samples. This indicates that at least 60 samples would be required to reach the same R-index (performance) in apple juice as in water for sucrose differences. Although no R-index differences occurred among the stimulus sets past sample 40, the concentration of sucrose

was three times greater in apple juice (1.0 g/100 ml) than in water (0.35 g/100 ml). This again suggests that one's sensitivity to sucrose in water does not indicate one's sensitivity in a more complex food system (apple juice), which was also supported by a lack of correlation. Mean R-index values for samples (number of) for the sucrose tests are shown in Table 15. No significant differences ($p > 0.05$) were detected among the R-index values across the stimulus set. This means that adaptation to sucrose in the water or apple juice tasks is not occurring. Because no differences were found across the R-index values for the stimulus set, it could be concluded that 20 samples were enough to indicate discrimination of sucrose differences in water or apple juice.

IV. SUMMARY

Similar results were found by O'Mahony et al. (1979a). They found that cumulative R-index values differed within panelists and across the stimulus set, but no trends were noted. They attributed the oscillation to different mean sensitivities of the judges to the taste stimulus. From an additional experiment (O'Mahony et al., 1979a), they concluded that the R-index measure was useful for determining NaCl sensitivity and would probably extend to other taste stimuli. In the present study, both NaCl and sucrose sensitivities were investigated. The panelists had oscillating values across the stimulus sets, yet differences were not found among cumulative R-index values across the stimulus set for sucrose tests. Repeated R-index values showed no significant differences

across the stimulus set for either of the sucrose tests, but differences were found among the values for the salt tests (Table 13). The oscillation of R-index values across the stimulus set leaves the explanation of adaptation unlikely. If adaptation to the stimulus difference (salt or sucrose) had taken place, curves with constant decreasing slopes would expect to be found. This was not the case.

Explanation for the variability among panelists in this study may be two fold. One, the panelists' sensitivities (thresholds) to the taste stimuli concentrations used may vary. Second, the motivation level of the panelists on the day of testing may have affected the results. Henderson and Vaisey (1970) found that a judge's performance over time in sensory tests was affected by one's personality traits, i.e. high achievers performed better on sensory tests of long duration than did low achievers. This was not investigated in the present study, but could have played a role in performance levels of the participating panelists. The threshold theory may be more accurate because panelists with high R-index values in salt tests did not always have high R-index values in sucrose tests (Figure 5).

100% IN USE
TYPYCLINE ROAD

LIST OF REFERENCES

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TWO-LEAF BOND

APPENDIXES

APPENDIX A

Basic Taste Test Procedure

Table A1--Concentration of solutions used in basic taste identification test

Solute	Concentration
Sucrose	0.4%
Sucrose	0.6%
NaCl	0.08%
NaCl	0.15%
Citric Acid	0.02%
Citric Acid	0.03%
Citric Acid	0.04%
Caffeine	0.02%
Caffeine	0.03%
Water	-----

(Jellinek, 1985)

Scorecard

Recognition test for the four basic tastes

Name _____ Date _____ Judge _____

You have received aqueous solutions containing low concentrations of sucrose (sweet), sodium chloride (salty), citric acid (sour), and caffeine (bitter).

Your task is to recognize the basic taste of each sample solution (sweet, salty, sour, bitter).

When the sample tastes like water (in concentrations below your threshold) mark with a zero (0). If your recognition of the taste is questionable, write a question mark (?). Retasting is allowed but you must make your decision before moving on to the next sample. Please taste in the order specified on this card.

Samle code	Taste quality
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

(Jellinek, 1985)

APPENDIX B

Triangle Test Scorecard

Two of the samples in each set are identical, one is different.

Taste the samples in the order indicated. Do not retaste. Rinse only between sets. Identify the odd sample by circling the code. Describe the difference that you found. Indicate the degree of ease in determining the difference. Expectorate all samples.

Set I _____ _____ _____
Describe the difference _____
Easy to pick odd sample _____ Difficult to pick odd sample _____

Set II _____ _____ _____
Describe the difference _____
Easy to pick odd sample _____ Difficult to pick odd sample _____

Set III _____ _____ _____
Describe the difference _____
Easy to pick odd sample _____ Difficult to pick odd sample _____

Set IV _____ _____ _____
Describe the difference _____
Easy to pick odd sample _____ Difficult to pick odd sample _____

Set V _____ _____ _____
Describe the difference _____
Easy to pick odd sample _____ Difficult to pick odd sample _____

Set VII _____ _____ _____
Describe the difference _____
Easy to pick odd sample _____ Difficult to pick odd sample _____

Set VIII _____ _____ _____
Describe the difference _____
Easy to pick odd sample _____ Difficult to pick odd sample _____

APPENDIX C

Individual R-index Table

Table C1--Repeated and cumulative R-index values for individual judges for sucrose and salt in water and apple juice

Solute/ solvent	Number of samples	Feedback					Nonfeedback				
		5	6	7	8	9	0	1	2	3	4

-----Repeated R-index values-----											
Sucrose/ water	1-20	.80	.68	.85	.55	.60	.80	.90	.85	.68	.95
	21-40	.95	.85	.82	.70	.70	.70	.95	.75	.64	.90
	41-60	.74	.74	.61	.79	.80	.44	.95	.74	.95	.75
	61-80	.93	.55	.65	.74	.35	.80	.90	.78	.78	.80
	81-100	.90	.68	.51	.72	.75	.42	.80	.63	.90	.95
	101-120	.77	.89	.70	.51	.55	.54	.95	.68	.70	.80
	121-140	.90	.70	.70	.71	.58	.60	1.00	.64	.82	.95
	141-160	.86	.90	.63	.63	.78	.63	.90	.65	.77	.85
	161-180	.88	.70	.80	.74	.63	.43	.90	.77	.86	.85
	181-200	.90	.65	.80	.72	.40	.64	1.00	.75	.82	.94
Sucrose/ apple juice	1-20	.60	.75	.60	.63	.70	.52	.80	.85	.63	.48
	21-40	1.00	.80	.40	.67	.95	.40	.80	.80	.83	.55
	41-60	.90	.55	.80	.84	.80	.72	.85	.90	.40	.80
	61-80	.90	.80	.75	.69	1.00	.52	.90	.75	.60	.75
	81-100	.85	.83	.80	.89	.95	.30	.85	.75	.74	.89
	101-120	.90	.70	.75	.70	.85	.74	.85	.80	.48	.74
	121-140	.95	.70	.70	.64	.80	.47	.85	.80	.40	.61
	141-160	.90	.70	.80	.96	.89	.62	.95	.80	.63	.95
	161-180	.80	.70	.65	.47	1.00	.49	.80	.80	.80	.68
	181-200	.75	.75	.85	.86	.55	.40	.90	.75	.57	.90

-----Cumulative R-index values-----											
Sucrose/ water	1-20	.80	.68	.85	.55	.60	.80	.90	.85	.68	.95
	1-40	.86	.76	.83	.62	.65	.75	.93	.81	.66	.93
	1-60	.82	.75	.78	.68	.70	.63	.93	.78	.75	.87
	1-80	.85	.70	.75	.69	.61	.66	.93	.79	.76	.85
	1-100	.85	.70	.70	.70	.64	.62	.89	.75	.78	.87
	1-120	.84	.73	.70	.67	.62	.60	.91	.74	.77	.86
	1-140	.85	.73	.70	.67	.62	.60	.92	.72	.78	.87
	1-160	.85	.75	.70	.67	.64	.61	.92	.72	.78	.87
	1-180	.85	.74	.71	.67	.64	.59	.92	.72	.78	.87
	1-200	.86	.73	.71	.68	.61	.59	.92	.73	.79	.87
Sucrose/ apple juice	1-20	.60	.75	.60	.63	.70	.52	.80	.85	.63	.48
	1-40	.80	.78	.50	.63	.83	.46	.80	.82	.72	.52
	1-60	.83	.70	.60	.72	.82	.55	.82	.85	.62	.62
	1-80	.85	.73	.64	.71	.86	.54	.84	.82	.62	.65
	1-100	.85	.74	.67	.73	.88	.50	.84	.81	.64	.69
	1-120	.86	.74	.68	.73	.88	.54	.84	.81	.61	.70
	1-140	.87	.73	.69	.72	.86	.53	.84	.81	.58	.69
	1-160	.88	.73	.70	.75	.87	.54	.86	.81	.59	.72
	1-180	.87	.72	.69	.72	.88	.54	.85	.81	.61	.72
	1-200	.86	.73	.71	.74	.85	.53	.86	.80	.61	.73

Table C1--(Continued)

Solute/ solvent	Number of samples	Feedback					Nonfeedback				
		0	1	2	3	4	5	6	7	8	9
-----Repeated R-index values-----											
NaCl/ water	1-20	.86	.65	.72	.71	.75	.85	.59	.74	.80	.68
	21-40	.91	.70	.93	.92	.80	.93	.53	.72	.95	.90
	41-60	.74	.64	.90	.98	.90	.88	.68	.74	.80	.98
	61-80	.85	.80	.94	1.00	.70	.81	.74	.75	.75	.84
	81-100	.94	.70	.72	.91	.65	.84	.72	.87	.81	.89
	101-120	.87	.85	.94	.99	.80	.84	.76	.85	.76	.75
	121-140	.95	.90	.88	.95	.89	.89	.85	.63	.84	.94
	141-160	.85	.90	.80	.97	.57	.89	.54	.75	.75	.77
	161-180	.74	.80	.88	.97	.90	.95	.68	.65	.85	1.00
	181-200	.98	.75	.87	.95	.47	.69	.84	.59	.78	.95
NaCl/ apple juice	1-20	.93	.85	.80	.69	.74	.86	.55	.86	.44	.76
	21-40	.98	.70	.62	.67	.75	.97	.79	.79	.34	.56
	41-60	1.00	.90	.86	.55	1.00	1.00	.84	1.00	.33	.54
	61-80	.97	1.00	.95	.55	1.00	.99	.76	1.00	.39	.66
	81-100	1.00	.95	.85	.65	1.00	.99	.80	.95	.43	.66
	101-120	.97	1.00	.72	.45	1.00	.92	.85	1.00	.59	.79
	121-140	.75	.95	.64	.55	.95	.89	.70	.95	.45	.49
	141-160	.93	.95	.80	.65	.95	.75	.83	.99	.71	.71
	161-180	.92	1.00	.61	.24	.84	.86	.65	.85	.56	.69
	181-200	.85	.90	.75	.40	.94	1.00	.80	1.00	.28	.44
-----Cumulative R-index values-----											
NaCl/ water	1-20	.86	.65	.72	.71	.75	.85	.59	.74	.80	.68
	1-40	.88	.68	.82	.82	.78	.90	.56	.73	.87	.81
	1-60	.83	.66	.85	.88	.82	.89	.60	.74	.85	.86
	1-80	.83	.70	.87	.92	.79	.86	.63	.74	.83	.85
	1-100	.85	.70	.83	.92	.76	.85	.65	.77	.82	.86
	1-120	.86	.72	.85	.94	.77	.85	.67	.79	.82	.84
	1-140	.87	.75	.86	.93	.78	.86	.70	.77	.83	.86
	1-160	.86	.77	.85	.93	.76	.86	.68	.75	.82	.84
	1-180	.85	.77	.85	.94	.77	.87	.68	.74	.82	.86
	1-200	.86	.77	.85	.94	.74	.85	.69	.72	.82	.87
NaCl/ apple juice	1-20	.93	.85	.80	.69	.74	.86	.55	.86	.44	.76
	1-40	.96	.78	.71	.68	.75	.91	.66	.48	.39	.68
	1-60	.97	.82	.75	.64	.83	.95	.72	.66	.37	.64
	1-80	.97	.86	.82	.63	.87	.96	.73	.76	.37	.64
	1-100	.98	.88	.83	.63	.89	.97	.74	.81	.38	.65
	1-120	.97	.90	.81	.60	.91	.96	.76	.85	.42	.66
	1-140	.94	.91	.78	.59	.92	.95	.76	.86	.42	.64
	1-160	.94	.91	.78	.60	.92	.93	.76	.88	.46	.64
	1-180	.94	.92	.76	.56	.91	.92	.75	.88	.47	.65
	1-200	.93	.92	.77	.55	.92	.93	.75	.89	.45	.63

VITA

Lisa Yvette Hanger was born in Manchester, Tennessee on February 9, 1962. She attended elementary and junior high schools in Franklin County. She graduated from Cannon County High School in June 1980. In the Fall of 1980, she entered Tennessee Technological University in Cookeville, Tennessee, and received the Bachelor of Science degree in Home Economics in June 1984. She entered the graduate program at The University of Tennessee, Knoxville in September 1984, and received the Master of Science degree in Food Science in December 1985. In January 1986, she entered the doctoral program. During her program, she worked as a teaching and research assistant. In December 1988, she completed the Doctor of Philosophy degree with a major in Food Technology and Science. She is a member of the Institute of Food Technologists, American Association of Cereal Chemists, Phi Kappa Phi and Gamma Sigma Delta Honor Societies.