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FLAVOR INTERACTION OF SOY PROTEIN AND TOMATO SAUCE

by

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ABSTRACT

Flavor interaction in a model system of soy/tomato mixtures was studied. The system consisted of a constant level of soy protein (5% w/w) in various concentrations of tomato sauces (55 - 100%). Since textural differences resulting from varying tomato concentrations might interfere with taste judgment, two series of tomato sauces of identical concentration were made up. Varying quantities of a thickener were added to one of the series, so that all the sauces were of equivalent viscosity.

A six-member trained panel defined the dominant odors of soy protein as whole grain-like, raw green beany, sweet and cooked cold potato-like; and its tastes as whole grain-like, beany, sweet and bitter. The odors of tomato sauce were described as fruit-like, heavy/earthy, acidic, metallic and canned tomato-like; while its tastes were described as acidic, harsh, bitter, astringent and canned tomato-like.

Perceived intensities of the tastes of tomato sauces as a function of tomato concentration were determined. The taste characteristics evaluated were overall taste, acidic, harsh, bitter and astringent. The intensities of the different tastes were found to increase with tomato concentration.

Combination of the soy and tomato components resulted in the repression of certain tomato flavors: harsh, bitter

and astringent. The presence of soy protein significantly reduced the intensities of the overall and acidic tastes of the tomato sauces. Reduction appeared to be greater at the lower concentration region. The slopes of the intensity functions were not significantly affected. Similarly, the individual odors and tastes of the soy protein became indistinguishable in the soy/tomato mixtures. The overall soy odor, taste and aftertaste were substantially reduced in intensities with the increase in tomato concentration in the mixtures. Pleasantness of the mixtures increased linearly with the increase in tomato concentration at a rate approximating those of the overall and acidic tastes of the tomato component in the mixtures. The addition of a thickener generally did not affect the intensities of the different tastes or the pleasantness of the mixtures.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF APPENDICES

INTRODUCTION

The importance of soy protein has emerged with the increasing demand for new protein sources. The U.S. alone produced 42 million metric tons of soybeans in 1975 and the figure was expected to reach 61 million metric tons by 1985.

Soy protein offers an economical and nutritional alternative to the conventional meat protein. It has been estimated that an annual 500 pounds of soy protein could be produced from the same acre of land which could only raise 58 pounds of beef protein. With heat treatment and proper processing, the nutritive value of soy protein could be improved to approach that of meat and milk.

In spite of the great potential for food use, the application of soy protein in human foods is still limited. The greatest deterrent was found in the unpleasant flavors, especially beaniness and bitterness, associated with the product. Many attempts have been made to ameliorate this problem. Most of the methods aim at removing the off-flavor components or preventing their formation. However, recent studies indicate that these endeavours have not been entirely successful. Unpleasant flavors still exist in various commercial soy protein products (Kalbrener et al., 1971) and the addition of certain brands of textured soy protein to beef patties has been demonstrated to greatly detract from flavor desirability ratings (Smith et al., 1976).

A practical alternative appears to be masking the off-flavor of soy protein with a food system that possesses flavors that are both pleasant and strong. The tomato seems to be a suitable food to serve this purpose. It has a strong flavor and is well liked by most people in North America. Tomato juice has demonstrated a superior masking ability for bitterness when compared to another food (Mackey and Valassi, 1956). The major amino acids in tomatoes are glutamic and aspartic acids which have been found useful for masking bitterness (Watanabe, 1974). A glutamic acid rich oligopeptide also displays potent bitter-masking activity (Noguchi et al., 1975). As well, the most common use of soy protein lies in the extension of communited meat products such as ground meat patties, meat sauce and sausages where the use of tomato sauce is customary. It was decided, therefore, to observe the masking effect of tomato flavors on the flavors of soy protein.

The major objectives of the present study are as follows:

1. To develop a model system in which to test the interaction between soy and tomato flavors.
    a. To determine the sensory attributes of the model system — flavor characteristics and intensities of the soy and tomato components.
    b. To test the effect of cornstarch, used as a thickening agent, on the sensory attributes of the model system.
2. To determine qualitatively and quantitatively the soy/tomato flavor interaction in the presence and absence of the thickening agent.
3. To observe the pleasantness of the soy/tomato mixtures.

REVIEW OF LITERATURE

A. Flavor of Soy Protein Products

Much effort has been expended to achieve a bland soy protein product. However, experimental evidence consistently confirmed the presence of undesirable flavors in soy protein, the most predominant ones being beaniness and bitterness. Slight variations in flavor had been observed in various product forms due to the different kinds of processing applied.

Moser et al. (1967) evaluated the effect of steaming on the flavors of full fat soy flour. A 16-member trained panel was selected to evaluate a 25% aqueous soy flour slurry on a 10-point scale (1 = strong; 10 = bland). The raw full fat soy flour which served as the control was rated a low 1.5 with flavors described as beany, bitter and green in order of their prominence (Table 1). The flavor was significantly improved to a score of 6.3 with steaming up to a duration of 20 minutes. The green flavor disappeared, bitterness was reduced while new flavors: nutty, toasted, sweet emerged. Honig et al. (1969) described raw defatted soybean meal as possessing green, beany, bitter flavors, with a throat-catching, lingering aftertaste. However, the conditions of the tasting procedures were not detailed. Kalbrener et al. (1971) substantiated the above findings in their study of the odors and tastes of various commercial de-

TABLE 1

EFFECT OF STEAMING ON THE FLAVOR OF SOY FLOUR

Steaming duration (min.)	Flavor score[a]	Flavor description
0	1.5	beany, bitter, green
3	4.5	beany, bitter, nutty, sweet, toasted
10	6.0	beany, nutty, bitter, toasted, sweet
20	6.3	beany, nutty, bitter, toasted, sweet
40	6.1	beany, nutty, bitter, toasted, sweet

[a] 1 = strong; 10 = bland.

(from Moser et al., 1967)

fatted soybean flavors, concentrates and isolates. Samples were presented to a 17-member panel as 2% dispersion in water. The panelists rated the odor and taste intensities of each sample on a 10-point scale (1 = strong; 10 = bland) and described the predominant odors and tastes present. Table 2 contains the intensity scores of the samples with a list of their odor and taste descriptors. Apparently, the additional processing procedures necessary to produce concentrates and isolates did not substantially affect the odor and taste intensities of soy protein, as all the three types of products achieved a similar maximum score. The effect of processing, however, was reflected in the descriptions. While some odor descriptors such as beany, cornmeal, CW (a combination of cereal and singed wool in water) were common to all, each type of product possessed a slightly different odor profile from the others. The predominant tastes in all the products were beaniness and bitterness. However, differences again appeared in the description of each type. The green beany taste was peculiar only to the soy flour. Astringency was noted only in the concentrates and isolates. The isolates received the most varied responses including cardboard, chalky, mealy, toasted, flour and nutty.

The range of odor and taste intensity scores within individual product type reflected the variability in quality among the commercial products. The flour samples exhibited the widest score range and the isolates the least. The considerable improvement in the scores of some flour samples was

TABLE 2

ODORS AND TASTES OF COMMERCIAL SAMPLES OF SOY PROTEIN PRODUCTS

	ODOR		TASTE	
SAMPLE[a]	Score[b]	Description	Score	Description
Soy flour	5.8-7.4	beany, toasted, cornmeal, vanilla, C.W.[c], N.P.[d]	4.2-6.7	bitter, beany, green beany, toasted
Concentrate	6.4-7.4	beany, stale, cornmeal, musty, toasted, C.W., N.P.	5.6-7.0	bitter, beany, astringent
Isolate	6.8-7.7	musty, cornmeal, beany, spoiled, flour, C.W.	5.9-6.4	beany, cardboard, bitter, astringent, chalky, mealy, cereal, toasted flour, nutty

[a] 2% dispersion in water at room temperature.

[b] 1 = strong; 10 = bland.

[c] C.W. = odor similar to a combination of high-protein oat cereal and singed wool in water.

[d] N.P. = none predominant.

(adapted from Kalbrener et al., 1971).

attributed to the increased amount of heat treatment received during processing. It was also noted that in some of the higher rated flours, the green beany flour was replaced by the toasted flavor. This is in agreement with the findings of Moser et al. (1967). Since all isolates were produced basically by the same process, these samples show the least difference in scores. A recent study by Rayner et al. (1978) indicated that there still existed a great deal of variation among the flavor quality of soy products. Three different soy flour samples were assigned flavor scores of 3.5, 5.2 and 7.9, respectively, by a trained panel (1 = strong; 10 = bland). Similarly, three protein isolates were variously described as bland, moderately off-flavor and unacceptable. Chromatographical analysis revealed that the number and concentration of flavor volatiles and residual solvents used in processing were inversely related to flavor ratings.

Flavor threshold of soy protein had been demonstrated to be very low. A comparison had been made between raw soy flour diluted with various levels of wheat flour and a wheat flour control (Moser et al., 1967). Panelists were asked to determine whether soy flour was present in the sample and to select from a pair of samples the one having the stronger raw beany flavor. It was discovered that even at a dilution as low as 1:2500 (wt. ratio), 44% of the 16-member panel were able to detect the presence of soy flour; and at a ratio of 1:500, all panelists could detect the difference. Kalbrener et al. (1971) determined the sample detection threshold for a raw defatted flour, a concentrate and two isolates. The threshold values represented the concentration of sample in water which the panelists found to taste different from the water control. The threshold values were found to be extremely low for all products, ranging from 0.005 to 0.06%. Average panel threshold was also determined for beaniness and bitterness, the most objectionable flavors in soy products. The low values obtained, except in the case of the isolates, implicated the intensity of such flavors in the soy products.

B. Off-Flavor Development in Soy Protein

(1) Mechanism

Development of off-flavor in soy protein is primarily attributed to lipid oxidation during processing and storage. Oxidation gives rise to hydroperoxides which, on further degradation, decompose into various volatile flavor components. Leu (1974) demonstrated that oxidation of linoleic acid, catalysed by soybean lipoxygenase, produced two hydroperoxide isomers: 13-hydroperoxy-9,11-octadecadienoic acid and 9-hydroperoxy-10,12-octadecadienoic acid, the reaction being in favour of the 13-hydroperoxy acid. Further degradation of these hydroperoxides gave rise to volatile compounds such as adlehydes, hydrocarbons and furan derivatives. Findings indicated that the reaction was specific for unsaturated fatty acids possessing a cis,cis-1,4-pentadiene system (Hamberg and Samuelson, 1967). In autoxidation, oxygen was taken up spontaneously by the unsaturated fatty acids to form equal amounts of the 13- and 9-hydroperoxides via a free radical system (Sessa and Rackis, 1977). Lipid oxidation had been found to occur during the preparation of full fat and defatted soy flakes as well as soy proteinate (Maga and Johnson, 1972; Sessa et al., 1969). Prolonged storage of the proteinate also resulted in decreased unsaturated fat level.

(2) Flavor components.

It has been shown that hydroperoxides and their decomposition products developed from oxidation of linoleic and linoleic acid possessed flavors that were characteristic of soy products, especially in the grassy/beany aspect (Kalbrener et al., 1974). Many volatile and non-volatile flavor compounds have been identified in soybean products. These include aldehydes, ketones, alcohols, fatty acids, furan derivatives, amines, phenols, sulphur compounds, phospholipids, and lactones. Whether all of these compounds arise directly from hydroperoxide decomposition remains to be proven. Not everyone of these compounds contribute to the undesirable flavors of soy protein products. Lactones have been reported to be pleasant smelling (Goossens, 1974). Several fatty acids such as n-caproic, isocaproic and n-caprilic acids have been identified in raw defatted soybean meal and found to possess green beany flavor. However, their concentration was considered too low to significantly affect the soybean flavor. Similarly, four polyamines: putrescine, cadaverine, spermidine, and spermine with odors described as putrid, musty and ammoniacal, were found to be present at subthreshold levels in soybean flour (Wang et al., 1975).

(a) Carbonyl compounds

Carbonyl compounds are one of the major groups of volatiles found in soy protein products. Hexanal with a green plant-like flavor had been identified in defatted soy flour at 1 - 5 ppm (Fujimaki et al., 1965; Hill and Hammond, 1965). Gas chromatogram of soy flours that was rated high in taste intensity revealed the presence of a significant amount of hexanal and residual solvents (Rayner et al., 1978). Cis-3-hexenal had been isolated from oxidized soybean oil (Hoffmann, 1961). Its odor was described as green bean-like. The development of a green bean odor and flavor during wet grinding of full-fat soybean had been attributed to the presence of vinylethyl ketone (Mattick and Hand, 1969). With heat treatment, the green beany flavor in soy product disappeared, and was replaced by a cooked beany flavor (Kalbrener et al., 1971). This was speculated to be partly due to the isomerization of some of the carbonyl compounds (Sessa and Rackis, 1977).

(b) Alcohols

The volatile neutral compounds in raw soybean had been investigated by Arai et al. (1967). A number of alcohols were identified including methanol, ethanol, 2-pentanol, isopentanol, n-pentanol, n-hexanol and n-heptanol. Isopentanol, n-hexanol and n-heptanol were found to possess green bean-like odor. Their respective content in raw soybean are shown in Table 3. The authors considered these compounds as important contributors to the green bean-like odor.

A significant amount of 1-octen-3-ol was found to develop during the soaking of soybean in water as a pretreatment for soy milk manufacture (Badenhop and Wilkens, 1969). The odor of this compound had been variously described as mushroom, musty or earthy. Its flavor threshold in soy milk was determined to be between 0.5 and 1.0 ppm.

(c) Furan

A volatile compound, 2-pentyl furan was isolated from reverted soybean oil and soy protein isolate (Krishnamurthy et al., 1967; Smouse and Chang, 1967; Quist and von Sydow, 1974). Its flavor threshold in oil at room temperature is approximately 1 ppm. In its concentrated form, this compound produced a licorice odor. However, at concentrations of 1 to 10 ppm, it imparted a grassy odor and flavor to oil.

(d) Phospholipids

Sessa et al. (1974) found that an intensely bitter taste developed during the autoxidation of purified soy phosphatidylcholine, a non-volatile compound. The bitterness detection threshold of this compound in water was determined to be 0.006% by weight. Since dehulled defatted soy flakes contained a minimum of 0.08% phosphatidylcholine by weight (Sessa et al., 1976), these constituents were considered to be a

TABLE 3

CONTENT OF SOME ALCOHOLIC COMPOUNDS IN RAW SOYBEAN

Compound	Amount (ppm)
Isopentanol	2.2
n-Hexanol	1.6
n-Heptanol	1.2

(from Arai *et al.*, 1967).

prime factor for the bitterness of soy protein products.

(e) Phenolic acids

Phenolic acids are flavor compounds that do not arise from lipid oxidation. Phenolic acids had been characterized as possessing sour, bitter and astringent flavor (Arai et al., 1966a). Maga and Lorenz (1974) observed 27 peaks from the free phenolic fraction of commercial defatted soy flour. Fourteen of these were identified. The total free phenolic acid content was calculated to be 256 ppm. Table 4 shows the content and flavor thresholds of the major phenolic acids. Combination of two or more of the compounds was known to result in synergistic effects which greatly reduced the threshold values.

(f) Amines

A total of 1.5 ppm of volatile amine was isolated from raw soybean (Arai et al., 1966b). The presence of ammonia, monomethylamine, dimethylamine, piperidine and cadaverine was detected. Dimethylamine was the main component and was considered to be responsible for the dried fishy flavor of raw soy flour.

Although many flavor components have been identified, there is little information on their relative importance in the soy products. Probably, no specific compound is entirely responsible for the off-flavors which are likely the result of interaction among the various components.

TABLE 4

CONTENT AND FLAVOR THRESHOLDS
OF SOME PHENOLIC ACIDS
IN DEFATTED SOY FLOUR

Compound	Amount (ppm)	Threshold (ppm)
Syringic	43	240
Ferulic	32	90
Vanillic	35	30
Salicylic	20	90
p-Hydroxybenzoic	22	40
Gentistic	21	90
p-Coumeric	16	40

(from Maga and Lorenz, 1974).

C. Flavor Improvement

Many approaches have been taken to improve or reduce the undesirable flavors of soy products. Preventive measures include grinding soybeans under acidic conditions (pH 3.85 or lower) (Kon et al., 1970), or applying heat treatment to soybean meats before grinding (Mustakas et al., 1969). Such procedures serve to deactivate the soy lipoxygenase enzyme which catalyses the formation of volatile compounds responsible for the off-flavors in soy products. Odor and flavor modification to more desirable forms through deep-fat frying of soybeans (Wilkens and Lin, 1970) or applying yeast on soy flour (Bradof, 1957) have been attempted. Solvent extraction, e.g. by using 80% aqueous alcohol or azeotropic mixture of hexane:alcohol (Moser et al., 1967; Eldridge et al., 1971) succeeded in partly reducing the flavors. Enzymatic proteolysis of soy protein was effective in removing the beany flavor, probably through the breakdown of the interaction between flavor components and soy protein (Fujimaki, 1968). However, in many cases, this effect was counteracted by a concommitant emergence of other flavors such as bitterness, astringency and oiliness. None of the approaches outlined above succeeded to produce entirely satisfactory products. Another alternative is to mask these undesirable flavors. Some attempts have been made in this area.

Rakosky Jr. (1974) reported that salt and lemon oil had a masking effect on soy flour. The latter could be used at a level of approximately 0.004 %. Nagel (1975) claimed that when heavily seasoned hot water was used to reconstitute extruded dehydrated soybean protein and the resulting product was incorporated into animal protein, the end product became indistinguishable in taste from the extended animal protein per se. Seasonings comprised table salt and a spice selected from a group consisting of pepper, garlic, sesame oil, chicken or bouillon cubes, oregano or soup. Haas (1975) claimed that high flavor malt was effective in masking the beany or bitter flavors of soy protein. A malt:soy ratio from 3:1 to 1:5 by weight was considered sufficient to improve palatability.

D. Flavor Interaction

(1) Taste interaction-masking

When taste substances are combined in a mixture, the interaction most often noted is one of mutual masking or suppression of the intensities of the different flavor components. Flavor enhancement has also been observed occasionally.

(a) Basic tastes

Numerous experiments have been conducted to observe taste interactions from different combinations of the four basic tastes. Most of the findings indicate the resultant interaction as a function of concentration. Fabian and Blum (1943) observed the effect of adding a subthreshold level taste component to a primary taste compound present at a suprathreshold level in aqueous solution. Both suppression and enhancement of the different flavors were noted. Sugars suppressed the saltiness of sodium chloride and the sourness of acids. Sodium chloride reduced the sourness of acids but increased the sweetness of sugars. Acids generally increased saltiness and sweetness. In a study of the interactions between sucrose and sodium chloride ranging from threshold to solubility limit, Beebe-Center et al. (1959) found the principal effect to be one of mutual masking. Enhancement of sweetness occurred in some cases when low levels of sodium chloride were added to the sucrose solutions. However, the effect was slight when compared to the amount of masking at the high levels of sodium chloride.

Pangborn (1960) examined the taste relationships among the four basic taste solutions. Taste compounds of subthreshold and threshold levels were added to a primary taste at suprathreshold concentration. All binary mixtures of the taste compounds: sucrose, citric acid, sodium chloride and caffeine, were studied. In general, all compounds were found to depress the taste intensity of each other, the most pronounced effect being the reduction of the intensity of sucrose by citric acid and vice versa. Dilute solutions (subthreshold level) of sodium chloride slightly enhanced the sweetness of sucrose. In two subsequent experiments, Pangborn (1961, 1962) studied taste interactions only at suprathreshold levels. Citric acid was found to depress the sweetness of sucrose. The masking effect appeared to increase with the concentration of citric acid and was greater at the lower level of sugar.

Sucrose reduced the saltiness of sodium chloride but the effect of sodium chloride on sucrose was more complex. High level of sucrose was depressed by all levels of sodium chloride added. However, at the lower sucrose concentrations, sweetness was generally enhanced by lower and depressed by higher levels of salt addition. Interestingly, the depression of both saltiness and sweetness was of a greater magnitude at the higher concentration of the primary tastes, in contrast to the results obtained by adding acid to sucrose.

Moskowitz (1972) studied the perceptual changes that occurred when sapid chemicals were tasted in simple and in mixture solutions. Sugar solutions (glucose and fructose) of demonstrated suprathreshold concentrations were separately mixed with sodium chloride, citric acid and quinine sulphate each at four different levels. The separate taste intensities of both components as well as the mixture were measured. A multiple regression program was used to assess the fitness of different equations to the empirical data. Results suggested a mutual suppression of each taste in the mixture. However, the reduction was not equal for the two components. It was also observed that when a constant level of a second taste was added across varying sugar concentrations, the former often completely masked sweetness at low sugar concentrations which did not taste sweet. This effect was especially pronounced when a high concentration of a second taste substance was added.

From the above findings, the effect of one taste substance on another appears to be related to their respective concentrations. In general, intensity of flavor components are being suppressed in a mixture. The amount of suppression usually increases with the concentration of the masking agent. However, enhancement may occur especially when one or both of the taste substances are present at dilute concentrations.

It has been suggested that the degree of suppression in the mixture may be related to the qualitative difference among the taste components. Moskowitz, in a series of experiments (1971, 1972, 1973, 1974), studied the interactions of mixtures of substances with different tastes as well as mixtures of substances with similar tastes. On the basis of his own data and those from the literature, he concluded that suppression occurred between pairs of substances with different taste qualities while simple additivity or synergism occurred between pairs of substances with similar taste qualities.

Bartoshuk (1977) contended that the relative suppression taste components underwent in a mixture depended on the psychological functions produced by the unmixed components themselves. Taste components with a compressed (slope < 1) function would exhibit suppression in a mixture and mixtures of taste components with an expanded (slope > 1) function would exhibit synergism instead. Simple additivity would be predicted only for taste substances with an exponent of 1.0. In an experiment utilizing different sugars, acids and bitter substances of equal perceived intensities, Bartoshuk demonstrated that mixture of two through four taste substances of similar taste qualities produced psychophysical functions similar to those of the unmixed components. When the unmixed components showed compression, the mixture showed suppression in the shape of the function. Thus, the different sugars with slopes 0.75 (sucrose), 0.78 (fructose), 0.69 (glucose), 0.70 (maltose), produced a mixture with a slope of 0.80. A similar relation was noted in mixtures of substances with different taste qualities. Intensity functions of each of the four basic taste solutions (sucrose, sodium chloride, hydrochloric acid, and quinine hydrochloride) were examined in their unmixed state and in combination with one through three different tasting components of equal perceived intensity. Functions of all the unmixed components showed compression while functions of the four taste substances in mixtures showed suppression. Hydrochloric acid which showed the least compression was also least suppressed in the mixture while quinine hydrochloride which exhibited the greatest compression was also most suppressed in the mixture. Thus, the substance that showed the most compression when added to itself also showed the most suppression when other taste substances were added to it. However, it was pointed out by the author that this suggested relation between mixture interaction and the shape of the psychological function of the component did not contradict the previous data. It had been noted that the slopes of the psychological function of the taste substances could be altered by employing different tasting procedures resulting in a corresponding change in the function of the respective mixtures (Meiselman, 1971). The experiments that led to the conclusion that simple additivity or synergism always occurred in mixtures of similar tasting substances were conducted with tasting techniques that tended to produce power functions with exponents of 1.0 or greater.

The dynamics of growth intensity of a given taste when a second taste is present as a background has been explored. Moskowitz (1971) obtained the power functions of the four basic tastes when these were judged in pure solutions and in mixture with another taste. All combination of tastes were examined and all stimulus solutions were presented at supra-threshold levels. A comparison of the sets of functions obtained from the primary tastes and their corresponding mixtures suggested that the intensity functions of a taste compound were not disturbed to any great extent by the addition of a constant level of a second taste. The percentage change in the exponent from the pure taste to the mixture always remained less than 25%. In a following study, Moskowitz (1972) again observed the effect of adding a constant level of a second taste across varying sugar concentrations. In general, there appeared to be slight distortion in the slopes of the functions by the addition of separate taste material. However, some severe changes occurred in the exponents in certain cases especially where high amounts of the second taste were present. Since the taste sweetness of the lower sugar concentrations had been completely masked by the background taste, it was not possible to determine whether the deviation was representative or merely a consequence of too few points due to the masking effect.

The interaction among taste components in a mixture should be viewed in connection with the concentrations of the taste substances, the tasting procedure and measuring technique employed. Such have been demonstrated to have a definite role on the effect obtained. These and other variables are probably contributing to the often contradictory data in the literature on taste interactions.

(b) Food systems

Flavor masking has been demonstrated to be a common phenomenon in the more complex food systems. Chappell (1953) found that lemon oil had a masking effect on the taste of salt depending upon the amount added. Hinreiner et al. (1955a, 1955b) observed that the minimum detectable concentration differences of a number of taste substances were raised when tasted in wine rather than in water. Similarly, the threshold levels of certain taste components of an artificial peach beverage were increased in the presence of other compounds (Keith and Powers, 1968). Pangborn (1960) reported that the greater the acidity of the fruit nectar, the greater the depressing effect it had on the intensity of added taste compounds. Noguchi et al. (1975) reported on the bitter masking activity of a glutamic acid-rich oligopeptide fraction. A plastein product, synthesized from fish protein hydrolyzate and enriched with glutamic acid, did not give rise to the usual bitterness on subsequent hydrolysis. An oligopeptide in the acidic fraction of this plastein was found to be L-glutamyl-L-glutamic acid. When this oligopeptide was added to solutions of various bitter substances, their bitterness scores were invariably reduced by a considerable extent.

A more complex situation occurred when more than one flavor component was used as a masking agent. Guadagni et al. (1973) observed the effect of sucrose and citric acid on limonin, the primary bitter components in grapefruit and orange juice. Both sucrose and citric acid created a masking effect on the bitterness of limonin when these were added separately to limonin in water. However, when citric acid and a sugar mixture were added simultaneously, with pH held constant at 3.5, the threshold of limonin fell significantly relative to that when acid was added alone, but still remained above the level when only sucrose was added. It was suggested that the intense sourness of the acid solutions interfered with bitterness detection while sugar reduced the extreme sourness and facilitated the tasting of bitterness. Similar results were obtained by Ahmed et al. (1978) whose group determined the effect on the threshold of d-limonene, the major volatile organic constituent of orange juice, when acids and sugars were added at a percentage approximately equal to that common in orange juice. Acids were found to significantly increase the threshold values of d-limonene. Sugar also increased the threshold values but the effect was not significant. When all three components were mixed together, the threshold value of d-limonene fell in between those obtained when sugar and acid were added separately. A contradictory finding was observed when citric acid and a sugar mixture was added to naringin (a bitter component in citrus juice) at pH 6.0 (Guadagni et al., 1973). The simultaneous addition of citric acid and sugars raised the threshold level of naringin above those observed when the two components had been added individually. It is not known whether this effect was due to the different pH, compounds or other variables involved.

Some flavor substances appeared to have a greater flavor masking effect than others. Tomato juice was found to exhibit a greater masking effect on bitterness than some other foods. Mackey and Valassi (1956) compared the effect of tomato juice and milk egg custard on taste perception. The results showed that at each level added, caffeine was more difficult to detect in tomato juice than in custard, whether these be in the liquid or gel form.

Flavor masking in natural food systems can be quite complex owing to the presence of many flavor components and other factors such as the pH value, texture, etc. However, with careful control, flavor masking can be successfully employed to optimize the flavor of a food product.

(2) Odor interaction-masking

It has been observed that when different odor stimuli are combined in a mixture, some odorants emerge dominant and mask the odors of the others. Jones and Woskow (1964) noted that in certain binary mixtures of odorous chemicals, only one odor appeared to be important in determining the intensity responses to the mixtures while the other odor had been suppressed.

The masking effect among odors appears to be related to the concentration of stimuli involved. Cain and Drexler (1974) estimated the perceived odor intensity of various concentrations of pure pyridine (a malodorant) and in separate mixtures with several secondary odorants presented at a constant level. It was found that the odor of pyridine was completely masked at the lowest concentration, but the masking effect weakened as the concentration increased. At the highest concentration, the pyridine odor predominated while the secondary odor was masked instead. Mitchell and McBride (1971) found that when propanol was added to various concentrations of eugenol at four levels, the perceived intensity of eugenol was affected most at the weaker concentrations while the highest concentration was little affected.

It has been suggested that large differences in masking ability existed among different odorants. Cain and Drexler (1974) observed that linalyl acetate/linalool and lavandin oil possessed more masking power for pyridine than linalool or linalyl acetate alone although all the masking agents were presented at equal perceived intensity. The difference was attributed to the richer and more complex qualities of the first two substances. Moskowitz (1976) noted that while some odorants possessed stronger masking ability than others, this ability was, nevertheless, modified by the number of odorants present in the mixture. The relationships between all possible combinations of five odorants (methyl disulfide, methyl salicylate, caproic acid, isobutyl, isobutyrate camphor) from two through five component mixtures were examined. All odorants presented were of equal perceived intensity. Methyl disulfide and methyl salicylate were found to be the most dominant odors with their maximal masking effect exhibited in binary mixtures. This effect was weakened considerably as more and more odor components were added. The weaker odorants emerged to be stronger (caproic acid, camphor) and even to be among the most dominating odors (isobutyl, isobutyrate) at different occasions. This moderation was attributed to the more complex masking which occurred in higher order mixtures. Each odorant masked each other in the mixture. Consequently, the strength of a dominant odor might be diminished by some odors present and the weaker ones might have been allowed to emerge.

The dominance of one odorant by another was demonstrated to be transitive, i.e. if odorant A dominated odorant B and odorant B dominated odorant C, then odorant A also dominated odorant C. Thus, methyl disulfide dominated caproic acid which in turn dominated camphor and as predicted methyl disulfide also dominated camphor. The same relationship existed among methyl salicylate, isobutyl, isobutyrate and camphor.

As in the taste system, odor masking is affected by the concentration of stimuli and different odorants possess different masking abilities. The interaction becomes more complex as the number of odor components increases.

(3) Flavor interaction in soy protein

It has been shown that the flavor of soy protein can be masked by the introduction of another food system. However, the flavor of the food system itself can also be affected by the presence of soy protein. Addition of flavor components to soy products usually results in some loss or change of flavor. This has been attributed to the influence from the beany flavor of the soy protein itself, suppressing the added flavor or combining with it to form a new quality; or the interaction between the flavor components and the soy protein.

Arai et al. (1970) presented experimental evidence that binding occurred between soy protein and flavor components. N-hexanal and n-hexanol added to soy protein samples were found to resist vacuum distillation. The amount of resistance increased with the degree of protein denaturation. It was suggested that the flavor components had interacted with soy protein through hydrophobic binding. Franzen and Kinsella (1974) demonstrated the binding of a homologous series of aldehydes and methyl ketones by various forms of soy proteins. The addition of water reduced the volatilities of the flavor components, probably through increased adsorption or solubilization of flavors by the protein-water mixture. Flavor binding by the concentrates, isolates and textured form of soy protein was affected by their compositions. Soy concentrate which contained 70% protein and 20% carbohydrate bound the most flavors. Similar amounts were bound by soy isolates and textured soy protein, neither of which contained significant amounts of carbohydrates and fats.

Gremli (1974) examined the interaction between soy protein and a series of flavor compounds: alcohols, aldehydes and ketones; and its implication on flavor performances. By determining the percentage retention of the compounds with the headspace and high vacuum transfer methods, it was shown that the different classes of compounds reacted differently with soy protein. Aldehydes reacted strongly and demonstrated both reversible and irreversible interaction while ketones only reacted reversibly with soy protein. None of the alcohols had reacted. It was pointed out that compounds which did not interact with soy protein would not be affected in their flavor performances. On the other hand, the reversibly bound compounds would be initially suppressed in their flavor impact. However, the flavors would be gradually released during mastication of the food product.

E. Composition of Tomatoes

Tomato is a popular item in the North American diet and enjoys wide application in different types of dishes as well as food products such as tomato juice, tomato sauce, catsup, and canned tomato.

The flavor of fresh tomatoes has been described as acidic, sweet, fresh, green and tomato-like (Bisogni and Armbruster, 1976; Kazeniac and Hall, 1970). Processed tomato juice is known to have developed a "cooked" or "heated" type of flavor.

The sensory properties of tomatoes are determined by the amount of solids, particularly the proportions of sugars and acids and the volatile compounds composition (Kazeniac and Hall, 1970; Simandle et al., 1966; Stevens, 1972). The proportions of the different components are shown in Table 5.

The free sugars in fresh tomatoes were found to be mostly reducing sugars of which glucose and fructose predominated (Miladi et al., 1969). The organic acids consisted almost entirely of citric acid (Hartmann and Hillig, 1934; Miladi et al., 1969). Nineteen amino acids had been identified in fresh tomato juice with glutamic acid comprising up to 48% of the total weight of amino acids in the juice (Miladi et al., 1969). Processing was demonstrated to have different effects on these components: a decrease in sugars and an increase in both organic and amino acids was noted. Glutamic acid was reported to increase by ten-fold.

Over a hundred volatile components have been identified in tomatoes (Buttery et al., 1971). The different classes of compounds so far identified included aldehydes, ketones, alcohols, acids, esters, acetals, lactones, heterocyclics, hydrocarbons and sulfur compounds. Compounds considered important to the fresh, green tomato flavor are 2-isobutylthiazole, cis-3-hexenal, deca-trans,trans-2,4-dienal and β-ionone (Buttery et al., 1971; Kazeniac and Hall, 1972). During processing, the formation of dimethyl sulfide and the increase in concentration of linalool were noted (Buttery et al., 1971; Guadagni and Miers, 1969; Nelson and Hoff, 1969). The cooked flavor of

TABLE 5

COMPOSITION OF TOMATOES

Constituents	Percentage
Total solids	7.0 - 8.5
Insoluble solids	1.0
Soluble solids	4.0 - 6.0
Sugar	2.0 - 3.0
Acid	0.3 - 0.5
Soluble protein and amino acid	0.8 - 1.2
Mineral constituents	0.3 - 0.6
Salt (sodium chloride)	0.05- 0.1

(from Gould, 1974).

processed tomato products has been attributed to these compounds.

With the great number of compounds identified, it is believed that the total tomato flavor is the result of complex interactions among the different components, rather than the effect of a single or group of compounds.

METHODS AND MATERIALS

A. Sensory Panel Selection

Six adult females were screened on the basis of their general taste acuity and bitterness sensitivity.

(1) Taste acuity

In the screening test, panelists were asked to identify solutions of the four basic tastes: sweet, sour, salty and bitter. Table 6 contains the percent concentrations of the four basic taste solutions. Panelists who could identify all four tastes were considered ideal, while panelists who failed to recognize saltiness were still considered acceptable as this particular taste was not present in the model system to be tested.

(2) Bitterness threshold

Since experimental evidence suggested that bitterness was an important flavor characteristic in soy protein, the bitterness threshold of the panelists were determined to examine their bitterness sensitivity. The samples consisted of a series of bitter solutions with different concentrations of caffeine (Table 7). The samples were coded and presented in random order to the panelists whose task was to identify the samples in which bitterness was detectable. The bitterness

TABLE 6

PERCENT CONCENTRATIONS OF THE FOUR BASIC TASTE COMPOUNDS USED IN PANEL SCREENING TEST

Basic Taste	Compound	% Concentration[a] (w/v)
Sweet	sucrose	1.00
Salty	sodium chloride	0.10
Sour	citric acid	0.06
Bitter	caffeine	0.04

[a] in glass distilled water.

TABLE 7

PERCENT CONCENTRATIONS OF CAFFEINE SOLUTIONS USED IN BITTERNESS THRESHOLD DETERMINATION

Percent concentration of caffeine[a] (w/v)
0.001875
0.003750
0.007500
0.015000
0.030000
0.060000

[a] in glass distilled water.

threshold was calculated as the average value of the first two successive concentrations in which the volunteers could detect bitterness. Panelists whose bitterness threshold fell within the range of threshold values for caffeine reported in literature were considered suitable candidates.

B. Sample Preparation

(1) Soy protein

Textured soy protein (Griffith's Promate 111 Soya Meat Extender 520023) was hydrated with tap water (70°C) at a ratio of 1:3 (w/v) in a covered beaker for 20 minutes. All the water was absorbed after the hydration period.

(2) Tomato sauces

(a) Preparation of sauces

A series of tomato sauces of various concentration were prepared by the dilution of a tomato paste (E. D. Smith Tomato Paste) with tap water. The percent concentration was calculated on the basis of the paste-water mixture (1:1.08 w/v) which was designated the 100% sample. The 90% sample was composed of 90% (by weight) of the mixture and 10% (by weight) of tap water. The 80, 70 and 60% samples were measured in the same way. For convenience, these percentages will be referred to as percent tomato concentration. The composition of the different samples is given in Appendix 1a. Since differing viscosities among the samples, due to their varied concentrations, might interfere with taste judgment, varying quantities of a thickening agent (National Clear-jel) were incorporated into the sauces to duplicate the viscosity of a commercial spaghetti sauce (Chef Boyardee Spaghetti Sauce Meatless). The composition of the different samples is given in Appendix 1b. The sauces were heated in covered double boilers on electric stoves until a temperature of 70°C (serving temperature) was reached. The heating period lasted approximately 25 minutes during which the sauces were stirred once. These sauces were used for tomato sauce characterization (Refer to Methods and Materials, Section E).

(b) Standardization of tomato sauce viscosity

In order to ensure equivalent viscosity among samples of varying tomato concentrations, the thickened tomato sauces were subjected to instrumental and sensory evaluation.

(i) instrumental evaluation

The tomato sauces and the reference (Chef Boyardee Spaghetti Sauce Meatless) each weighing 340 gm were measured into a 600 ml beaker, covered with foil lids and heated on electric stoves to 70°C. The samples were then placed on a warming tray which maintained the 70°C temperature during subsequent testing. Viscosity of the samples was measured with the Brookfield synchro-lectric viscometer (Model LVT, Serial No. C2303) stationed on a Brookfield Helipath Stand (Model C, Serial No. 2409) using a T bar D spindle. Viscosity readings were taken at shear rates of 3, 6, 12, 30 and 60 rpm.

(ii) sensory evaluation

Viscosity of the series of thickened tomato sauces (60, 70, 80, 90 and 100% tomato concentration) was evaluated by five panelists since one panelist was not available at that time. The panelists were instructed to rate the viscosity of the samples against a reference sample (80% tomato concentration, with thickener) using magnitude estimation which is a form of ratio scaling. The panelists were instructed to assign a score to each sample in relation to the reference which, in this case, was arbitrarily given a numerical value of 10. A sample found to be twice as thick as the reference would receive a score of 20. Similarly, a score of 5 would be assigned to a sample considered to be half as thick as the reference. The magnitude estimation method was briefly explained to the panelists who were already familiar with the technique. Tap water was provided for rinsing between samples. Two replicates of the experiment were held. An example of the ballot is given in Appendix 1c.

(3) Soy/tomato mixture

Four concentrations of tomato sauces (55, 70, 85 and 100%) were prepared. The percent tomato concentration was measured in the same manner described previously (Refer to Methods and Materials, Section B. 2a). The amount of thickener to be incorporated into each sauce was obtained by plotting the proportion of thickener used in the original five tomato sauces against the percent tomato concentration (Figure 1). The com-

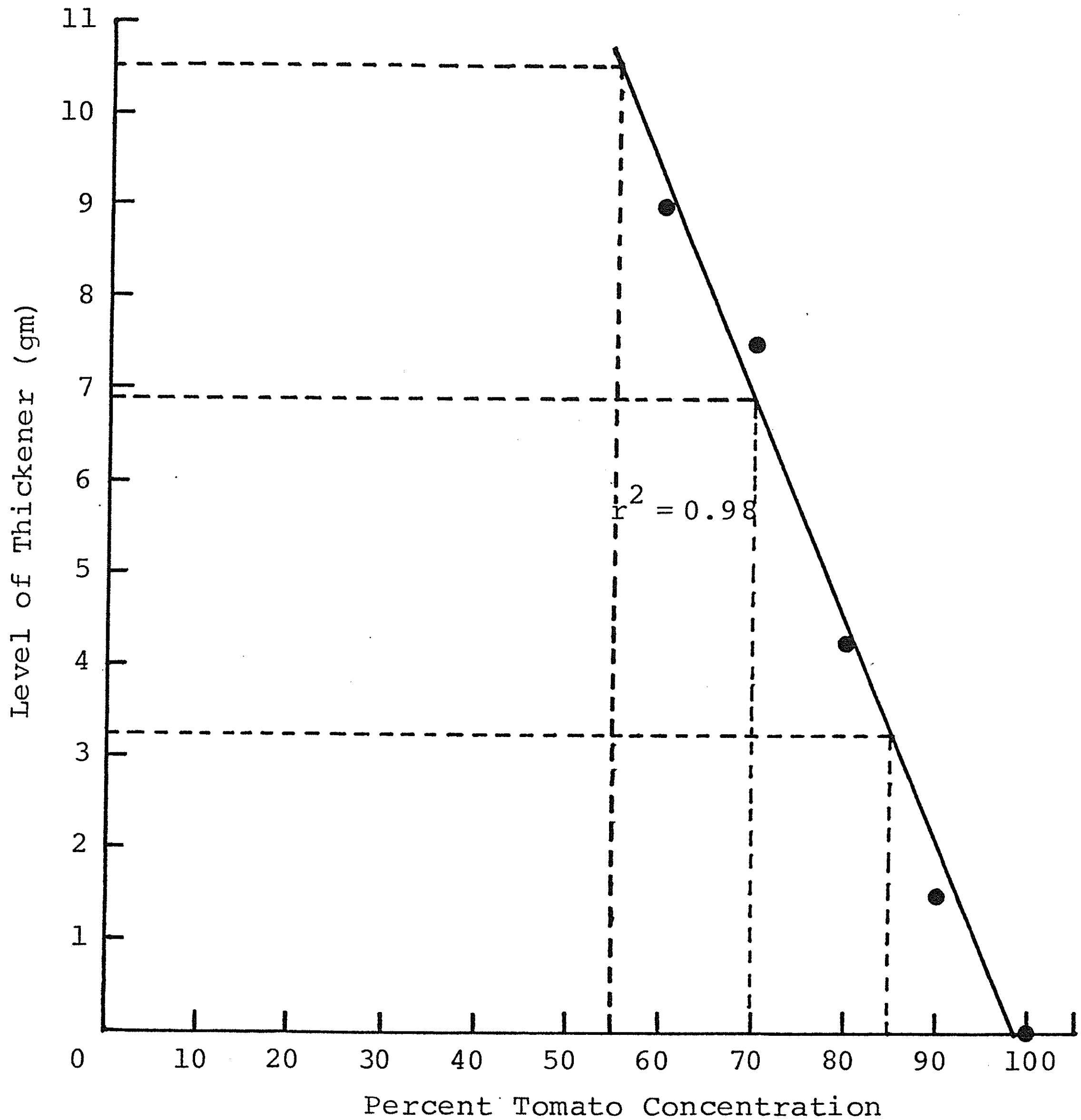

FIGURE 1. LEVEL OF THICKENER VS. PERCENT TOMATO CONCENTRATION.

position of the sauces is given in Appendix 1d. Five percent (w/w) dry soy protein was added to each sauce. Prior to addition, the soy protein was hydrated with tap water (70°C) at a soy:water ratio of 1:3 (w/v) for 20 minutes.

(4) Storage of samples

The hydrated soy protein, tomato sauces and soy/tomato mixtures were placed in glass bottles covered with plastic lids (≃ 4 ml per bottle) for subsequent odor evaluation; and in white plastic creamers with paper lids for taste evaluation. The samples were frozen at -26°C.

(5) Presentation of samples

One hour before serving, the samples were placed in water baths on warming trays and reheated to approximately 70°C. The samples were coded and the order of presentation randomized for each panelist. Evaluation was carried out in individual booths where the use of red light effectively masked any color differences among the samples. Tap water and crackers were provided for rinsing between tastings.

C. Soy Protein Characterization

(1) Aroma and taste description

The objectives of this panel were to characterize and define the aroma and taste of the soy protein under investigation (Griffith's Promate 111 Soya Meat Extender 520023); and to provide training sessions to familiarize the panelists with the soy flavors.

Each panelist received a sample of hydrated soy protein and ballots on which were listed the odor and taste description of soy protein (Appendix 2a, b). These descriptors had been gathered from the literature and from preliminary discussions. Panelists evaluated the odors and tastes of the soy protein sample and noted on the ballots the descriptors they found applicable, indicating their intensities on a 5-point intensity scale. The panelists were also invited to describe any flavors in the samples that were not listed on the ballots. Subsequent discussions and the use of standard flavor samples (Table 8) assisted panelists to clarify and concur on the meaning of each descriptor. The relative importance of each flavor in regard to its intensity in the sample was also discussed. The panelists selected the final set of descriptors on the basis of their importance to the flavor. Six replicates of the panel were conducted.

D. Tomato Sauce Characterization

(1) Aroma and taste description

The flavor description panels were held to define the aroma and taste characteristics of the tomato sauces and to familiarize the panelists with the tomato flavors.

The two samples used were the 60% concentration tomato sauce (with thickener) and the 100% concentration tomato sauce. The 60% concentration sample was included so that any new flavor contributed by the thickener could be detected at this

TABLE 8

STANDARDS USED TO DEVELOP AROMA
& TASTE DESCRIPTORS OF SOY PROTEIN

Soy protein descriptor	Standard
Aroma:	
whole grain	Red River cereal
raw green beany	soaked soy bean
cooked cold potato-like	cooked, mashed cold potato
Taste:	
beany	boiled soy bean
whole grain	Red River cereal

stage. The procedure for developing tomato flavor descriptors was identical to those described in the soy flavor description panel (Refer to Methods and Materials, Section C). The panelists evaluated the odors and tastes of tomato sauces and noted their intensities on a 5-point scale. Group discussions and the use of standard samples helped to achieve agreement among the panelists on the definitions and relative importance of each flavor descriptor. Appendix 3a and b presents the ballots used in this panel. The standard samples used for flavor identification are given in Table 9. The panel was replicated six times.

(2) Effect of tomato concentration on perceived odor and taste

The effect of the varying tomato concentration on the odor and taste intensities of thickened and unthickened tomato sauces was measured.

The samples consisted of the 60, 80 and 100% tomato concentration samples. The 70 and 90% samples had been excluded as it was discovered during the training sessions that the panelists could not successfully evaluate more than three samples at one time. The thickened and unthickened series were evaluated separately for the same reason.

The odor characteristics studied were overall odor intensity, canned tomato-likeness and acidity. Only two of the five descriptors developed in the odor description panel (fruit-like, metallic, heavy/earthy, canned tomato-like and acidic) were retained. Results from the training sessions in-

TABLE 9

STANDARDS USED TO DEVELOP AROMA AND TASTE DESCRIPTORS OF TOMATO SAUCE

Tomato sauce descriptor	Standard
Aroma:	
fruit-like	canned peach
tomato-like	canned tomato
Taste:	
canned tomato-like	canned tomato
astringent	0.08% alum in distilled water
harsh	1.0% malic acid in tap water

dicated that the panelists were not able to evaluate the intensities of the individual odors of the tomato sauces except for canned tomato-likeness and acidity which yielded more consistent results. Therefore, only these two characteristics and the overall odor of the sauces were observed.

The taste characteristics evaluated were overall taste intensity, acidity, harshness, astringency and bitterness. All the taste descriptors developed during the taste description panel, with the exception of "canned tomato-like", were studied. The panelists were of the opinion that "canned tomato-like" was not a meaningful characteristic due to its low intensity in the samples. Accordingly, it was replaced by the term "overall taste intensity".

Panelists were asked to estimate first the odor and then the taste intensities of the samples against a reference (80%, without thickener) using magnitude estimation. Panelists were instructed to take three short sniffs for each odor testing; re-cover the sample container immediately; and rest between samples. For taste evaluation, panelists were asked to stir the sample before tasting and to expectorate except when evaluating bitterness. Rinsing with water and crackers after tasting each sample was advised. Three replicates of the experiment were carried out. An example of the ballot is given in Appendix 4a and b.

E. Soy/Tomato Mixture

This experiment was designed to measure the mutual masking effects between the soy and tomato flavors as well as the pleasantness of the soy/tomato mixtures.

A refresher panel was held to renew the panelists' memory of the soy protein flavor and to detect any new flavor development, if any, due to the combination of soy protein and tomato sauce. The panelists had no difficulty remembering the soy protein flavor and no new flavor was noted in the soy-tomato mixture. However, it was found that the panelists were unable to evaluate the individual odors and flavors of the soy protein in the mixtures, as evidenced by the large number of "NPs" (odor or taste not present) in the data. Through panel discussions, it was resolved that only the overall soy odor, soy flavor and soy aftertaste should be studied. Of the five tomato flavors studied, only overall taste and acidity were retained as the panelists could not discriminate among the sample intensities with regard to the other three taste components after the introduction of the soy protein.

The panelists were presented with a series of soy/tomato mixtures (55, 70, 85 and 100% tomato concentration). The tomato concentrations were changed to increase the number of observations. The thickened and unthickened series were again evaluated separately. The panelists estimated the soy odor, flavor and aftertaste of the soy protein in the mixture against a reference of hydrated soy protein. The pleasantness of the mixture was then compared to a reference of tomato sauce (80%, without thickener). Finally, the panelists evaluated the overall taste and acidic intensities of the tomato sauce in the presence of soy protein against the reference tomato sauce. Odor testing technique was identical to that employed in evaluating tomato odors. For taste evaluations, the panelists were instructed to stir the samples before tasting, to chew on the samples, to swirl them in their mouths and to expectorate. Rinsing with water and crackers between samples was advised. Three replicates of the experiment were conducted. An example of the ballot can be found in Appendix 5a and b.

F. Statistical Analysis

Since the technique of magnitude estimation allows the panelists to select any appropriate number to reflect the ratios of perceived intensities between the samples and the reference, disparity of scale among individual panelists is common. To reduce the difference among scales, the data were subjected to a normalization process. The geometric mean of the data generated by each panelist in all the replicates was calculated. Each data point was then divided by the panelist's geometric mean. In this way, each set of normalized data had a geometric mean of one. As magnitude estimates are distributed log normally, the data were then converted to logarithms for statistical analysis.

A 5 x 5 x 2 factorial analysis of variance was performed on the panel viscosity data to detect if there was any significant difference among the samples.

Linear regression of the following form:

$$\log S = \log k + n \log C$$

where S = sensory intensity given by the magnitude estimates

k = intercept

C = physical concentration of the samples

n = slope of regression line

was performed on the logarithms of the data to observe the relationship between concentration of tomato sauces and the various taste intensities.

The significance of the correlation coefficient (r) of each intensity function was tested with the test statistics:

$$t_{n-2} = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

In order to test for the effect of the addition of a thickening agent, the pairs of intensity functions representing the thickened and unthickened tomato sauces or soy/tomato mixture were compared statistically. The difference between the slopes and elevations of the pairs of functions was tested.

To observe the change in overall taste and acidic intensities of the tomato sauces before and after soy protein addition, the intensity functions representing the corresponding tomato sauce and soy-tomato mixtures were also compared by testing the statistical difference between their slopes and elevations.

RESULTS AND DISCUSSIONS

A. Sensory Panel Selection

(1) Taste acuity

The taste acuity test served as a screening procedure to find panelists with normal taste sensitivity. Solutions of the four basic tastes were presented to six volunteers. Four of the volunteers correctly identified all the basic tastes while the remaining two could not recognize the salty taste. Since this particular taste was not present in either the soy protein or the tomato based samples, all the volunteers were considered suitable candidates for the taste panel.

(2) Bitterness threshold

The bitterness thresholds of the panelists were determined to establish their sensitivity to the bitter taste. All volunteers, with the exception of one, had a bitter threshold value of 0.0113% caffeine in water. One panelist had a value of 0.0225%. These figures agreed well with threshold values for caffeine reported in literature. Knowles and Johnson (1941) reported a threshold value of 0.0155% and Pangborn (1959) reported a threshold value of 0.0272%. All panelists were considered to be sufficiently sensitive to bitterness.

B. Standardization of Tomato Sauce Viscosity

Since the attainment of equivalent viscosity among the five thickened tomato sauces was a prerequisite for the initiation of the experiment, instrumental and sensory tests were conducted to determine the viscosity of the samples.

(1) Instrumental measurement

Calculated viscosity values from Brookfield synchrolectric viscometer readings of the various tomato sauces and the reference (Chef Boyardee Spaghetti Sauce Meatless) are given in Table 10. It was concluded from the similarity of the data among the various samples that the tomato sauces were of comparable viscosity.

(2) Sensory evaluation

The viscosity data were subjected to analysis of variance. No significant difference in viscosity was found among the samples (Appendix 6).

From the results of the instrumental and sensory tests, it was concluded that equivalent viscosity was achieved among the samples. It was decided, therefore, to proceed with the study as originally planned.

C. Soy Protein Characterization

(1) Aroma and taste description

The dominant odors and tastes of the hydrated soy protein were characterized and defined through panel discussion.

TABLE 10

CALCULATED VISCOSITY VALUES OF TOMATO SAUCES OF VARIOUS TOMATO CONCENTRATIONS

Sample[a]	Shear rate (rpm)	Mean viscosity value[b] (cps)	Log viscosity value (cps)
Reference sauce[c]	3	21511.80	4.33
	6	12737.25	4.11
	12	6487.28	3.81
	30	3133.53	3.50
	60	1754.24	3.24
100% tomato sauce	3	31055.58	4.49
	6	14855.13	4.17
	12	7474.98	3.87
	30	2843.15	3.45
	60	1654.68	3.22
90% tomato sauce	3	26706.60	4.43
	6	13066.92	4.13
	12	6618.42	3.82
	30	2771.23	3.44
	60	1628.37	3.21
80% tomato sauce	3	28131.84	4.45
	6	13962.69	4.14
	12	1285.74	3.86
	30	2937.06	3.47
	60	1710.62	3.23

continued...

Table 10 Continued...

Sample[a]	Shear rate (rpm)	Mean viscosity value[b] (cps)	Log viscosity value (cps)
70% tomato sauce	3	26493.48	4.42
	6	12197.79	4.09
	12	6386.02	3.81
	30	2730.60	3.44
	60	1609.06	3.21
60% tomato sauce	3	37695.60	4.58
	6	12983.67	4.11
	12	6678.18	3.82
	30	3030.30	3.48
	60	1683.98	3.23

[a] For composition of sample, refer to Appendix 1b.

[b] Mean of 2 replicates, calculated from readings taken with Brookfield synchro-lectric viscometer, Model LVT, Serial No. C2303, on Brookfield Helipath Stand, Model C, Serial No. 2409; using a T bar D spindle.

[c] Reference sauce = Chef Boyardee Spaghetti Sauce Meatless.

The selected odor descriptors, in order of their importance, were: whole grain-like, raw green beany, sweet and cooked potato-like. The descriptors considered to best describe the taste of the soy protein, in the descending order of their intensities, were: whole grain-like, beany, sweet and bitter.

D. Tomato Sauce Characterization

(1) Aroma and taste description

The dominant odor and taste of the 60% (with thickener) and 100% tomato concentration samples were described by the panelists. Group discussions were used to obtain agreement on the definitions and relative importance of the various descriptors. The odor qualities of the two samples were found to be identical. The selected odor descriptors were, in order of their prominance: fruit-like, heavy/earthy, acidic, metallic and canned tomato-like. The two samples also had identical taste components. In order of their importance, these were: acidic, harsh, bitter, astringent and canned tomato-like.

(2) Effect of tomato concentration on perceived odors

The effect of tomato concentration on perceived intensity was estimated for three tomato sauce odors: acidic, canned tomato-like and overall odor. However, no meaningful conclusion could be derived from the data which reflected a great deal of inconsistency among the panelists. The discordant responses indicated that the panelists were unable to discriminate among the odor intensities of the three tomato concentrations. From the panelists' comments, it appeared that the odor evaluation was made very difficult by the strong initial intensity of the tomato odors and the fact that the odors escaped quickly when one sample was opened.

(3) Effect of tomato concentration on perceived tastes

Perceived taste intensities, as a function of tomato concentration, were determined for the thickened and unthickened tomato sauces at tomato concentrations of 60, 80 and 100% (Refer to Appendix 1a, b for composition of sauces). The taste characteristics evaluated were overall taste, acidity, harshness, bitterness and astringency.

The intensities of the different tastes were found to increase with tomato concentration (Figure 2a - e). The lines on the graphs represent the intensity functions of the different tastes. The relationship was significantly linear in only six cases. The intensity functions that were not significantly linear represent overall taste intensity (of the unthickened sauce) (Figure 2a); acidity (of the thickened sauce) (Figure 2b); and harshness (of both types of sauces) (Figure 2c). Statistical significance is difficult to obtain with only three points on the graph. A high r^2 value of at least 0.976 is required for the correlation coefficient to be statistically significant. This may account for the lack of signficance of some of the regression lines. It is also possible, judging from the distribution of the points in the case of harshness, that the lines could be curvilinear. How-

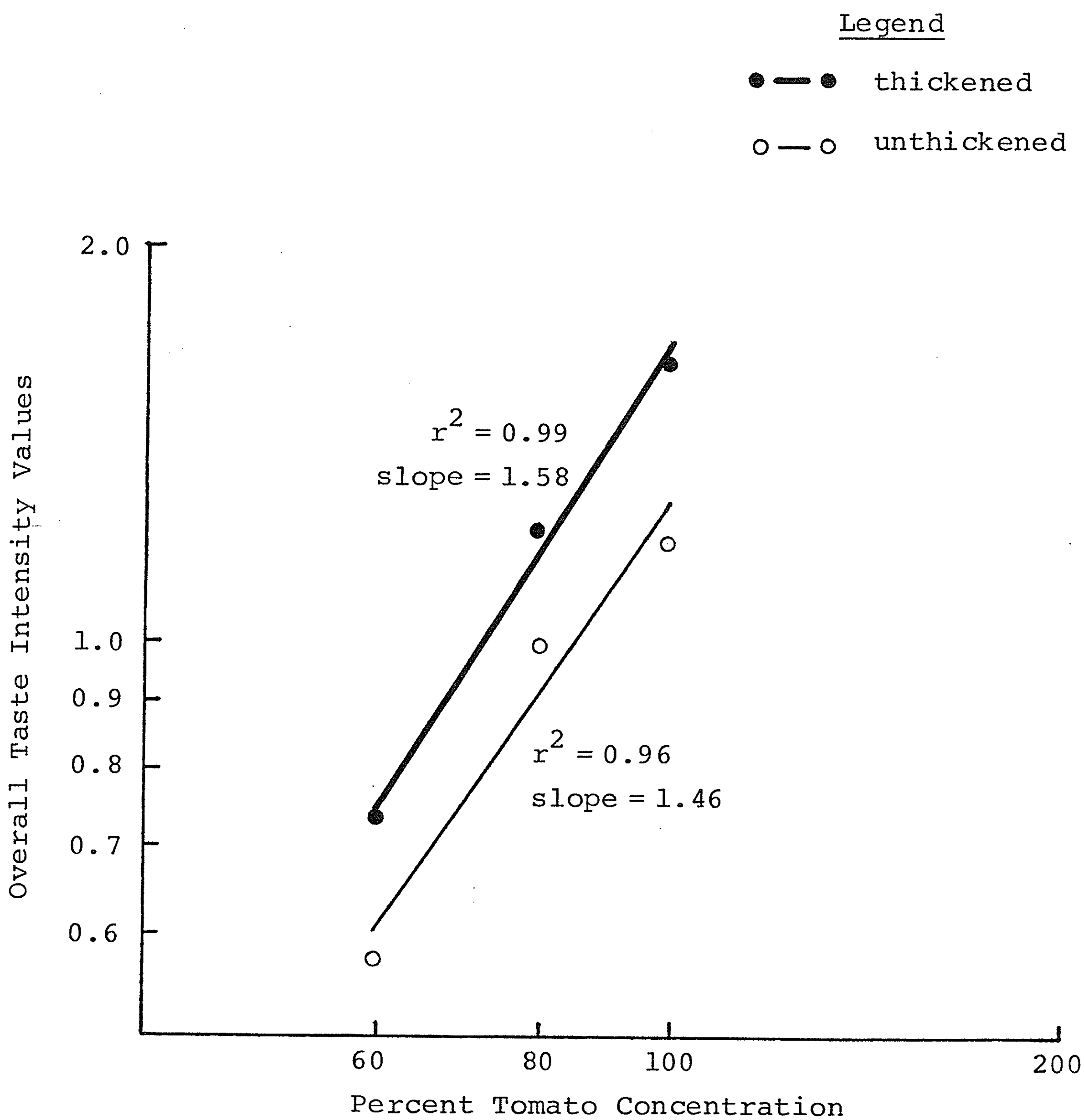

FIGURE 2a. OVERALL TASTE INTENSITY VALUES OF TOMATO SAUCES VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

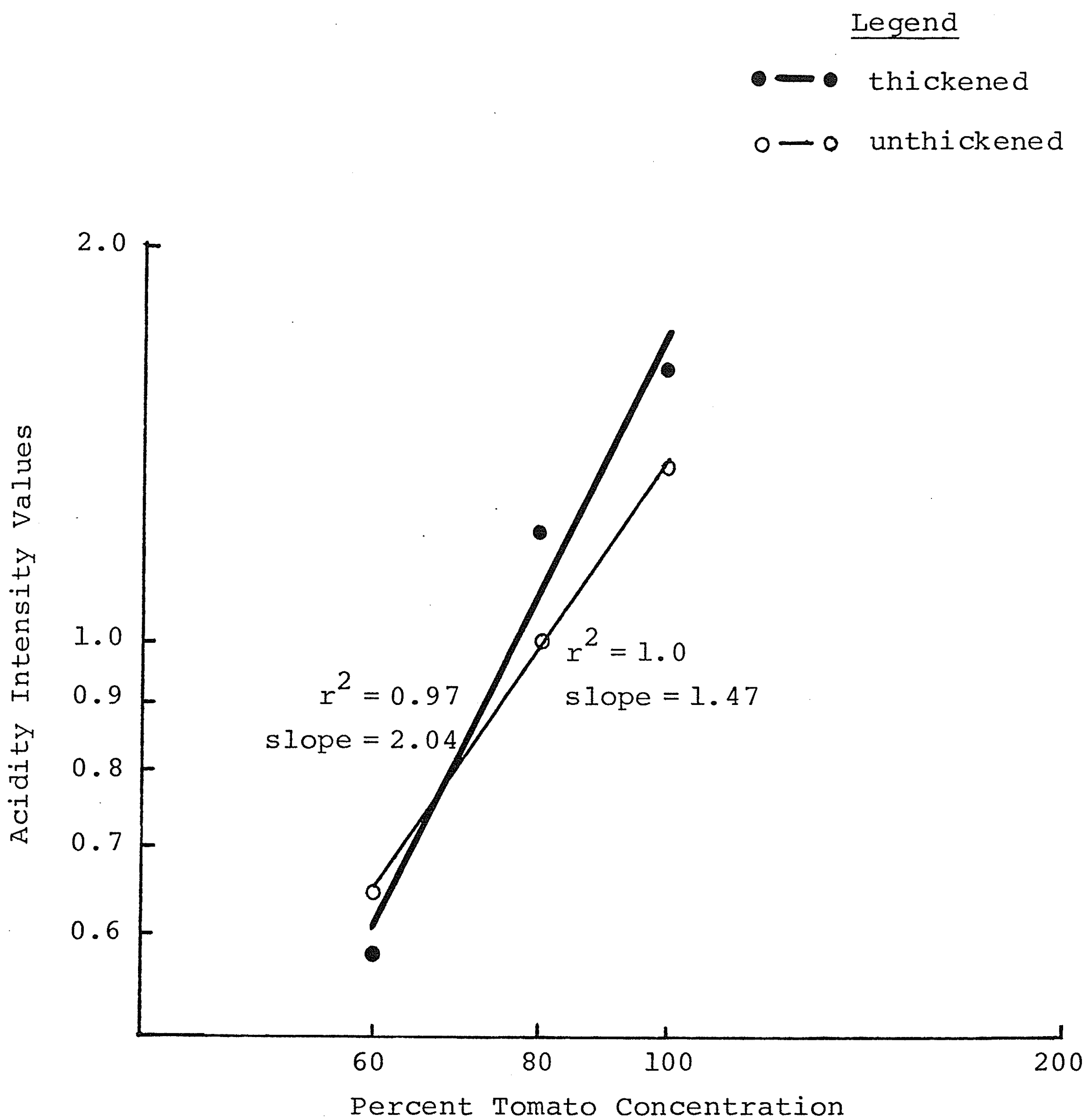

FIGURE 2b. ACIDITY INTENSITY VALUES OF TOMATO SAUCES VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

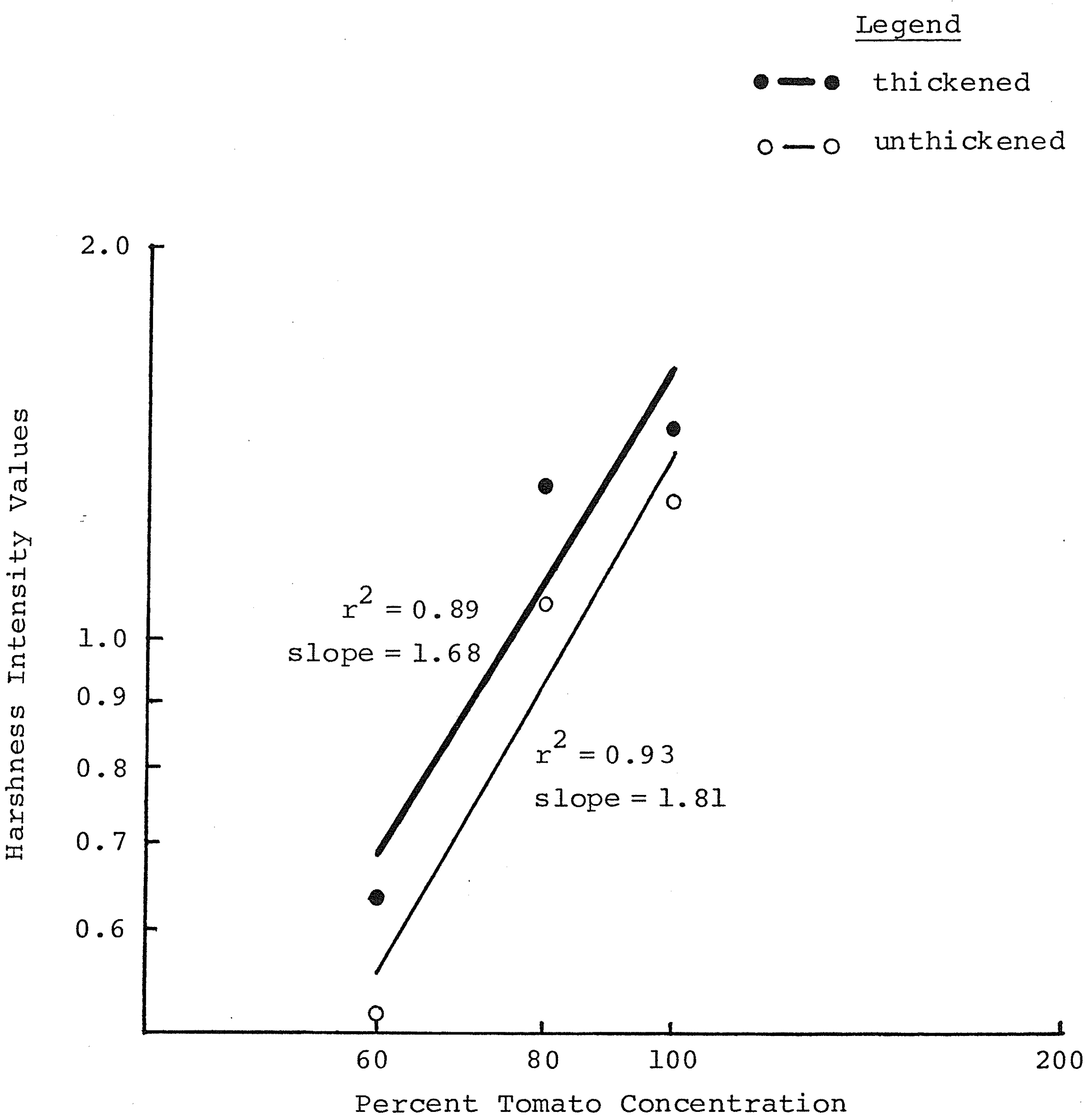

FIGURE 2c. HARSHNESS INTENSITY VALUES OF TOMATO SAUCES VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

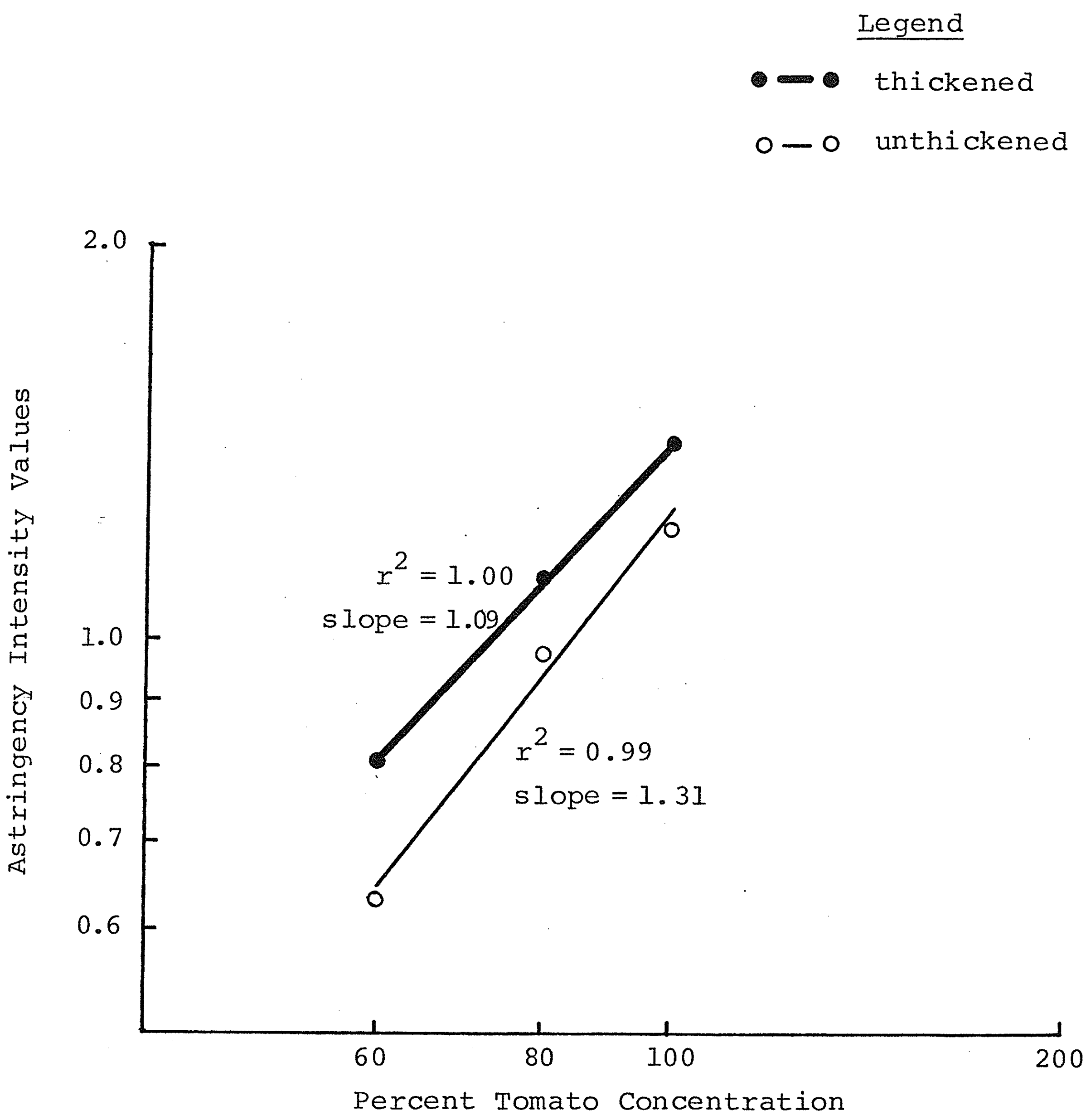

FIGURE 2d. ASTRINGENCY INTENSITY VALUES OF TOMATO SAUCES VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

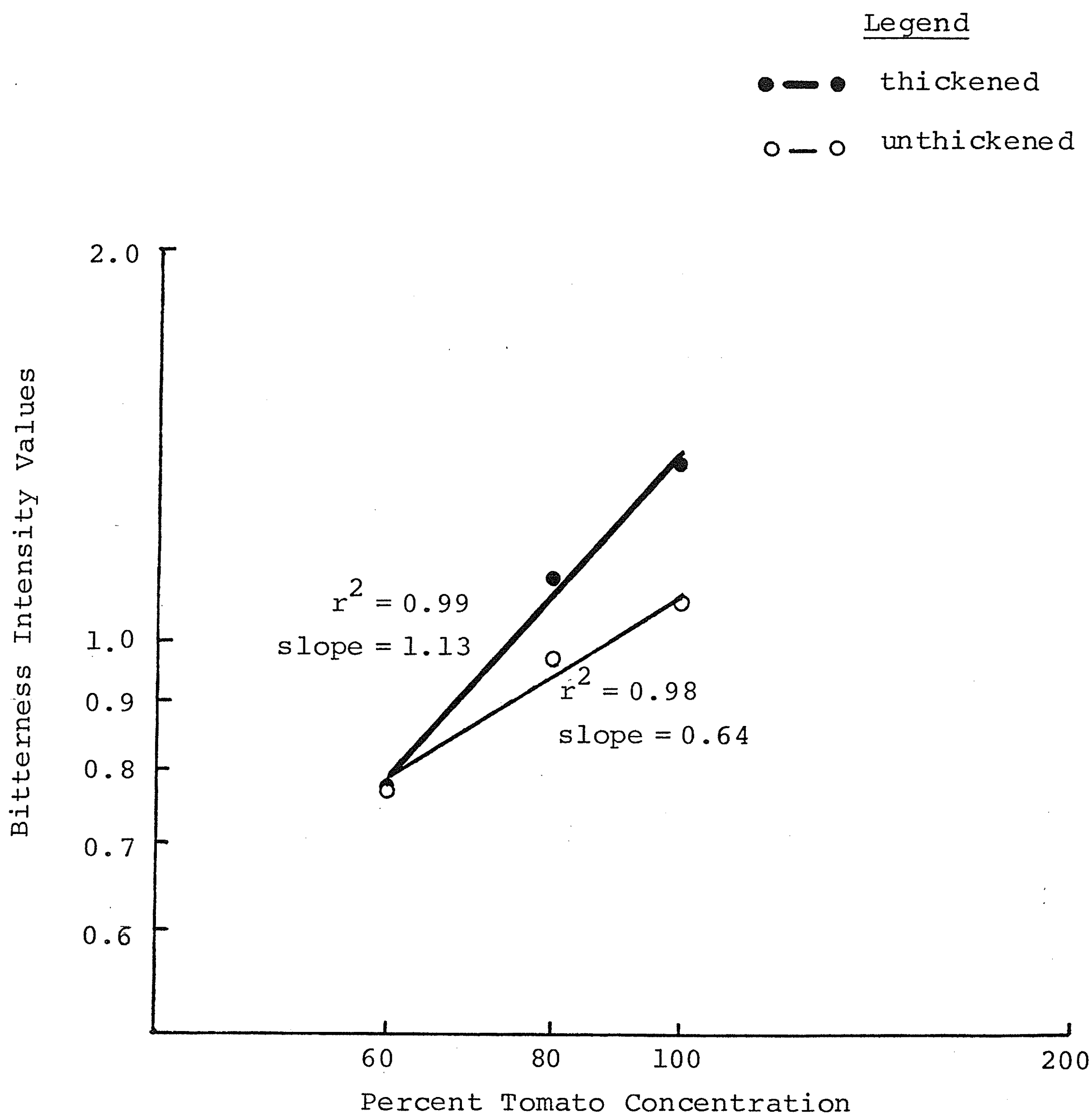

FIGURE 2e. BITTERNESS INTENSITY OF TOMATO SAUCES VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

ever, the limited number of points prevented a definite conclusion from being reached.

The effect of the addition of a thickener on the slopes of the taste intensities of the tomato sauces was examined. For the overall taste, harshness and astringency, only a small difference was noted between the slopes of the two regression lines representing the thickened and unthickened sauces (Figure 2a, c, d). A greater difference was found in acidity and bitterness (Figure 2b, e). However, no significant difference was found between the slopes when the pairs of lines were compared statistically (Appendix 7a - e).

In most of the cases, the thickened series of sauces were rated higher in taste intensities than the unthickened series. When the pairs of regression lines representing the thickened and unthickened series were tested for differences in elevations, significant differences were found in two cases: the overall taste and astringency. Although the addition of thickening agents had been reported to depress or enhance the taste intensities of the four basic taste solutions and solutions of flavor compounds (Moskowitz and Arabie, 1970; Pangborn et al., 1973; Pangborn and Szczesniak, 1974), the increased intensities of the thickened series in the present case was probably not the result of the addition of a thickener. This is evident when one compares the intensity values of the 100% tomato concentration sample of the thickened and unthickened series of sauces. The samples in either case were identical in composition. However, it was consistently judged to be higher in intensity in the thickened series. The result was more likely due to the lapse of time between the evaluation of the two series of sauces. Owing to the fact that the panelists could not successfully evaluate more than three samples at one time, the thickened series of sauces was evaluated apart from the unthickened sauces. The judgment of the panelists might have been affected by this procedure.

E. Soy/Tomato Mixture

(1) Tomato taste intensity

A constant level of soy protein was incorporated into various concentrations of tomato sauces in order to observe its effect on the various tomato tastes. The taste characteristics evaluated were the overall taste and acidity of the tomato sauces.

A positive and significant linear relationship was found between tomato concentration and the perceived intensities of the overall and acidic tastes of tomato sauces with added soy protein (Figure 3a, b). Compared to the tomato sauce lines, the soy-tomato mixture lines had relatively steeper slopes in both cases. The slopes of the overall taste intensity in the thickened and unthickened mixtures were 2.67 and 2.93, respectively. The corresponding slopes for the tomato sauces were 1.58 and 1.46. In the case of acidity, the slopes were 4.05 for the thickened and 3.17 for the unthickened mixtures, whereas for the sauces, they were 2.04 and 1.47.

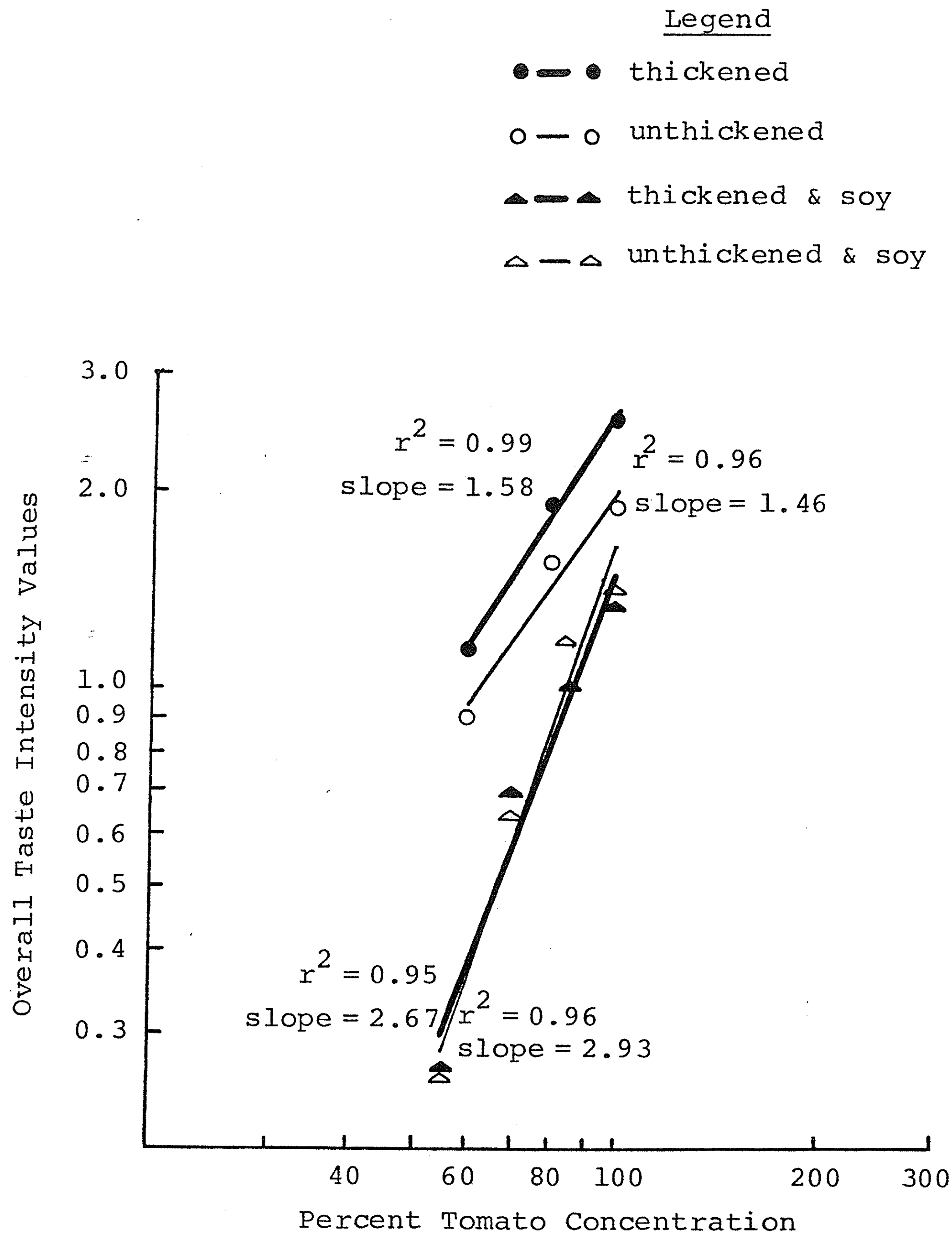

FIGURE 3a. OVERALL TASTE INTENSITY VALUES OF TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

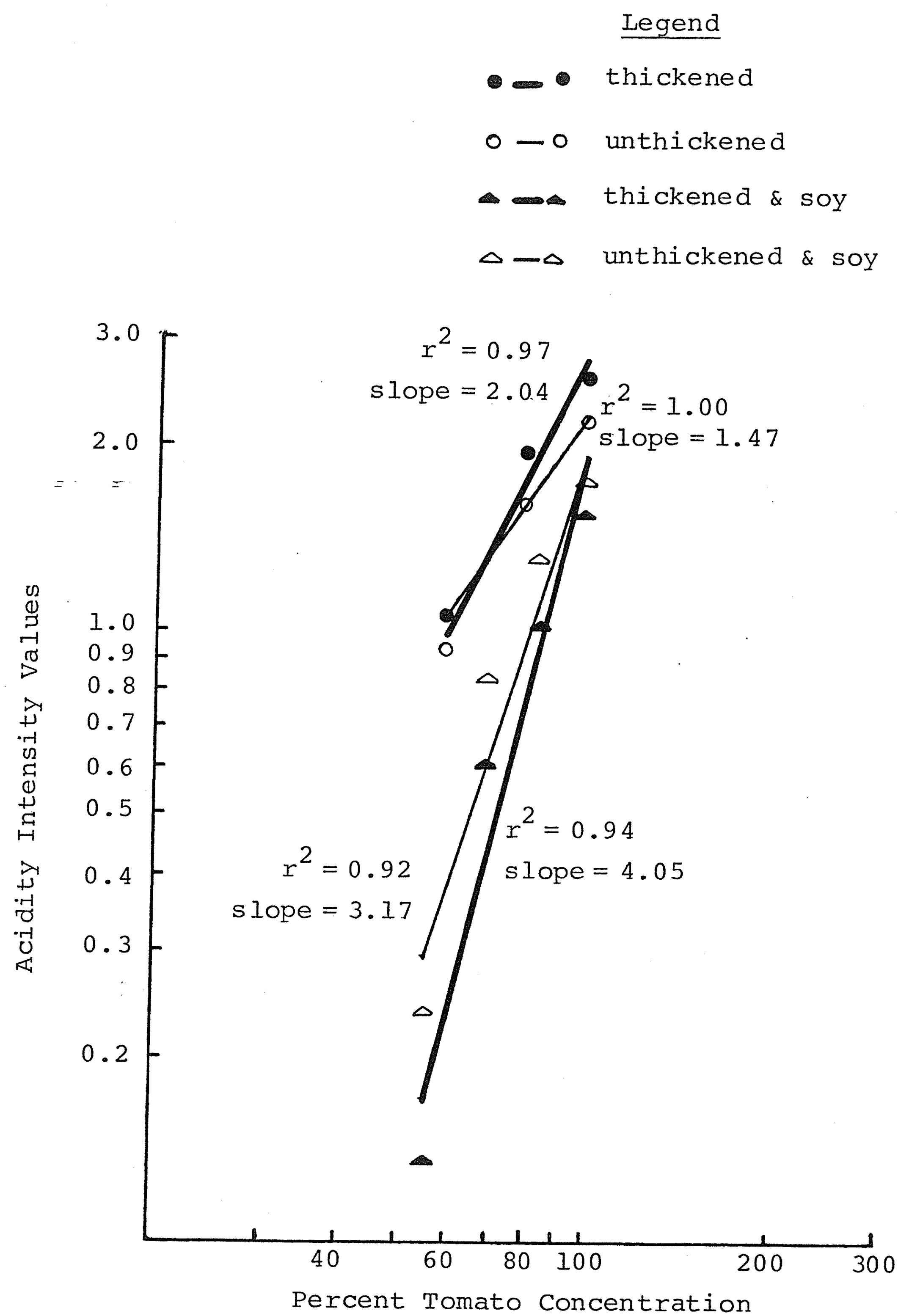

FIGURE 3b. ACIDITY INTENSITY VALUES OF TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

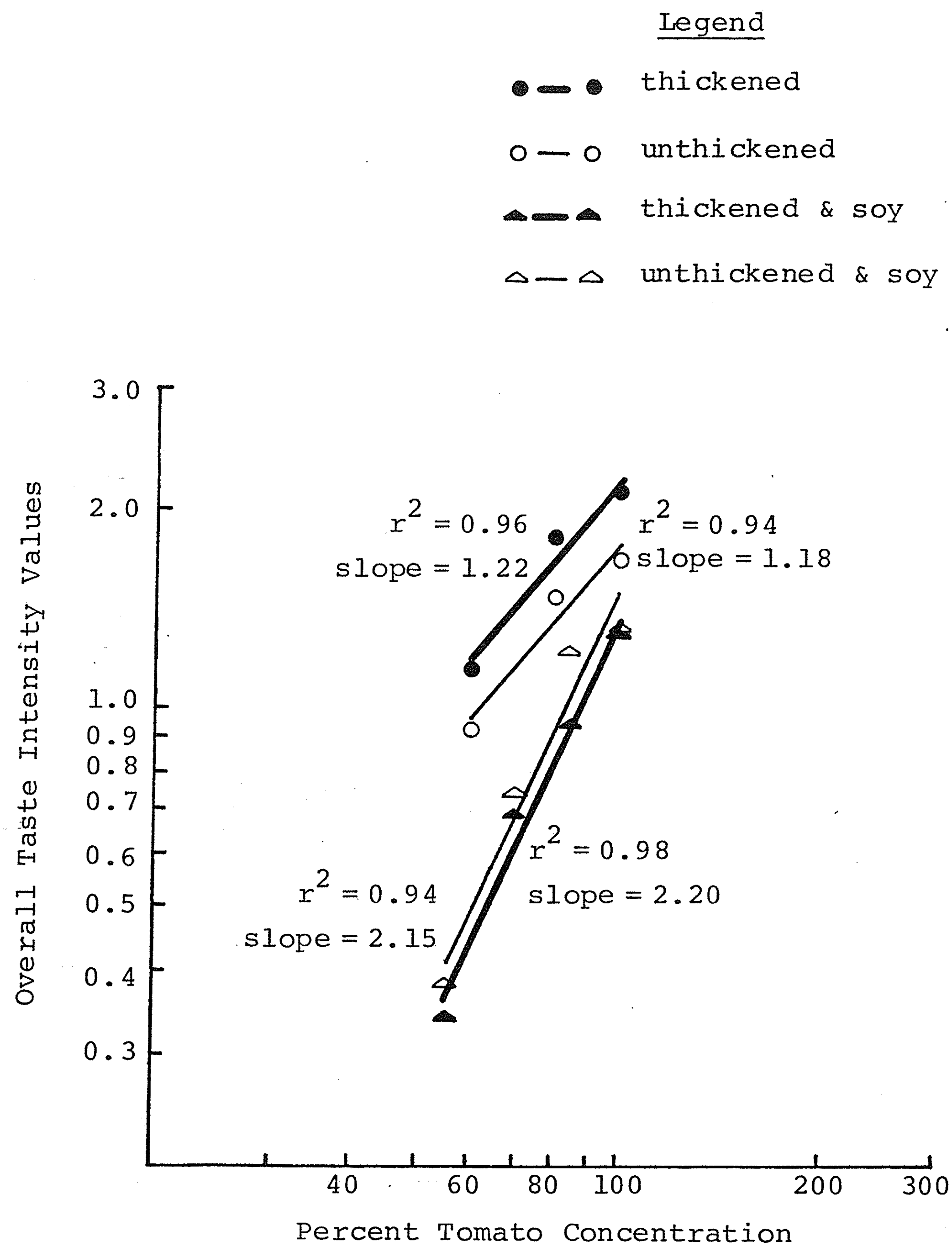

FIGURE 3c. OVERALL TASTE INTENSITY VALUES OF TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION VS. PERCENT TOMATO CONCENTRATION (REANALYSED DATA, LOG-LOG CO-ORDINATES).

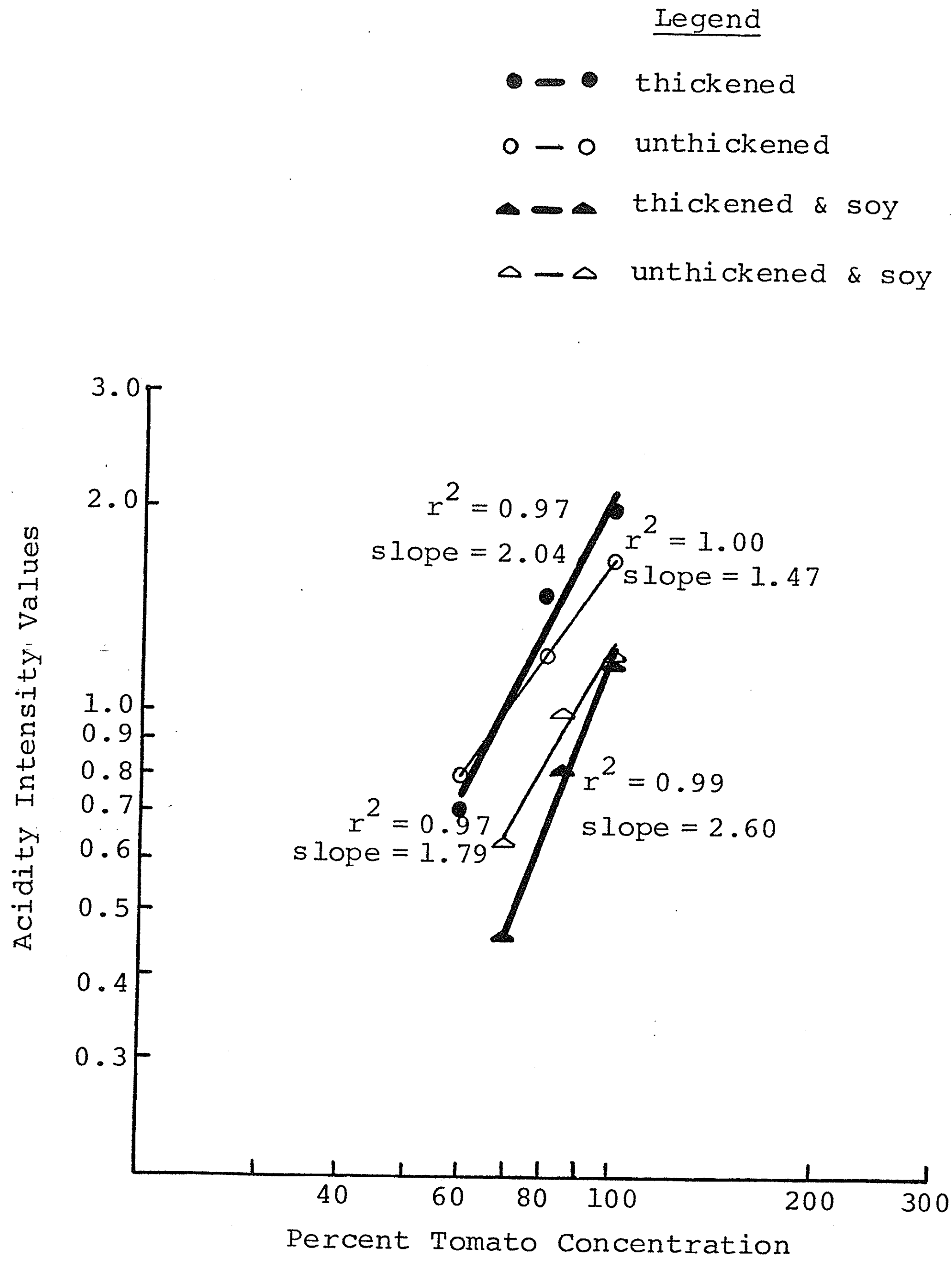

FIGURE 3d. ACIDITY INTENSITY VALUES OF TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION VS. PERCENT TOMATO CONCENTRATION (REANALYSED DATA, LOG-LOG CO-ORDINATES).

The steepness of the mixture lines, in the case of overall intensity, was the result of the exceptionally low scores given by one of the panelists to the lowest concentration (55%) mixture sample. Consequently, the average score of this particular sample was depressed. However, the same panelist also assigned low values to the lowest concentration (60%) tomato sauce sample, and higher than average values to the highest concentration (100%) tomato sauce which undoubtedly contributed to the steepness of the tomato sauce lines. In the case of acidity, the relative steepness of the mixture lines can be explained by the fact that half of the panelists rated the 55% mixture sample exceedingly low in intensity. Although the difference between the corresponding slopes of the sauces and mixtures appeared to be considerable in both cases, the difference was not statistically significant (Appendix 8a - d).

Since the slopes of the mixture functions appeared to be extraordinarily steep, compared to the slopes of basic taste intensity functions reported in the literature, the data was re-examined with the lower than average values omitted. The overall intensity scores of the particular panelist, as well as the acidity scores pertaining to the 55% mixture sample were excluded from the analysis.

As expected, the overall intensity slopes of both the sauces and the mixtures were reduced (thickened and unthickened sauces from 1.58 and 1.46, respectively to 1.22 and 1.18; thickened and unthickened mixtures from 2.67 and 2.93, respectively to 2.20 and 2.15) (Figure 3a, c). However, the relative steepness between the corresponding slopes of the sauces and the mixtures remained unchanged. Apparently, this panelist's scores affected the sauces and mixtures data in the same manner. The r^2 value of the intensity function was increased in the case of the thickened mixture but reduced in the rest.

In the case of acidity, the slopes of the intensity functions of thickened and unthickened mixtures were reduced markedly (from 4.05 to 2.60 and 3.17 to 1.79, respectively) (Figure 3b, d). The r^2 values also increased considerably indicating that the intensity functions fitted the data better when the values of the 55% samples were omitted from analysis.

The statistical difference between the corresponding slopes of the sauces and mixtures were re-examined. No significant difference was found for either taste (Appendix 8e - h). In two taste interaction studies, Moskowitz (1971,1972) also observed that the slopes of the sensory function of a given taste were generally little affected by the presence of a second taste. However, a marked change in exponent was occasionally noted, especially where higher concentrations of the second taste had been added.

While the differences between the slopes of the intensity functions of tomato sauces before and after soy protein addition were not significant, the elevations between the pairs of lines were significantly different for both the overall taste and acidity (Appendix 8a - d). The difference persisted after the data had been reanalysed (Appendix 8e - h).

From the graphs (Figure 3a, b, c, d) it can be seen that the taste intensities of the tomato sauces were depressed in the presence of soy protein. Suppression appeared to be greater at the more diluted concentration of tomato. These results agreed with the findings of previous research which indicated that when different tasting substances were combined in mixtures, suppression was the most common phenomenon encountered (Beebe-Center et al., 1959; Moskowitz, 1972; Pangborn, 1960,1961, 1962). Although suppression had been noted to be greater at higher concentration of the primary taste (Pangborn, 1962), Pangborn (1961) found that when citric acid was added to sucrose, the masking effect was greater at the lower level of sucrose. Moskowitz (1972) also observed that when a constant level of a second taste (sodium chloride, citric acid, and quinine sulphate) was added separately across varying sugar concentrations, the former exerted a greater masking effect at the lower concentrations. Apart from the masking effect of the soy protein, the depressed intensity of the tomato sauce could also be attributed to the interaction between soy protein and the tomato flavor components. Experimental results evidenced the binding of various flavor components by soy protein (Arai et al., 1970; Franzen and Kinsella, 1974; Gremli, 1974).

The effect of the addition of a thickening agent on the taste intensities of tomato sauces with added soy protein was examined. For the overall taste intensity, the presence of the thickener did not significantly affect the slopes nor the elevations of the intensity functions (Appendix 9a). Although it appeared that the acidity of the tomato sauces was depressed progressively with the amount of thickener added (Figure 3b), the difference in the slopes and elevations between the two regression lines was again not significant (Appendix 9b). Reanalysis of the data did not affect the above results (Appendix 9c, d).

(2) Soy flavor

The soy taste intensity of soy protein in the soy-tomato mixtures was estimated to observe the interaction between tomato and soy flavor. The scores of one panelist were omitted in the analysis due to inconsistency.

Tomato flavor successfully masked the soy taste of the soy protein in the mixtures (Figure 4). The intensities of the soy taste were found to be inversely related to the tomato concentration. The relationship was significantly linear. The suppression of the soy flavor was considerable as indicated by the slopes of the intensity functions, -2.46 and -3.07 for the thickened and unthickened mixtures, respectively. The result of this experiment was in accordance with the findings of taste interaction studies (Beebe-Center et al., 1959; Guadagni et al., 1973; Pangborn, 1961,1962) which generally agreed that the masking effect increased with the concentration of the masking agent.

The equality of slopes and elevations of the two intensity functions representing the thickened and unthickened mix-

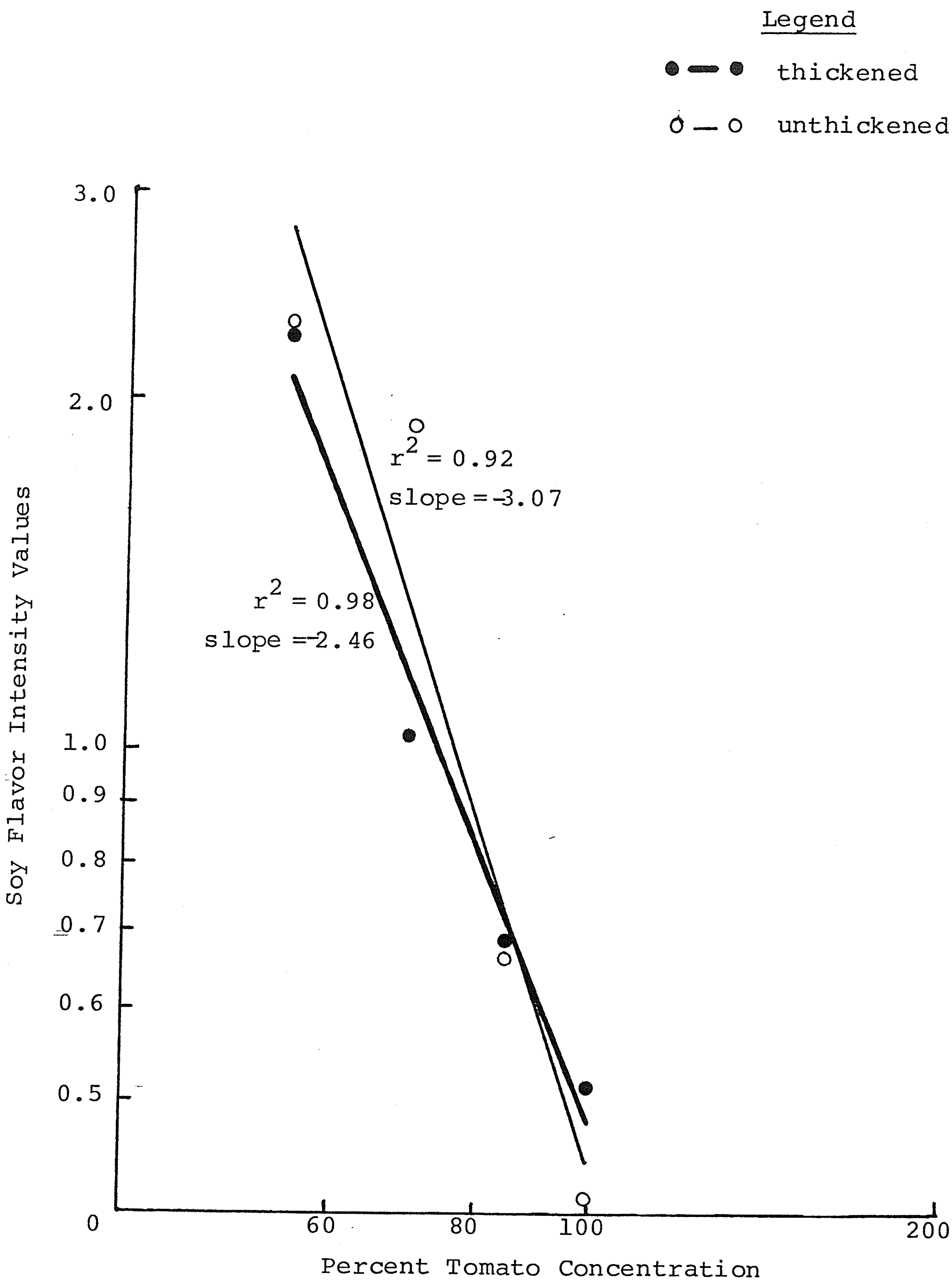

FIGURE 4. SOY FLAVOR INTENSITY VALUES OF SOY-TOMATO MIXTURE VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

tures was tested (Appendix 10). No significant difference was found indicating that the intensity of the soy taste was not affected by the addition of the thickener.

(3) Soy odor and aftertaste

The soy odor and aftertaste intensities in the soy/tomato mixtures were also evaluated. However, the data were not analysed statistically since there were many instances when the panelists could not perceive the odor and the taste. Instead, their respective mean scores and total number of "NP" values, i.e. "odor or taste not present" values are presented in the following two tables. The mean scores represent the average of the raw magnitude estimates. The "not present" values were arbitrarily assigned a "0" value for the calculation.

All the concentrations of tomato sauce had a considerable masking effect on the soy odor. No values were greater than 2 which indicated that the soy odor of the various samples was less than ¼ the strength of the reference which was a sample of rehydrated soy protein with no tomato sauce added. The mean scores did not show a consistent decrease with an increase in tomato sauce concentration. A closer look at the individual panelist's scores revealed the same inconsistency indicating that the panelists had not been able to discriminate accurately between the various samples. In general, the soy odor was more suppressed at the higher tomato concentrations (85 and 100%) than at the lower concentrations (55 and 70%). The 85% concentration gave the lowest soy odor scores.

TABLE 11

THE SCORES OF SOY ODOR INTENSITY IN SOY/TOMATO MIXTURES

Tomato Concentration (%)	MEAN SOY ODOR INTENSITY[a]		TOTAL NO. OF NP[b]	
	Unthickened	Thickened	Unthickened	Thickened
55	1.75	1.23	6	4
70	1.32	1.83	4	3
85	0.59	0.35	10	10
100	1.04	0.64	7	8

[a] Mean raw magnitude estimates of 3 replicates (3 x 6 = 18 judgments); reference = 10.

[b] Total over 3 replicates (3 x 6 = 18 judgments); NP = odor not present = 0.

TABLE 12

THE SCORES OF SOY AFTERTASTE INTENSITY IN SOY/TOMATO MIXTURES

Tomato Concentration (%)	MEAN SOY AFTERTASTE INTENSITY[a]		TOTAL NO. OF NP[b]	
	Thickened	Unthickened	Thickened	Unthickened
55	5.17	4.39	3	2
70	2.94	2.04	4	3
85	2.17	1.45	6	6
100	1.69	1.34	9	7

[a] Mean raw magnitude estimates of 3 replicates (3 x 6 = 18 judgments); reference = 10.

[b] Total over 3 replicates (3 x 6 = 18 judgments); NP = aftertaste not present = 0.

The soy aftertaste data can be found in Table 12. The soy aftertaste intensity of soy protein was progressively suppressed by increasing the tomato concentration. Both thickened and unthickened mixtures yielded similar results. The higher concentration had a considerably greater masking effect. At 55% tomato concentration, the samples were rated approximately ½ as strong as the reference in soy aftertaste. However, at 100% tomato concentration, the soy aftertaste of the samples, were less than 1/5 of the intensity of the reference sample.

(4) Pleasantness

The pleasantness of the mixture of soy protein and various concentrations of tomato sauce was measured to determine which level of tomato concentration in combination with soy protein would give the most desirable product.

The pleasantness values increased progressively with tomato concentration in a linear manner (Figure 5) indicating that samples with higher tomato concentration were better liked. It was interesting to note that the slopes of the pleasantness functions (1.85 and 2.13 for thickened and unthickened mixtures, respectively) were comparable to those of the overall taste (2.20, 2.15) and acidity (2.60, 1.79) of the tomato components of the mixtures (reanalysed data). This indicated that pleasantness grew at approximately the same rate as the taste intensities of the tomato sauces.

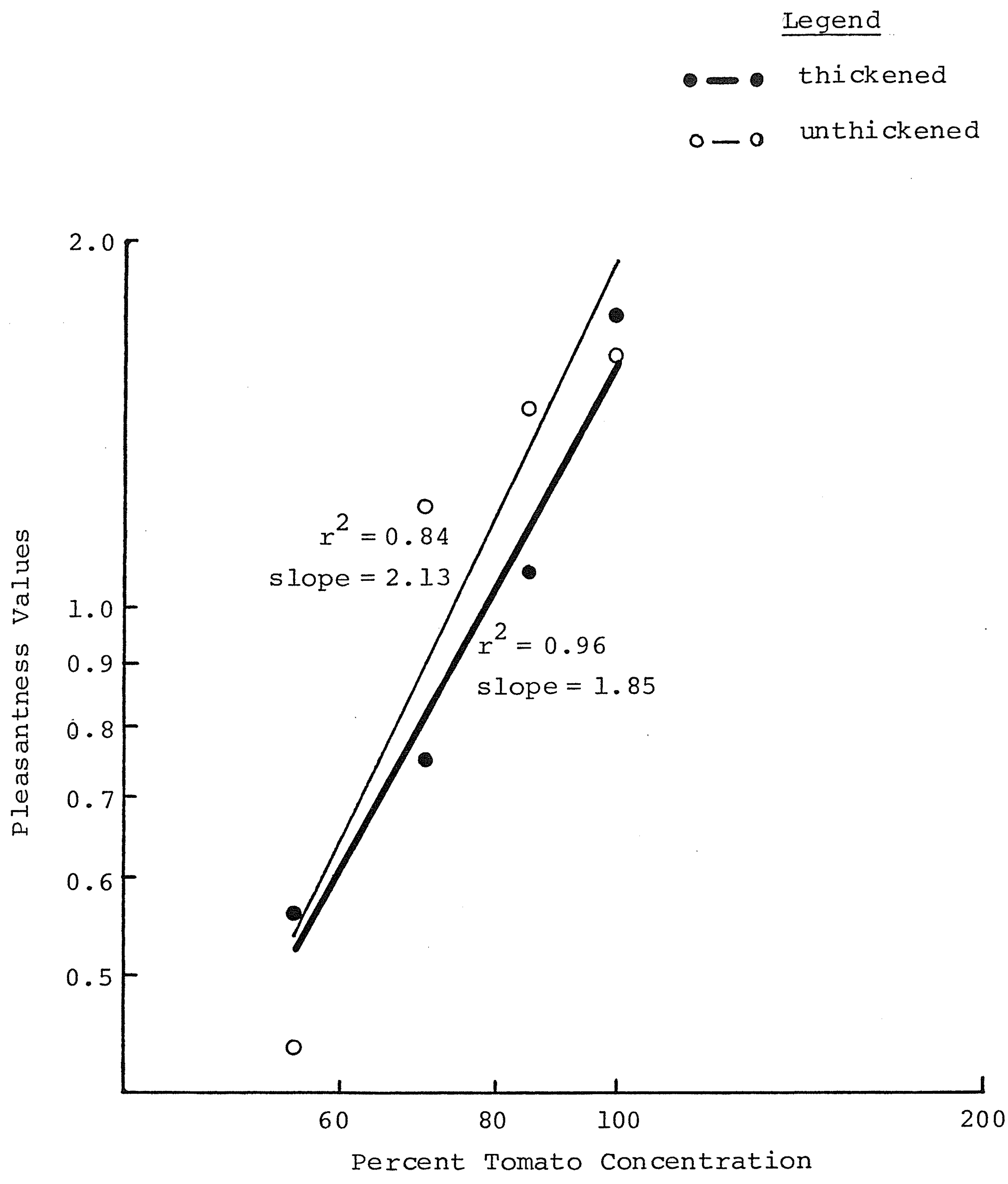

FIGURE 5. PLEASANTNESS VALUES OF SOY TOMATO MIXTURES VS. PERCENT TOMATO CONCENTRATION (LOG-LOG CO-ORDINATES).

The effect of the addition of a thickener was examined by testing the equality between the slopes and elevations of the two sensory functions (Appendix 11). A lack of significant difference indicated that pleasantness of the thickened and unthickened mixture was similar.

SUMMARY AND CONCLUSIONS

A model system of soy-tomato mixture (with and without thickener) was developed to observe the interaction between the soy and tomato flavors. The level of soy protein (5%, w/w) was held constant whereas the tomato concentration of the sauces was varied between 55 and 100%.

The addition of a thickening agent did not significantly affect the slopes nor the elevations of the sensory functions of the samples in most cases. Exceptions were found in two instances where the overall taste and astringent intensities of the thickened tomato sauces were judged to be significantly higher than the unthickened sauces. This was attributed to the effect of time lapse between the evaluation of the two series of sauces rather than a true difference in intensity.

The odors of soy protein were described as whole grain-like, raw green beany, sweet and cooked potato-like. Its tastes were described as whole grain-like, beany, sweet and bitter. The dominant odors of the tomato sauce were fruit-like, heavy/earthy, acidic, metallic and canned tomato-like and the dominant tastes were acidic, harsh, bitter, astringent and canned-tomato like.

The effect of tomato concentration on the perceived intensities of the odor and taste of the sauces was determined. The three odors evaluated were overall odor, acidic and canned tomato-like. The inconsistent results indicated that the panelists were not able to discriminate among the sample intensities. The taste characteristics studied were overall taste, acidic, harsh, bitter and astringent. The intensities of the different tastes were found to increase with tomato concentration. The relationship between tomato concentration and taste intensities was significantly linear in the cases of overall taste intensity (of the thickened sauces), acidity (of the unthickened sauces), astringency and bitterness (of both types of sauces). The small number of data points available was probably responsible for the lack of statistical significance in the remaining intensity functions. In the case of harshness, a curvilinear relationship appeared plausible, as suggested by the distribution of the data points.

After soy protein was incorporated into the tomato sauce, some of the tomato flavors: harshness, bitterness and astringency became less pronounced and the panelists were not able to evaluate their intensities in the various samples. The presence of a second taste probably interfered with the perception of the primary tastes. Addition of soy protein did not significantly affect the slopes of the overall and acidic tastes of the sauces. However, the intensities of both tastes were significantly depressed. Suppression appeared to be greater at the lower concentration of the tomato sauces.

As in the case of the tomato sauces, the individual odors and tastes of the soy protein were no longer evident in the soy-tomato mixture, probably due to the masking effect of the tomato flavors. The overall soy odor, taste and after-taste generally decreased in intensity with the increase in tomato concentration in the mixtures. The reduction was considerable.

Pleasantness of the mixture increased linearly with the increase in tomato concentration. The pleasantness function grew at a rate comparable to the overall and acidic tastes of the tomato component in the mixture, indicating that increases in pleasantness and taste intensities of the tomato sauces more or less paralleled each other.

In this experiment, tomato flavors successfully masked the soy flavors. The pleasantness function provided a useful guideline for the concentration of tomato to be employed as it grew at approximately the same rate as the taste intensities of the tomato sauces. Within the concentration range tested, the 100% mixture gave the most palatable product. A slight increase (10 - 20%) in tomato concentration might partially compensate for the loss of tomato flavors due to the addition of soy protein and further enhance the pleasantness of the mixtures. The results of the present study would probably be applicable to other legume protein such as the fababean and field pea which have similar flavor problems.

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APPENDIX 1

APPENDIX 1a

COMPOSITION OF UNTHICKENED TOMATO SAUCES

Sample concentration (%)	Wt. of mixture[a] (gm)	Wt. of water (gm)	Total weight (gm)
60	204	136	340
70	238	102	340
80	272	68	340
90	306	34	340
100	340	0	340

[a] mixture of tomato paste and water at a ratio of 1:1.08 (w/v).

APPENDIX 1b

COMPOSITION OF THICKENED TOMATO SAUCES

Sample concentration (%)	Wt. of mixture[a] (gm)	Wt. of thickener (gm)	Wt. of water (gm)	Total wt. (gm)
60	204	9.0	127.0	340
70	238	7.5	94.5	340
80	272	4.25	63.75	340
90	306	1.5	32.5	340
100	340	0	0	340

[a] mixture of tomato paste and water at a ratio of 1:1.08 (w/v).

APPENDIX 1c

BALLOT FOR THE EVALUATION OF TOMATO SAUCE VISCOSITY

Name ____________________

Date ____________________

Please taste the following samples of tomato sauces in the order presented and magnitude estimate the thickness of each sauce against the reference (marked R).

Please place the sample in your mouth and draw it in along the surface of the tongue. Measure the force required for doing so and compare it to that required for the reference. Please rinse your mouth with water between samples.

Code No.	Magnitude Estimate
R	10
________	________
________	________
________	________
________	________
________	________

APPENDIX 1d

COMPOSITION OF THICKENED TOMATO SAUCES

Sample concentration (%)	Wt. of mixture[a] (gm)	Wt. of thickener (gm)	Wt. of water (gm)	Total wt. (gm)
55	187	10.5	142.5	340
70	238	6.90	95.1	340
85	289	3.25	47.75	340
100	340	0	0	340

[a] mixture of tomato paste and water at a ratio of 1:1.08 (w/v).

APPENDIX 2

APPENDIX 2a

BALLOT FOR DEVELOPING AROMA DESCRIPTORS OF SOY PROTEIN

Name ______________________

Date ______________________

The following is a sample of soy protein. Please smell the sample and check-off the odors found to be present, indicating its intensity on the ballot below.

Please take 3 short sniffs for each testing and RE-COVER THE CONTAINER IMMEDIATELY. Please take a short pause between testings.

Intensity

Odor descriptors	faintly	slightly	moderately	strongly	extremely
vegetable-like	____	____	____	____	____
cooked veg.	____	____	____	____	____
cardboardy	____	____	____	____	____
musty	____	____	____	____	____
cereal	____	____	____	____	____
cooked cereal	____	____	____	____	____
whole grain	____	____	____	____	____
cornmeal	____	____	____	____	____
toasted	____	____	____	____	____
vanilla	____	____	____	____	____
nutty	____	____	____	____	____
rice	____	____	____	____	____
fresh grassy	____	____	____	____	____
beany	____	____	____	____	____
green beany	____	____	____	____	____
painty	____	____	____	____	____
cold cooked potato	____	____	____	____	____

APPENDIX 2b

BALLOT FOR DEVELOPING TASTE DESCRIPTORS OF SOY PROTEIN

Name ______________________

Date ______________________

Please taste the following sample of soy protein. From the ballot below, check off the flavors found to be present indicating its intensity.

Intensity

Flavor descriptors	faintly	slightly	moderately	strongly	extremely
green					
beany					
green beany					
raw beany					
chalky					
musty					
stale					
sweet					
sour					
sour veg.					
bitter					
walnut					
nutty					
toasted					
cereal					
bland					
astringent					
rancid					
pea					
dried pea					
cardboard-like					
straw-like					

APPENDIX 3

APPENDIX 3a

BALLOT FOR DEVELOPING AROMA DESCRIPTORS OF TOMATO SAUCE

Name ______________________

Date ______________________

Before you are 2 samples of tomato sauce. Please smell the first sample, and check off the odors present in the sample, indicating their intensity on the ballot below. Then go on to the next sample.

For each testing, please take 3 short sniffs. Then RECOVER THE CONTAINER IMMEDIATELY.

Odor descriptors	Intensity: faintly	slightly	moderately	strongly	extremely
green	____	____	____	____	____
grassy	____	____	____	____	____
green leafy	____	____	____	____	____
onion-like	____	____	____	____	____
cabbage-like	____	____	____	____	____
tomato-like	____	____	____	____	____
ripe tomato-like	____	____	____	____	____
musty	____	____	____	____	____
spicy	____	____	____	____	____
fruit-like	____	____	____	____	____

APPENDIX 3b

BALLOT FOR DEVELOPING TASTE DESCRIPTORS OF TOMATO SAUCE

Name ____________________

Date ____________________

Before you are 2 samples of tomato sauce. Please taste the first sample and check off the flavors present in the sauce, indicating their intensity on the ballot below. Then go on to the next sample.

Please rinse your mouth with water between samples.

Flavor descriptors	Intensity: faintly	slightly	moderately	strongly	extremely
fresh green	____	____	____	____	____
fresh tomato-like	____	____	____	____	____
green tomato-like	____	____	____	____	____
processed tomato: stewed	____	____	____	____	____
canned	____	____	____	____	____
spoiled vine-like	____	____	____	____	____
slightly horseradish	____	____	____	____	____
rancid, vegetable fat-like	____	____	____	____	____
medicinal	____	____	____	____	____
flat	____	____	____	____	____
insipid	____	____	____	____	____
hay-like	____	____	____	____	____
cardboard-like	____	____	____	____	____
acidic	____	____	____	____	____
sharp	____	____	____	____	____

Appendix 3b Continued...

Flavor descriptors	faintly	slightly	moderately	strongly	extremely
sweet	______	______	______	______	______
bland	______	______	______	______	______

APPENDIX 4

APPENDIX 4a

BALLOT FOR EVALUATING ODOR INTENSITIES OF TOMATO SAUCES

Name ______________________

Date ______________________

Before you are 3 coded samples of tomato sauces and a reference marked "R". Please smell the samples in the order presented and estimate their odor intensities against the reference (R).

For each testing - please take 3 short sniffs, then RE-COVER THE CONTAINER IMMEDIATELY. Please take a short pause between samples.

Overall intensity	Magnitude estimate
R	10
____________	____________
____________	____________
____________	____________

Canned tomato-like	Magnitude estimate
R	10
____________	____________
____________	____________
____________	____________

Acidic	Magnitude estimate
R	10
____________	____________
____________	____________
____________	____________

APPENDIX 4b

BALLOT FOR EVALUATING TASTE INTENSITIES OF TOMATO SAUCES

Name ____________________

Date ____________________

Before you are 3 coded samples of tomato sauce and a reference marked "R". Please taste the samples in the order presented and magnitude estimate their flavor intensities against the reference (R).

Please rinse your mouth with water and cracker between samples. DO NOT SWALLOW samples except when evaluating bitterness intensity.

Overall intensity	Magnitude estimate
R	10
______	______
______	______
______	______

Astringent	Magnitude estimate
R	10
______	______
______	______
______	______

Bitter	Magnitude estimate
R	10
______	______
______	______
______	______

Appendix 4b Continued...

Harsh	Magnitude estimate
R	10

Acidic	Magnitude estimate
R	10

APPENDIX 5

APPENDIX 5a

BALLOT FOR EVALUATING ODOR AND TASTE INTENSITIES OF SOY PROTEIN IN TOMATO SAUCES

Name ____________________

Date ____________________

Before you are 4 coded samples of tomato sauce with added soy protein. Please evaluate the samples in the order presented and magnitude estimate the intensities of their soy odor and flavor against those of the reference (S).

For odor testing: please take 3 short sniffs for each testing, then RE-COVER THE CONTAINER IMMEDIATELY.

For taste testing: please chew on the sample and swirl it in your mouth. Rinse your mouth with water and cracker between samples. DO NOT SWALLOW samples.

Soy Odor	Magnitude estimate	Soy Flavor	Magnitude estimate
S	10	S	10
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______

Soy after-taste	Magnitude estimate
S	10
______	______
______	______
______	______
______	______

APPENDIX 5b

BALLOT FOR EVALUATING PLEASANTNESS OF SOY/TOMATO MIXTURES AND TASTE INTENSITIES OF TOMATO SAUCES WITH ADDED SOY PROTEIN

Name ____________________

Date ____________________

Before you are 4 coded samples of tomato sauce with added soy protein. Please taste the samples in the order presented and magnitude estimate their pleasantness and flavor intensities against those of the reference (T).

Please chew on the sample and swirl it in your mouth. Rinse your mouth with water and cracker between samples. DO NOT SWALLOW samples.

IMPORTANT: Overall intensity and acidity - evaluate the overall intensity and acidity of the tomato sauce in the samples (not the combined product of tomato sauce and soy).

Pleasantness - evaluate the pleasantness of the combined product of tomato sauce and soy.

Pleasantness	Magnitude estimate	Overall intensity	Magnitude estimate
T	10	T	10
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______

Acidity	Magnitude estimate
T	10
______	______
______	______
______	______
______	______

APPENDIX 6

APPENDIX 6

5x5x2 FACTORIAL ANALYSIS OF VARIANCE OF PANEL VISCOSITY JUDGMENT OF VARIOUS TOMATO SAUCES[a]

Source of variation	df	SS	MS	F
Concentrations	4	0.19915	0.04979	2.74860
Panelists	4	0	0	0
Replications	1	0	0	0
Panelists x Replications	4	0	0	0
Concentrations x Replications	4	0.02985	0.00746	0.41195
Panelists x Concentrations	16	0.36387	0.02274	1.25540
Error	16	0.28983	0.01811	

[a] for composition of tomato sauces refer to Appendix 1b.

APPENDIX 7

APPENDIX 7a

COMPARISON OF REGRESSION LINES - OVERALL TASTE INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES

	df	Σx^2	Σxy	Σy^2	Reg. Coef.	Deviations from regression df	SS	MS
Within								
Thickened	2	0.0247	0.0391	0.0620	1.5830	1	0.0001	0.0001
Unthickened	2	0.0247	0.0361	0.0549	1.4615	1	0.0021	0.0021
						2	0.0022	0.0011
Pooled, W	4	0.0494	0.0752	0.1169	1.5223	3	0.0024	0.0008
Difference between slopes						1	0.0002	0.0002
Between, B	1	0.0001	-0.0001	0.0174				
W + B	5	0.0495	0.0751	0.1343		4	0.0204	
Difference between adjusted means*						1	0.0180	0.0180

* Significant at the 5% level.

APPENDIX 7b

COMPARISON OF REGRESSION LINES - ACIDITY INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Thickened	2	0.0247	0.0504	0.1058	2.0405	1	0.0030	0.0030
Unthickened	2	0.0247	0.0363	0.0535	1.4696	1	0.0002	0.0002
						2	0.0032	0.0016
Pooled, W	4	0.0494	0.0867	0.1593	1.7551	3	0.0071	0.0024
Difference between slopes						1	0.0039	0.0039
Between, B	1	0.0001	0	0				
W + B	5	0.0495	0.0867	0.1593		4	0.0074	
Difference between adjusted means						1	0.0003	0.0003

No significant differences were detected.

APPENDIX 7c

COMPARISON OF REGRESSION LINES - HARSHNESS INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Thickened	2	0.0247	0.0415	0.0787	1.6802	1	0.0090	0.0090
Unthickened	2	0.0247	0.0448	0.0870	1.8138	1	0.0057	0.0057
						2	0.0147	0.0074
Pooled, W	4	0.0494	0.0863	0.1657	1.7470	3	0.0149	0.0050
Difference between slopes						1	0.0002	0.0002
Between, B	1	0.0001	0	0.3402				
W + B	5	0.0495	0.0863	0.1745		4	0.0240	
Difference between adjusted means						1	0.0091	0.0091

No significant differences were detected.

APPENDIX 7d

COMPARISON OF REGRESSION LINES - ASTRINGENCY INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES

	df	Σx^2	Σxy	Σy^2	Reg. Coef.	Deviations from regression		
						df	SS	MS
Within								
Thickened	2	0.0247	0.0269	0.0293	1.0891	1	0.0001	0.0001
Unthickened	2	0.0247	0.0324	0.0428	1.3117	1	0.0003	0.0003
						2	0.0004	0.0002
Pooled, W	4	0.0494	0.0594	0.0722	1.2024	3	0.0008	0.0003
Difference between slopes						1	0.0004	0.0004
Between, B	1	0.0001	0.0009	0.0084				
W + B	5	0.0495	0.0603	0.0806		4	0.0071	
Difference between adjusted means*						1	0.0063	0.0063

* Significant at the 5% level.

APPENDIX 7e

COMPARISON OF REGRESSION LINES - BITTERNESS INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES

	df	Σx^2	Σxy	Σy^2	Reg. Coef.	Deviations from regression df	SS	MS
Within								
Thickened	2	0.0247	0.0281	0.0321	1.1377	1	0.0001	0.0001
Unthickened	2	0.0247	0.0159	0.0104	0.6437	1	0.0002	0.0002
						2	0.0003	0.0002
Pooled, W	4	0.0494	0.0440	0.0425	0.8907	3	0.0033	0.0011
Difference between slopes						1	0.0030	0.0030
Between, B	1	0.0001	0	0.0480				
W + B	5	0.0495	0.0440	0.0473		4	0.0082	
Difference between adjusted means						1	0.0049	0.0049

No significant differences were detected.

APPENDIX 8

APPENDIX 8a

COMPARISON OF REGRESSION LINES - OVERALL TASTE INTENSITY VALUES OF THICKENED TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Intensity before	2	0.0247	0.0390	0.0620	1.5700	1	0.0004	0.0004
Intensity after	3	0.0376	0.1004	0.2817	2.6702	2	0.0136	0.0068
						3	0.0140	0.0047
Pooled, W	5	0.0623	0.1394	0.3437	2.2376	4	0.0318	0.0080
Difference between slopes						1	0.0178	0.0178
Between, B	1	0.0004	0.0104	0.2793				
W + B	6	0.0627	0.1498	0.6230		5	0.2651	
Difference between adjusted means*						1	0.2333	0.2333

* Significant at the 5% level.

APPENDIX 8b

COMPARISON OF REGRESSION LINES - OVERALL TASTE INTENSITY VALUES OF UNTHICKENED TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Intensity before	2	0.0247	0.0361	0.0550	1.4615	1	0.0022	0.0022
Intensity after	3	0.0376	0.1099	0.3344	2.9229	2	0.0132	0.0066
						3	0.0154	0.0051
Pooled, W	5	0.0623	0.1460	0.3894	2.3435	4	0.0472	0.0118
Difference between slopes						1	0.0318	0.0318
Between, B	1	0.0004	0.0074	0.1399				
W + B	6	0.0627	0.1534	0.5293		5	0.1540	
Difference between adjusted means*						1	0.1068	0.1068

* Significant at the 5% level.

APPENDIX 8c

COMPARISON OF REGRESSION LINES - ACIDITY INTENSITY VALUES OF THICKENED TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Intensity before	2	0.0247	0.0504	0.1058	2.0405	1	0.0030	0.0030
Intensity after	3	0.0376	0.1522	0.6551	4.0479	2	0.0390	0.0195
						3	0.0420	0.0140
Pooled, W	5	0.0623	0.2026	0.7609	3.2520	4	0.1020	0.0255
Difference between slopes						1	0.0600	0.0600
Between, B	1	0.0004	0.0113	0.3348				
W + B	6	0.0627	0.2139	1.0957		5	0.3660	
Difference between adjusted means*						1	0.2640	0.2640

* Significant at the 5% level.

APPENDIX 8d

COMPARISON OF REGRESSION LINES - ACIDITY INTENSITY VALUES OF UNTHICKENED TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Intensity before	2	0.0247	0.0363	0.0535	1.4696	1	0.0002	0.0002
Intensity after	3	0.0376	0.1189	0.4110	3.1622	2	0.0350	0.0175
						3	0.0352	0.0176
Pooled, W	5	0.0623	0.1552	0.4645	2.4912	4	0.0779	0.0195
Difference between slopes						1	0.0427	0.0427
Between, B	1	0.0004	0.0074	0.1427				
W + B	6	0.0627	0.1626	0.6072		5	0.1855	
Difference between adjusted means*						1	0.1076	0.1076

* Significant at the 5% level.

APPENDIX 8e

COMPARISON OF REGRESSION LINES - OVERALL TASTE INTENSITY VALUES OF THICKENED TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION (reanalysed data)

	df	Σx^2	Σxy	Σy^2	Reg. Coef.	Deviations from regression df	SS	MS
Within								
Intensity before	2	0.0247	0.0303	0.0387	1.2267	1	0.0015	0.0015
Intensity before	3	0.0376	0.0827	0.1868	2.1995	2	0.0049	0.0025
						3	0.0064	0.0021
Pooled, W	5	0.0623	0.1130	0.2255	1.8138	4	0.0205	0.0051
Difference between slopes						1	0.0141	0.0141
Between, B	1	0.0004	0.0014	0.2084				
W + B	6	0.0627	0.1144	0.4339		5	0.2252	
Difference between adjusted means*						1	0.2047	0.2047

* Significant at the 5% level.

APPENDIX 8f

COMPARISON OF REGRESSION LINES - OVERALL TASTE INTENSITY VALUES OF UNTHICKENED TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION
(reanalysed data)

	df	Σx^2	Σxy	Σy^2	Reg. Coef.	Deviations from regression df	SS	MS
Within								
Intensity before	2	0.0247	0.0292	0.0366	1.1822	1	0.0021	0.0021
Intensity after	3	0.0376	0.0807	0.1840	2.1463	2	0.0108	0.0054
						3	0.0129	0.0043
Pooled, W	5	0.0623	0.1099	0.2706	1.7640	4	0.0267	0.0067
Difference between slopes						1	0.0138	0.0138
Between, B	1	0.0004	-0.0307	0.0734				
W + B	6	0.0627	0.0792	0.2940		5	0.1940	
Difference between adjusted means*						1	0.1673	0.1673

* Significant at the 5% level.

APPENDIX 8g

COMPARISON OF REGRESSION LINES - ACIDITY INTENSITY VALUES OF THICKENED TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION (reanalysed data)

	df	Σx^2	Σxy	Σy^2	Reg. Coef.	Deviations from regression df	SS	MS
Within								
Intensity before	2	0.0247	0.0503	0.1058	2.0364	1	0.0034	0.0034
Intensity after	2	0.0120	0.0312	0.0818	2.6000	1	0.0007	0.0007
						2	0.0041	0.0021
Pooled, W	4	0.0367	0.0815	0.1876	2.2207	3	0.0066	0.0022
Difference between slopes						1	0.0025	0.0025
Between, B	1	0.0015	-0.0103	0.0748				
W + B	5	0.0382	0.0712	0.2624		4	0.1297	
Difference between adjusted means*						1	0.1256	0.1256

* Significant at the 5% level.

APPENDIX 8h

COMPARISON OF REGRESSION LINES - ACIDITY INTENSITY VALUES OF UNTHICKENED TOMATO SAUCES BEFORE AND AFTER SOY PROTEIN ADDITION (reanalysed data)

	df	Σx^2	Σxy	Σy^2	Reg. Coef.	Deviations from regression df	Deviations from regression SS	Deviations from regression MS
Within								
Intensity before	2	0.0247	0.0363	0.0535	1.4696	1	0.0002	0.0002
Intensity after	2	0.0120	0.0216	0.0399	1.8000	1	0.0010	0.0010
						2	0.0012	0.0006
Pooled, W	4	0.0367	0.0579	0.0934	1.5804	3	0.0021	0.0007
Difference between slopes						1	0.0009	0.0009
Between, B	1	0.0015	-0.0052	0.0190				
W + B	5	0.0382	0.0527	0.1124		4	0.0397	
Difference between adjusted means*						1	0.0376	0.0376

* Significant at the 5% level.

APPENDIX 9

APPENDIX 9a

COMPARISON OF REGRESSION LINES - OVERALL INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES AFTER SOY PROTEIN ADDITION

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Thickened	3	0.03754	0.10040	0.28170	2.6702	2	0.01360	0.00680
Unthickened	3	0.03754	0.10920	0.32889	2.9043	2	0.01124	0.00562
						4	0.02484	0.00621
Pooled, W	6	0.07508	0.20960	0.61059	2.7872	5	0.02545	0.00509
Difference between slopes						1	0.00061	0.00061
Between, B	1	0	0	0.00009				
W + B	7	0.07508	0.20960	0.61068		6	0.02554	
Difference between adjusted means						1	0.00009	0.00009

No significant differences were detected.

APPENDIX 9b

COMPARISON OF REGRESSION LINES - ACIDITY INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES AFTER SOY PROTEIN ADDITION

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Thickened	3	0.0376	0.1522	0.6552	4.0479	2	0.0391	0.0196
Unthickened	3	0.0376	0.1189	0.4110	3.1622	2	0.0350	0.0175
						4	0.0741	0.0185
Pooled, W	6	0.0752	0.2711	1.0662	3.0651	5	0.0889	0.0178
Difference between slopes						1	0.0148	0.0148
Between, B	1	0	0	0.0280				
W + B	7	0.0752	0.2711	1.0942		6	0.1169	
Difference between adjusted means						1	0.0280	0.0280

No significant differences were detected.

APPENDIX 9c

COMPARISON OF REGRESSION LINES - OVERALL INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES AFTER SOY PROTEIN ADDITION (reanalysed data)

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Thickened	3	0.0376	0.0827	0.1868	2.1995	2	0.0049	0.0025
Unthickened	3	0.0376	0.0807	0.1840	2.1463	2	0.0108	0.0054
						4	0.0157	0.0039
Pooled, W	6	0.0752	0.1634	0.3708	2.1729	5	0.0158	0.0032
Difference between slopes						1	0.0001	0.0001
Between, B	1	-0.0001	0	0.0039				
W + B	7	0.0751	0.1634	0.3747		6	0.0192	
Difference between adjusted means						1	0.0034	0.0034

No significant differences were detected.

APPENDIX 9d

COMPARISON OF REGRESSION LINES - ACIDITY INTENSITY VALUES OF THICKENED AND UNTHICKENED TOMATO SAUCES AFTER SOY PROTEIN ADDITION (reanalysed data)

	df	Σx^2	Σxy	Σy^2	Reg. Coef.	Deviations from regression df	SS	MS
Within								
Thickened	2	0.0120	0.0312	0.0818	2.6000	1	0.0007	0.0007
Unthickened	2	0.0120	0.0216	0.0399	1.8000	1	0.0010	0.0010
						2	0.0017	0.0009
Pooled, W	4	0.0240	0.0528	0.1217	2.2000	3	0.0055	0.0018
Difference between slopes						1	0.0038	0.0038
Between, B	1	0.0001	0	0.0086				
W + B	5	0.0241	0.0528	0.1303		4	0.0146	
Difference between adjusted means						1	0.0091	0.0091

No significant differences were detected.

APPENDIX 10

APPENDIX 10

COMPARISON OF REGRESSION LINES - SOY TASTE INTENSITY VALUES OF SOY PROTEIN IN THICKENED AND UNTHICKENED TOMATO SAUCES

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Thickened	3	0.0376	-0.0925	0.2329	-2.4601	2	0.0053	0.0027
Unthickened	3	0.0376	-0.1153	0.3866	-3.0665	2	0.0330	0.0165
						4	0.0383	0.0096
Pooled, W	6	0.0752	-0.2078	0.6195	-2.7633	5	0.0453	0.0091
Difference between slopes						1	0.0070	0.0070
Between, B	1	0	0	0.0036				
W + B	7	0.0752	-0.2078	0.6231		6	0.0489	
Difference between adjusted means						1	0.0036	0.0036

No significant differences were detected.

APPENDIX 11

APPENDIX 11

COMPARISON OF REGRESSION LINES - PLEASANTNESS VALUES OF THICKENED AND UNTHICKENED SOY/TOMATO MIXTURES

						Deviations from regression		
	df	Σx^2	Σxy	Σy^2	Reg. Coef.	df	SS	MS
Within								
Thickened	3	0.0376	0.0695	0.1343	1.8484	2	0.0058	0.0029
Unthickened	3	0.0376	0.0800	0.2032	2.1277	2	0.0330	0.0165
						4	0.0388	0.0097
Pooled, W	6	0.0752	0.1495	0.3375	1.9880	5	0.0403	0.0081
Difference between slopes						1	0.0015	0.0015
Between, B	1	0	0	0.0048				
W + B	7	0.0752	0.1495	0.3423		6	0.0451	
Difference between adjusted means						1	0.0048	0.0048

No significant differences were detected.