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Acceptability and Proximate Composition of Meat-Vegetable Sticks Versus All-Meat Sticks Adjusted to pH 4.6 or 5.2 with Citric or Lactic Acids

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ACCEPTABILITY AND PROXIMATE COMPOSITION OF MEAT-VEGETABLE STICKS VERSUS ALL-MEAT STICKS ADJUSTED TO pH 4.6 or 5.2 WITH CITRIC OR LACTIC ACIDS

by

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ABSTRACT

Acceptability and Proximate Composition of Meat-vegetable Sticks Versus All-meat Sticks Adjusted to pH 4.6 or 5.2 With Citric or Lactic Acids

by

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A new innovative product, stewsticks, made with beef, pork, spices, and dehydrated vegetables, was developed as a nutritious snack. Lactic or citric acid was added at pH 5.2 or 4.6 to both meatsticks and stewsticks. Meatsticks and stewsticks were prepared by mixing ingredients until a cohesive mass was obtained. This mixture was then extruded into sticks that were cooked to about 50% of original weight. Sticks were then cut to desired length, packaged, and stored. Then meatsticks (beef, pork, and spices) were compared to stewsticks for appearance, texture, flavor, and overall acceptability.

The stewsticks had excellent shelf life due to combined hurdles of pH 5.2, water activity of 0.95 or less, salt, and vacuum packaging. Compared to meatsticks, one serving (2 ounces) of stewsticks had less fat (9 vs 11 g respectively), less cholesterol (75 vs 90 mg) and more dietary fiber (4 vs 2 g), carbohydrates (20 vs 4 g), vitamin A (11 vs 2% RDA), and vitamin C (32 vs 1% RDA). The type of acid did not affect panel preference, but the samples at pH 5.2 were preferred over samples at pH 4.6. Overall, meatsticks were preferred by the consumer panel over stewsticks although there were 25% of them who rated stewsticks as moderately acceptable or higher.

(96 pages)

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Ronnald Quinton

CONTENTS

LIST OF TABLES

INTRODUCTION

The majority of the adult population of North America is holding down at least one job. When both parents are working, neither is home when their children arrive from school. A typical child is hungry and wants a snack when he/she gets home. The question is what do the children snack on? Is it nutritious or is it "junk food"? One problem with many snacks is that they do not meet the recommended dietary allowances for healthy people ("the levels of intake of essential nutrients that, on the basis of scientific knowledge, are judged by the Food and Nutrition Board to be adequate to meet the known nutrient needs of practically all healthy persons"; RDA, 1989, p. 1). The U.S. National Cancer Institute executed a five-year project, trying to get Americans to consume at least five servings of fruits and vegetables every day. Shelf-stable snacks presently on the market which contain fruits or vegetables are fruit leathers and meat snacks. The problem with these products is that the former is high in sugar, and the latter is high in fat. A new innovative product (beef, pork, or lamb stewsticks) has been developed by Dr. Cornforth and Dr. Hendricks at Utah State University (USU). This product is nutrient dense, containing high protein, B vitamins, and minerals, and has excellent storage life and taste. The product is approximately 50% meat and 50% vegetables and is cooked to about 50% of original weight. The vegetables include potatoes, carrots, tomatoes, onions, peas, celery, and peppers. This addition of vegetables drops the percentage of fat by about 15%, compared to all-meat sticks. The percent fat is relatively low since the raw meat cuts are lean and trimmed of excess fat. This product is an excellent outdoor food suitable for use by campers, hikers, mountain bikers, back packers, scout or explorer troops, horseback riders in lunches, snacks, and emergency kits (if rotated at least quarterly).

As described previously, stewsticks are cooked (dried) to about 40% moisture. As such, the product is an intermediate moisture (IM) food. "An IM food is one that can be eaten as is, without rehydration, and yet is shelf stable without refrigeration or thermal processing" (Kaplow, 1970, p.53). Corry (1976) stated that IM foods have water activity (a_w) of between .70 and .90. He went on to say that a_w of .90 or below does not support growth or toxin production by most bacteria. Stewsticks have an a_w of .86 to .94. Since this is above the high end of the IM a_w limits of Corry (1976), additional methods are needed to inhibit bacterial growth. The U.S.A. Good Manufacturing Practice Regulations specify that hermetically sealed foods must be thermally processed for 12D inactivation of <u>C. botulinum</u> unless the pH < 4.6 or a_w

> .85 (U.S. Food and Drug Administration, 1985). However, according to Leistner et al. (1981), botulinal growth did not occur in vacuum-packaged cooked meat products when a_w was .95 or lower combined with a pH at or below 5.2. This is an example of the hurdle effect, where two factors (low pH and a_w) combine to inhibit bacterial growth. Su (1992) showed that shelf life of porksticks (an all-meat product) was extended by a combination of low pH (5.1) and reduced water activity (0.91).

LITERATURE REVIEW

Gelation of meat proteins

The protein matrix is the main structure that binds restructured meat products together. This is done by mixing comminuted meat or meat pieces in the presence of salt, which causes swelling and solubilization of myofibrillar proteins. Grinding also causes the bundles of muscle fibers to separate, which disrupts their membranes, including the sarcolemma, and frees the myofibrils and filaments. This disruption of the cells allows for a much better protein extraction. A mechanical treatment combines the meats together. Four methods of doing this are mixing, massaging, tumbling, and mechanical tenderization. Siegel and Schmidt (1979a, 1979b) reported that myosin and actin, when combined with salt and then heated, formed a coherent three-dimensional network of fibers. In the absence of salt the same proteins formed a spongy gel.

Factors that affect gel formation are rate and severity of heating, postmortem biochemical state of the muscle, salt concentration, and pH. According to Cheftel et al. (1985), protein denaturation and unfolding occurs prior to protein-protein interaction and aggregation. The component of muscle that is of the most significance for gel formation is myosin. F-actomyosin adds strength to the gel by forming a cross-link between the tail portions of actin and free myosin molecules. Myosin has two different portions, the head and the tail, that take different parts in the formation of heat-induced gels. The formation of the three-dimensional network occurs from a balance of protein-protein and protein-solvent (water) interactions, and between attractive and repulsive forces between adjacent polypeptide chains (Hultin, 1985). "Hydrophobic interactions (enhanced at high temperatures), electrostatic interactions (such as bridges with Ca^{2+} and other divalent ions), hydrogen bonding (enhanced by cooling) and/or disulfide cross-links are known to represent the attractive forces" (Cheftel et al., 1985, p. 292). The irreversible oxidation of the -SH groups of the head portion of the myosin forms the three-dimensional protein network of the gel. The tail portion participates in the formation of a three-dimensional protein network when heated to form a partially irreversible helix-to-coil transition (Hultin, 1985). When Samejima et al. (1969), Nakayama and Sato (1971a, 1971b), and Siegel and Schmidt (1979b) used purified muscle protein, they found that myosin and actomyosin were the most essential of the myofibrillar proteins in the formation of gels.

When salt is bound to muscle proteins, the molecules set up an electrostatic repulsion that loosens the protein network (Hultin, 1985).

Yasui et al. (1979) reported that optimum gel formation occurred when the meat solution was cooked to a temperature between 60°C and 70°C at a pH of 6.0. Siegel and Schmidt (1979a) reported that there was a linear increase in the binding of myosin in the temperature range of 45-80°C but that there was still a small increase in myosin binding up to about 95°C.

Siegel et al. (1979) found that the binding abilities of non-meat proteins (starch) were inferior to the binding ability previously reported for myosin. Whistler and Daniel (1985) reported gelatinization of starch as having a narrow temperature range, 61-72°C for corn and 62-68°C for white potato starch.

Organic acids are used as antimicrobial agents to extend shelf life of meat products. Since they have limited antimicrobial properties, they should be used in conjunction with other methods that also limit microbial growth. This method, the hurdle effect, was used on stewsticks and meatsticks to inhibit microbial growth. The factors used to inhibit microbial growth in our meatsticks were pH, a_w, salt, nitrites, temperature, and vacuum packaging.

pH

Most bacteria, yeast, and mold have an optimum pH for growth of about 7.0 and ranges from 5.0 to 8.0 (Lechowich, 1978). Hultin (1985) has stated that the optimum pH of red meat is 5.5, but Lechowich reported that fresh meat can range from 5.3 to 6.5. Lechowich also stated that meat with a pH of 6.5 will spoil by bacteria much faster than meat with a pH of 5.3.

Leistner et al. (1981) found that there was no refrigeration required for products made with a pH 5.0. Su (1992) reported that with a a_w 0.80 and pH 5.18 there was no bacterial spoilage in meatsticks.

Lechowich also stated that C. botulinum will be inhibited with a pH of 4.6 or higher if the food is salted. He went on to say that S. aureus can be inhibited at a pH of 4.8.

Water activity

Fennema (1985) described water activity as p/p_o where p is the partial pressure of water above the sample, and p_o is the vapor pressure of pure water at the same temperature. Fennema reported that a_w is a better indicator of perishability than is water content.

We are all familiar with mold in our natural surroundings and that growth proceeds faster in humid conditions and slower in dry conditions. Another known situation is that fresh meat and fish are susceptible to bacteria, and that if dried to a certain point, the bacterial growth is inhibited while the growth of molds is not inhibited. Further drying is required to inhibit mold growth.

The results of Tomkins' (1929) studies on the germination of several spore types at numerous a_w using six temperatures between 5° and 37°C, with and without nutrients, allowed several generalizations to be made. The first is that a reduction of a_w at a given temperature causes germination rate to decrease. This decrease in germination rate was always manifested in two ways: 1) by an increase in the latent period or time required for the first appearance of germ tubes, and 2) by a reduction in the rate of elongation of the germ tubes. The second is that each fungus had its own optimum temperature at which the rate of germination was greatest. Third, that in the presence of nutrients, germination and growth of fungus occur over a greater range of a_w and temperature. Scott (1957) reported that germination was dependent on temperature, and reported an a_w range of 0.71 to 0.90 for spore germination. Snow (1949) found a wider a_w range for spore germination of 0.64 to 0.93.

Yeasts, in general, tolerate drier conditions than do bacteria and moister conditions than do molds. The lower limit of yeast growth is a_w 0.94 to 0.88 (Lodder and Kreger-van Rij, 1952).

Molds and yeasts are destroyed by heat; thus, the cooking process of most cured meat is sufficient to kill molds but recontamination occurs during processing. Sperber (1983) reported that the maximum growth rate for bacteria was at a_w of 0.990 to 0.995. The minimum a_w reported by Beuchat (1981) was 0.91. Leistner et al. (1981) found that no refrigeration was required for products made with a_w 0.91 or less. He also found that by using a_w 0.95 and pH 5.2 (a hurdle effect) microbial growth was inhibited.

Williams and Purnell (1953) reported that C. botulinum was inhibited from 0.94 to 0.96 a_w. Scott (1955) stated that 0.95 or slightly less is the minimum a_w. Lechowich (1978) reported that the optimum a_w of C. botulinum types A, B, and E was between 0.94 to 0.98.

Corry (1976) stated that IM foods have water activity (a_w) of between .70 and .90. He went on to say that a_w of .90 or below does not support growth or toxin production by most bacteria.

Salt

Salt, one of the first antimicrobial agents, was used by the Sumarians about 3000 B.C. (Jay 1992). Steinke and Foster (1951) reported that salt at the 3.0% level inhibited botulinal toxin formation in liver sausage held at 30°C for at least 30 days.

Nitrites

As reported by Cornforth (1994), nitrite is added to cured meat for three purposes. These are: 1) to develop pink cured meat (pink) color, 2) to inhibit rancidity 3) to inhibit the growth of food spoilage organisms and food pathogens, particularly C. botulinum. Steinke and Foster (1951) reported that adding 200 ppm sodium nitrite with 2.5% salt, to liver sausage inhibited the microbial growth substantially over the use of salt alone. Salt with sodium nitrite inhibited the formation of botulinal toxin for 30 days, as compared with salt alone which was inhibitory for only 6 days.

Temperature

It is commonly understood that foods store better when frozen or refrigerated than at room temperature. Su (1992) reported that vacuum-packaged pork sticks with a a_w 0.80 and pH 5.18 stored at 2°F (-20°C) for 6 months did not have bacterial spoilage.

Vacuum packaging

Because molds and yeasts and some bacteria are aerobic, vacuum packaging or other methods of excluding oxygen are effective in inhibiting their growth (Lechowich, 1978).

Vacuum packaging was a factor preventing bacterial spoilage of pork sticks with a a_w 0.80 and pH 5.18 stored at 2°-20°C for six months (Su 1992).

Related products

There are currently three U.S. patents for products that use meat and vegetables. The patent by Lewis and Lewis (1983) is for an intermediate moisture product; they added vegetables to raw meat along with salt alone or in combination with dextrose, sucrose, or fructose. The patent assigned to Gerber (Maher and Billerbeck, 1975) describes a high moisture product used as an ingredient in canned baby foods. McKee et al. (1994) also described a low moisture, jerky-type product made from meat and potato powder.

Nutritional labeling

A new labeling regulation from the USDA Food Safety and Inspection Service required that most food products must have a nutrition label by August 8, 1994 (Tybor and Reynolds, 1995). Some foods that are exempt from nutrition labeling are foods of no nutrition significance, infant formula, medical foods, donated foods, dietary supplements, individual units in multi-unit package, foods shipped in bulk, custom processed fish and game meat, raw fruit, vegetables and fish, restaurant food, ready-to-eat foods not for immediate consumption, and foods prepared in low volume in small businesses. This regulation was to be phased in over a 4-year period from 1994 to 1997 (Tybor and Reynolds, 1995). Beginning in 1997, firms with fewer than 100 employees and producing less than 100,000 lb product per year will be exempt from nutrition labeling requirements. This allows small firms to produce new products such as the stewsticks without the expense of nutrition labeling.

OBJECTIVE

Acidification for meat preservation may be done to pH 4.6, as specified by the U.S. Food and Drug Administration (1985), when acid is the only inhibitor to microbial growth. When other hurdles are also present (lower a_w, nitrite), acidity may be lowered to only pH 5.2 (Leistner et al., 1981). Either citric or lactic acids are available as acidulants.

The purpose of this study was 1) to determine the amount of encapsulated citric or lactic acid necessary to achieve the desired pH of 4.6 or 5.2 for meat/vegetable sticks (stewsticks) compared to a 100% meat sticks, and 2) To determine if there is a difference in taste, appearance, or composition of products made with citric versus lactic acid at pH 4.6 and 5.2.

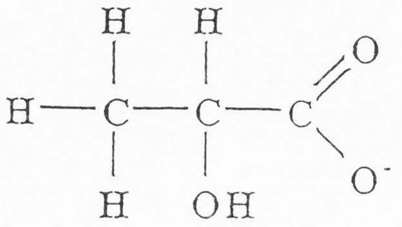
EXPERIMENTAL DESIGN

Experiment 1

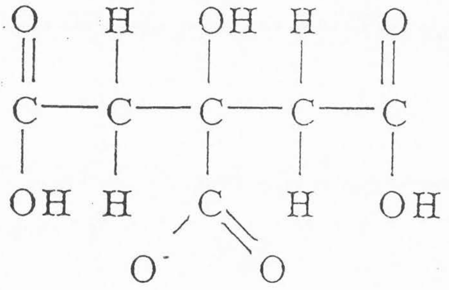
The objective was to determine the amount of citric acid needed to lower pH of cooked product to 4.6 or 5.2. For each product (100% meat or 50:50 meat:vegetable), samples were prepared with 0.50%, 0.75%, 1.0%, 1.25%, and 1.50% citric acid, and the levels closest to the desired pH values were used in later experiments. The experiment was replicated once. Similar experiments were done using 2.75%, 3.0%, 3.25%, and 3.50% lactic acid. As pH is a logarithmic measurement of H-ion-concentration, in solution, the higher the H-ion-concentration the stronger the acid and the lower the ph measurement. Lactic acid has one carboxyl group and citric acid has three carboxyl groups (Fig. 1). Thus, more lactic acid is required to lower meat pH to 4.6 or 5.2 compared to citric acid.

Experiment 2

This study was done to compare sensory acceptability and proximate composition of meat-vegetable sticks vs all-meat sticks adjusted to pH 4.6 or 5.2 with citric or lactic acid. The study was a factorial design as follows: 2 meat types (meatsticks or stewsticks) * 2 acid types (citric or lactic acid) * 2 acid levels (ph 4.6 or 5.2)



Lactic Acid



Citric Acid

Fig. 1--Structure of lactic acid and citric acid.

run in triplicate. Samples were evaluated by both trained and consumer taste panels. Proximate analysis, pH, a_w, and Warner Bratzler shear values were also measured on each sample.

The trained panel consisted of 18 panelists (Appendix A Fig. A2). They were asked to evaluate each sample according to the following attributes: major color, color intensity, texture, acid intensity, spice intensity, salt intensity, and hot flavor intensity.

The consumer panel had about 70 panelists (Appendix A Fig. A1). They used a hedonic scale to evaluate each sample for appearance, texture, flavor, and overall acceptability. Results were evaluated using Minitab version 7.2 (State College, PA) for analysis of variance and appropriate correlation coefficients.

MATERIALS AND METHODS

Stewstick processing steps

Frozen lean beef or pork (beef inside rounds, pork blade meat; 5 - 7% fat) was tempered for 24-48 hr in a cooler at .56 -1.7°C. Meat was cut into cubes small enough to go into the grinder. Dehydrated vegetables and tomato powder were rehydrated 1:1 with water for at least 1 hr prior to grinding. Hydrated vegetables were passed through a .95-cm grinder plate. Vegetables were ground first followed by meat. Dry ingredients were weighed, including all spices, salt, Prague powder (6.25% sodium nitrite, 93.75% sodium chloride; Koch, Kansas City, MO), and encapsulated acid as specified in Table 1. The encapsulated lactic acid was obtained from Balchem Corporation (Slate Hill, NY). The encapsulated citric acid was obtained from Van Den Berg food ingredients group (San Francisco, CA). Note that the tomato powder was already added to the dry vegetables before hydration. Salt and spices were added to meat and mixed sufficiently to obtain a sticky texture. Vegetables and other ingredients were then added to the mixer. Mixing continued for an additional 3-5 min.

The meat and vegetable mixture was transferred to a vacuum sausage stuffer (Vemag 500, Robert Reiser and Co., Canton, MA) and extruded into 3.17 cm wide x 0.63 cm thick strips. The extruded strips were spread on screens, then cooked in a smokehouse at 74°C for 3.75 hr. This was sufficient to fully cook the product and to dry to about 40% moisture. The sticks were then cut to desired length, vacuum packaged, labeled, and stored at 4°C for further testing.

Table 1--Formulas for stewsticks and meatsticks

	Stewsticks		Meatsticks	
INGREDIENTS	wt	% of meat wt	wt	% of meat wt
beef, round	35.0 lb	50	49.0 lb	50
pork, blade	35.0 lb	50	49.0 lb	50
potato, sliced*	6.0 lb	8.6	0	0
carrots,1/4" diced*	2.5 lb	3.6	0	0
onions, minced*	2.0 lb	2.9	0	0
corn*	1.0 lb	1.4	0	0
tomato powder	2.0 lb	2.9	0	0
pepper, green*	0.8 lb	1.1	0	0
salt	2.0 lb	2.9	2.0 lb	2.0
Prague powder	73.0 g	0.2	73.0 g	0.2
black pepper	104.0 g	0.3	104.0 g	0.2
red pepper	95.0 g	0.3	95.0 g	0.2
garlic powder	18.0 g	0.1	18.0 g	0.1
fennel seeds	150.0 g	0.5	150.0 g	0.3
LA pH 4.6	95.0 g	0.3	90.0 g	0.2
LA pH 5.2	45.0 g	0.1	25.0 g	0.1
CA pH 4.6	50.0 g	0.2	50.0 g	0.1
CA pH 5.2	15.0 g	0.1	23.0 g	0.1
water	13.7 lb		0.0 lb	
Total**	101.1 lb**		101.1 lb**	

* = dehydrated vegetables
** = used LA pH 4.6 MS in Total wt.
LA = lactic acid, CA = citric acid,
MS = meatsticks, SS = stewsticks

Meatstick processing steps

Meatsticks were formulated as shown in Table 1 and processed as previously described for stewsticks.

A preliminary test was conducted to determine the amount of encapsulated citric or lactic acid needed to lower the pH of meatsticks and stewsticks to 4.6 and 5.2. Two batches of each acid were prepared. Products at these pH's (4.6 and 5.2) were then evaluated by a 70-member consumer panel using a hedonic scale for appearance, texture, flavor, and overall acceptance (Appendix A, Fig. A1). An 18-member trained panel also evaluated products, using a 7-point intensity scale, for color, color intensity, texture, acid flavor, spice flavor, salt flavor, and hot flavor intensity (Appendix A, Fig. A2).

Samples were measured for tenderness (Warner-Bratzler shear test), proximate composition (lipid, protein, moisture, ash, carbohydrate), pH, and water activity (a_w).

Nutrient content of dried products was determined by the use of a computer program (Diet Simple Plus, N-Squared Computing, Salem, Oregon), using USDA data, or from data furnished by the suppliers.

Sensory testing methods

The samples (2.5 cm^2, 8/session) were coded and blocked for position on the ballot. The tray was placed in front of the panelist so that the samples were in order from left to right on the tray according to the ballot coding. The samples were served at room temperature to participants who were seated in individual booths that were lighted with white fluorescent bulbs. Water was provided in each booth for mouth rinsing between each sample. There were two types of evaluation of the stewsticks. The first was a consumer panel, and the second was a trained panel. The consumer panelists (ca 70/session) were asked to evaluate the samples in the order listed, using a 9-point hedonic scale (Appendix A, Fig. A1). Each sample was evaluated for appearance, texture, flavor, preference, and overall acceptability, where 1 = dislike extremely and 9 = like extremely. Space was allotted on the ballot for name, date, and comments.

For the trained panel, the first session was held to evaluate and modify the ballot and to familiarize panelists with the products to be evaluated. There were 18 trained panelists. They evaluated stewsticks and meatsticks on a 7-point scale for major color (1=red, 2=brown, 3=orange), texture, acid intensity, spice intensity, salt intensity, and hot flavor intensity, where 1 = no color, not firm, acidic , spicy, salty, or hot and 7 = very intense color, firmness, acidity, spiciness, saltiness, or hot flavor intensity. Each individual booth had posted instructions describing the procedure for receiving a sample and rinsing the mouth between samples.

Moisture analysis

Samples were finely ground in a food processor. Then about 5 g dry material was weighed into a preweighed flat-bottom, disposable aluminum dish. Samples were dried in a vacuum oven (<100 mm Hg) at 95-100°C for 16-18 hr to a constant weight. Samples were then cooled in a desiccator for 15 min and reweighed. The percent moisture was calculated as follows:

$$\% \text{ moisture} = ((W_a - W_b)/W_a) \times 100$$

where W_a = original weight of sample; W_b = final weight of sample (AOAC, 1980).

Lipid analysis (crude fat)

After moisture determination, a small amount of sand was added to the dried samples. The aluminum dish was then folded and inserted into a thimble and reweighed. The thimble was placed in the condenser bracket of a Labconco Goldfish Fat Extraction Apparatus Model 35001 (Kansas City, MO), and the extraction of fat was performed for 4 hr at a setting of about 5.5 using petroleum ether. Caution was used to make sure the ether did not touch the thimble. After extraction and cooling in a desiccator for

15 min, the thimble and contents were reweighed. Percent fat of samples was calculated as follows:

$$\% \text{ fat} = ((W_b - W_c)/W_a) \times 100$$

where W_a = original weight of sample; W_b = weight of thimble and contents before extraction; W_c = weight of thimble and contents after extraction (AOAC, 1980).

Protein analysis (crude protein)

A homogenized sample (0.5-0.75 g) was weighed on a 4" square weighing paper, folded, and dropped into a 100-ml Kjeldahl digestion flask containing a Kjeldahl tablet and 15 ml sulfuric acid. Digestion was conducted with a Labconco Rapid Digester Model 23012 (Kansas City, MO) for 12 hr at 100°C for 1 hr, 250°C for 1 hr, and 260°C for 10 hr. The sample was distilled using a Labconco Rapid Kjeldahl Distillator until 50 ml distillate was collected in a flask containing 25 ml boric acid solution and four drops of Tashiro's indicator (0.25 g methylene, 0.375 g methyl red and 300 ml 95% ethanol). Titration was performed after distillation with 0.1 N HCl. Percent crude protein was calculated using the following formula:

$$\% \text{ crude protein} = (V_s - V_b) \times 1.4007 \times N \times 6.25 \text{ / gram sample}$$

where V_s and V_b = Volume of HCl required for the titration of sample and blank, respectively; (1.4007 = milliequiv. wt of Nitrogen x 100%); N = normality of HCl; and 6.25 =

protein factor for meat products (100/16% N/unit protein) (AOAC, 1980).

Ash analysis

A homogenized sample (3 g) was weighed into preweighed porcelain crucibles. The crucibles were heated in a muffle furnace (550°C) for 24 hr, until samples were white, to complete ashing. The samples were removed from the furnace, cooled in a desiccator, and reweighed. The weight of ash was determined by difference. Percent ash was calculated by the following:

$$\%\ ash = (W_a - W_c)/(W_s - W_c) \times 100$$

where W_c = weight of crucible; W_s = weight of crucible and sample; W_a = weight of crucible and ash (AOAC, 1980).

Carbohydrate determination

Total carbohydrate was determined by difference, as follows:

$$\%\ CHO = 100 - (\%\ lipid + \%\ protein + \%\ moisture + \%\ ash)$$

Nutrients

The nutrient content (protein, calories, vitamins, minerals) was determined by using the Diet Simple Plus (1993) computer program developed for this purpose. Input data were obtained from suppliers, undergraduate nutrition courses, and USDA, 1979, 1983, 1984, and 1990 reports for nutrient content of dehydrated vegetables, meats, spices, and other ingredients.

pH measurement

To measure pH, 10 grams of each sample were blended with 90 ml distilled water for 1 min with a Waring commercial blender, filtered, and the pH of filtrate measured. Readings of raw meat or meat emulsions were obtained by inserting the electrode into the sample and taking the pH reading after the meter stabilized (usually within 10 sec). Three pH measurements were made of each sample using a portable pH meter (Accumet 1000, Fisher Scientific, Salt Lake City, UT) calibrated to pH 4.0 and 7.0.

Water activity measurement

A_w was measured using a LUFFT-a_w-Wert-Messer meter (Abbeon Cal Inc., Santa Barbara, CA). Calibration was with four 2.5" filter papers placed in the bottom of the container and saturated with barium chloride. Any excess was poured out. The head was placed on the container and allowed 3 hr for equilibration. The meter was then finely adjusted to read 0.90 at 20°C. Comminuted samples were then placed in the container, to about a 1/2-full level. The calibrated head was placed onto the container, containing the sample, and allowed 3 hr for equilibration. Duplicate readings (3-hr each) were taken for each sample.

Shear measurement

The firmness of the samples was measured using a Warner-Bratzler Shear Press (G.R. Electric Man. Co., Manhattan, KS). This device measures the wt in pounds applied to shear a cooked meat core or other sample. Each measurement was made in triplicate using the full width of the stick.

Vacuum Packaging

The process to package meatsticks and stewsticks was with a rollstock Multivac packaging machine using top and bottom Cryovac films that are impermeable or semi-impermeable to moisture or air.

The top film R265B was 2.7 mils thick (2.7 thousandths of an inch) and had a moisture vapor transmission rate of 0.50 g/100 sq in/day at 100% relative humidity. The oxygen transmission rate was 1.0cc/100 sq in/day at 0% relative humidity at 73°F. The bottom film T060B was 6.0 mils thick and had a moisture vapor transmission rate of .35g/100 sq in/day at 100% relative humidity. The oxygen transmission rate was .18cc/100sq in/day at 0% relative humidity at 73°F.

Data Analysis

By using Minitab version 7.2 (State College, PA), analysis of variance and correlation coefficients were obtained for consumer panel data, trained panel data, and measured values (proximate analysis, pH, a_w, shear test). This was first done to compare all data from each group. To compare sensory characteristics between groups, the means of each group were calculated, the data were pooled, and correlation coefficients were calculated.

RESULTS AND DISCUSSION

Preliminary experiments

In initial experiments, there were some stewsticks made with vinegar-based hot sauce that were very noncohesive when extruded from the Vemag 500. Stewsticks made with one type of encapsulated citric acid (150/85) had the same characteristics. Thus, it was suspected that the acid was released from encapsulation even before cooking. To test this possibility, experiments were done using acids with varying levels of encapsulation to determine the effect of acid encapsulation on pH.

Crystal's Hot Sauce (Table 2) had a high vinegar content that probably denatured the meat proteins before cooking, decreasing the meat cohesiveness. This was verified by the low pH (4.65) of uncooked sticks with Crystal's Hot Sauce (Table 2), compared to a pH of 5.67 of raw beef (Table 3). The pH of stewsticks acidified with encapsulated citric acid (150/50) was pH 5.40 (uncooked) vs pH 4.84 (cooked; Table 2). This difference between cooked and uncooked stewsticks was expected, since heating melts the encapsulation oil, releasing the acid during cooking.

The effect of encapsulation level on pH of lean ground beef is shown in Table 3. It is evident that the encapsulated 150/85 citric acid was dissolving rapidly,

Table 2--Effect of acid encapsulation on pH of cooked and uncooked stewsticks*

	Non-encapsulated**		Encapsulated***	
	cooked	uncooked	cooked	uncooked
	4.43	4.67	4.82	5.38
	4.46	4.63	4.85	5.42
Mean	4.45	4.65	4.84	5.40

*Formulated as shown in Table 1.
**Crystal's Hot Sauce, vinegar base (Baumer Foods Inc., New Orleans, LA)
***Encapsulated lactic acid 135/50

Table 3--Effect of encapsulation level on pH of lean ground beef (7% fat)

Ingredients	type	grams	15 min pH	24 hr pH
	Beef	90	5.67	
CA	N	0.25	4.91	5.19
CA	E 150/50*	0.50	5.84	5.85
CA	E 150/85	0.90	4.84	4.87
LA	E 135/50	1.50	5.76	5.72

Ingredients were added at about the ratio they were used in stewsticks.
CA = citric acid, LA = lactic acid, N = non encapsulated.
* E 150/50 = Encapsulated oil, 150°F melting point, 50% acid, 50% oil.

causing pH reduction to pH 4.84 after 15 min compared to pH 5.84 for the CA E 150/50 (Table 3). According to the product specifications provided by Van Den Bergh Foods (San Francisco, CA), the soy encapsulation oil does not melt until heated to 152-158°F. The citric acid must have been only partially coated with soy oil, in order for the pH of uncooked samples to decrease so rapidly. However, in CA 150/50, the pH did not go below 5.84 even after 24 hr, indicating that the CA was not released.

Since water has no buffering capacity, all of the acids quickly lowered the pH of water (Table 4). Note that the CA with 15% encapsulating soy oil (E 150/85) lowered pH of water just as well as pure citric acid. The 50% citric acid: 50% soy oil sample after 1 hr had a pH of 3.50 compared to pH 2.36 for the CA sample with 85:15 acid to oil. Consequently, at 85:15 acid to oil, not all of the acid was encapsulated. Also note that by 24-hr, even the 50:50 CA:oil sample had dissolved with a 24-hr pH of 2.62, while the LA sample had a higher pH of 3.30. Among vegetables, addition of tomato powder lowered the sample pH the most, with a pH of 4.04 after 1 hr. However, by 24 hr, samples with onion, green pepper, and tomato all had a pH of 3.7 (Table 4).

It is not known why the pH of meat (beef 5.87 and pork 5.99) decreased to 5.76 after mixing with the Hobart mixer (Table 5). Could the mixing be adding CO_2 from the air and lowering the pH? When meat and vegetables were combined, the pH was 5.93, showing the buffering capacity of the meat. The similar pH of the three different meat + spices + vegetables (5.40, 5.37 and 5.40; Table 5), using the 50% encapsulated acids (LA and CA), corroborates previous data, that these acids were not dissolving before cooking and that there was little or no difference in the raw product pH due to addition of the encapsulated acids.

Table 4--Effect of vegetables and encapsulation level (50:50 or 85:15 w/w acid:oil) on pH

Sample	type	grams	1 hr pH	24 hr pH
Water (Control)		100	7.25	
CA	N	0.5	2.33	2.48
CA	E 150/50*	1.0	3.50	2.62
CA	E 150/85	1.8	2.36	2.31
LA	E 135/50	3.0	3.62	3.30
CA+Potato	E 150/50	1.0+19.0	5.12	4.76
CA+Carrot	E 150/50	1.0+ 7.0	5.26	4.17
CA+Onion	E 150/50	1.0+ 5.5	5.27	3.74
CA+Peppers	E 150/50	1.0+ 4.0	4.98	3.70
CA+Tomato	E 150/50	1.0+ 5.5	4.04	3.71

Ingredients were added at the level they were used in stewsticks.
CA = citric acid, LA = lactic acid, N = non encapsulated.
* E 150/50 = Encapsulated oil, 150°F melting point, 50% acid, 50% oil.

Table 5--The pH of stewstick and meatstick ingredients at various steps during processing

Ingredients	grams	pH	normal pH[a]
Meat			
Beef, ground	740	5.87	5.1 - 6.2
Pork, ground	740	5.99	5.9 - 6.1
Pork & Beef mixed	1480	5.76	
Rehydrated vegetables[b]			
Potato + W	125	6.00	5.3 - 5.6
Carrot + W	60	5.78	4.9 - 5.2
Onion + W	45	5.46	5.3 - 5.8
Corn + W	20	7.43	7.3
Pepper, green	15	5.55	
Tomato powder	45	4.40	4.2 - 4.3
Mixtures of ingredients[b]			
Veg all mixed + W	310	5.71	
Meat + spices 20 g LA	843	5.22	
Meat + spices[c] 45 g LA	1237	5.55	
Meat + spices[c] 90 g LA	1237	5.47	
Meat + veg [d]	1050	5.93	
Meat + spices + veg[e]	1153	5.40	
Meat + spices + veg[e]	1153	5.37	
Meat + spices + veg[f]	1173	5.40	

pH values were means of four readings per sample.
[a]Jay, 1992.
[b]LA = lactic acid, CA = citric acid, W = water.
[c]Meatstick - 1134 g meat + 103 g spices, the ratio shown in Table 1.
[d]Stewstick - 740 g meat + 310 g veg.
[e]Stewstick - 740 g meat + 310 g veg + 103 g spices + 25 g LA.
[f]Stewstick - 740 g meat + 310 g veg + 103 g spices + 45 g CA.

Sensory evaluation

Consumer panel. Results differed significantly by gender on consumer panel ratings of meat and stewsticks (Appendix B, tables B1, B2, B3, and B4). In general, males gave higher ratings to the products for appearance, texture, and overall acceptability than did females (Table 6). There was also a higher standard deviation for the mean ratings for females, indicating a wider range of ratings by females (Table 6).

Table 6--Means and standard deviations of consumer panel sensory scores of stewsticks and meatsticks by gender

Gender	Appearance*	Texture	Flavor	Overall
Male**	$5.9^b \pm 1.8$	$6.1^b \pm 1.7$	5.6 ± 2.0	$5.7^b \pm 1.9$
Female**	$5.7^a \pm 2.0$	$5.7^a \pm 1.8$	5.5 ± 2.1	$5.5^a \pm 1.9$
Un**	$5.6^a \pm 1.9$	$5.6^a \pm 1.7$	5.4 ± 1.9	$5.4^a \pm 1.8$

* Mean ± standard deviation.
** n = 103 males, 108 females, 21 unknown (gender could not be determined from name).
[ab] Means in the same column with the same superscript letters are not different ($p < 0.05$).

Appearance was significantly affected by acid type ($p < 0.01$), acid level ($p < 0.01$), and stick type ($p < 0.01$) (Appendix B, Table B5). This would indicate that the panelists could distinguish between lactic and citric acid samples, the level of each acid added, and the type of stick (stew or meat) by its appearance. Samples made with citric acid were rated higher for appearance than were samples with lactic acid (Table 7). Panelists preferred samples that contained the lower level of acid (pH 5.2)

Table 7--Treatment effects on consumer panel mean sensory scores (> 70 panelists/session; 3 sessions)

Treatment	Appearance	Texture	Flavor	Overall
LA	5.50[a]	5.79	5.53	5.50[a]
CA	6.03[b]	5.96	5.58	5.65[b]
4.6	5.48[a]	5.71[a]	5.15[a]	5.22[a]
5.2	6.05[b]	6.04[b]	5.95[b]	5.93[b]
SS	5.38[a]	5.44[a]	4.93[a]	5.03[a]
MS	6.15[b]	6.31[b]	6.18[b]	6.12[b]
D1	5.57	5.73	5.45	5.45
D2	5.89	6.04	5.63	5.72
D3	5.33	5.86	5.58	5.56
LA*4.6	5.01	5.51	5.10	5.07[a]
LA*5.2	5.99	6.07	5.95	5.93[b]
CA*4.6	5.95	5.91	5.21	5.37[a]
CA*5.2	6.10	6.02	5.95	5.93[b]
LA*SS	5.26	5.40	4.99	5.07[a]
LA*MS	5.74	6.18	6.06	5.94[b]
CA*SS	5.50	5.49	4.87	5.00[a]
CA*MS	6.55	6.44	6.29	6.30[c]

LA = lactic acid, CA = citric acid; 4.6 = acid level of ca 4.6, 5.2 = acid level of ca 5.2; SS = stewsticks, MS = meatsticks; D1 = day one, D2 = day two, D3 = day three; [abc] values in columns within groups with the same superscript letters are not different ($p < 0.05$).

than samples with the higher levels of acid (pH 4.6). Meatsticks were rated higher than the stewsticks (Table 7). There were some ballots that mentioned white spots on the sticks made with the higher percentage of lactic acid (pH 4.6). This would explain how appearance was related to acid type, and may also have been why the acid level (4.6 or 5.2) showed a significant difference.

Consumer panel texture ratings were significantly affected ($p < 0.01$) by acid level and by stick type (Appendix B, Table B6). Therefore, the amount of acid added had an influence on the texture of the products. The texture difference between the two types of stick can be explained by the presence of vegetables, which were added only to stewsticks.

Consumer panel flavor scores were also significantly affected ($p < 0.01$) by acid level (Appendix B, Table B7). Panelists could not distinguish between citric or lactic acid, but they could distinguish between acid levels and preferred the less acidic products. This was verified by a correlation of 0.52 (Table 8) between flavor intensity and acid level. Panelists preferred the flavor of meatsticks over the stewsticks. The mean flavor score for stewsticks was 4.93, just below neither like nor dislike. Some panelists liked it extremely, and some disliked it extremely, resulting in a split population. There was a

Table 8--Correlation of means of data from combined consumer panel, trained panel, and physical and chemical values

	Acid Type	Acid Leve	Stick Type	Day	Appearance-C	Texture-C	Flavor-C	Overall-C	Color-T	Intensity-T	Texture-T
Appearance-C	0.39	0.41	0.56	0.15							
Texture-C	0.16	0.31	0.81	0.10	0.82						
Flavor-C	0.04	0.52	0.81	0.07	0.79	0.90					
Overall-C	0.11	0.51	0.77	0.06	0.86	0.93	0.99				
Color-T	-0.07	-0.05	-0.96	0.02	-0.49	-0.75	-0.76	-0.71			
Intensity-T	0.08	0.28	-0.48	-0.50	-0.15	-0.39	-0.27	-0.24	0.39		
Texture-T	0.27	0.13	0.77	-0.10	0.51	0.68	0.66	0.65	-0.90	-0.20	
Acid-T	0.15	-0.96	-0.10	0.02	-0.36	-0.36	-0.57	-0.54	0.14	-0.20	-0.20
Spice-T	0.42	0.54	-0.30	0.30	0.22	-0.07	0.05	0.06	0.20	0.21	0.02
Salt-T	0.01	0.02	0.44	-0.50	0.18	0.18	0.33	0.29	-0.40	0.12	0.55
Hot-T	0.12	0.15	-0.57	0.30	-0.14	-0.30	-0.31	-0.26	0.56	0.31	-0.50
pH, Measured	0.03	0.97	0.10	0.00	0.50	0.43	0.60	0.59	-0.10	0.22	0.22
Aw	0.11	0.06	0.76	0.34	0.71	0.80	0.74	0.75	-0.60	-0.50	0.44
Moisture	0.08	0.34	0.76	0.23	0.78	0.87	0.87	0.88	-0.70	-0.30	0.54
Ash	0.00	0.00	-0.42	-0.10	-0.50	-0.50	-0.42	-0.48	0.36	0.09	-0.20
Protein	0.24	0.03	0.80	-0.20	0.52	0.70	0.68	0.68	-0.80	-0.20	0.78
Fat	-0.55	-0.28	0.51	-0.20	-0.17	0.16	0.23	0.14	-0.40	-0.40	0.21
Carbohydrate	-0.01	-0.12	-0.95	0.06	-0.60	-0.85	-0.86	-0.84	0.88	0.42	-0.70
Shear	-0.12	-0.18	-0.32	-0.40	-0.53	-0.45	-0.42	-0.43	0.16	0.37	0.01

-C = Consumer Panel, -T = Trained Panel

Table 8--(Continued)

	Percieved Acid-T	Spice-T Intensity	Salt-T intensity	Hot-T Flavor	Measured pH	Measured Aw	Measured Moisture	Measured Ash	Measured Protein	Measured Fat	Carbohydrate
Spice-T	-0.40										
Salt-T	-0.10	-0.10									
Hot-T	0.00	0.45	-0.50								
pH, Measured	-1.00	0.45	0.12	0.03							
Aw	-0.10	-0.20	0.13	-0.20	0.17						
Moisture	-0.40	-0.10	0.17	-0.20	0.42	0.91					
Ash	0.05	0.36	0.06	0.00	0.00	-0.60	-0.60				
Protein	-0.10	-0.30	0.51	-0.50	0.15	0.49	0.53	-0.40			
Fat	0.14	-0.60	0.36	-0.40	-0.20	0.16	0.08	0.00	0.37		
Carbohydrate	0.21	0.32	-0.40	0.47	-0.20	-0.80	-0.80	0.48	-0.90	-0.50	
Shear	0.15	-0.10	0.26	0.00	-0.20	-0.70	-0.60	0.25	-0.10	0.02	0.30

high positive correlation (0.81) between stick type and flavor intensity scores (Table 8).

Sample overall acceptability was significantly affected by type of acid ($p < 0.05$), acid level ($p < 0.01$), stick type ($p < 0.01$), interaction of acid type and acid level ($p < 0.05$), and the interaction of acid type and stick type ($p < 0.01$; Appendix B, Table B8). Panelists preferred samples made with citric acid over lactic acid by a small margin. Panelists also preferred products with the lower level of acid (pH 5.2) and the meatsticks over the stewsticks (Table 7). It was not surprising that the lactic acid (LA) and citric acid (CA)*5.2 level was preferred over the LA and CA*4.6 since samples at higher acid levels (pH 4.6) were quite bitter. The meatsticks were probably preferred over the stewsticks based mainly on appearance. It is interesting that there was also a preference for the LA and CA*MS over LA and CA*SS. Since there were no significant three-way interaction effects on sensory characteristics, they were not included in Table 8.

Trained panel. A trained panel was used to obtain data on sample color and flavor intensity since this information could not be obtained from consumer hedonic panels. Color refers to the major color rating for each sample (1 = red, 2 = brown, 3 = orange, Appendix A, Fig.

A2). Sample color was affected by stick type (Appendix B, Table B9). As previously stated in the consumer panel analysis, the reason for the difference between meatsticks and stewsticks was that stewsticks had vegetables added (Table 1). The addition of vegetables to stewsticks seemed to cause a change in color (Fig. 2) when compared to meatsticks with no vegetables (Fig. 3), not only because of the mixture of vegetables and meat, but also because of mixing time. It was noted that stewsticks from day 1 were a different color than days 2 and 3. The only part of the processing procedure that was different was that the stewsticks from days 2 and 3 were mixed longer. This resulted in an orange color, while day 1 samples were brown (mixed for a shorter time). This color difference was again noticed when using the Hollymatic, mixer grinder (Holly Sales & Service Intermountain Inc., Salt Lake City, Utah). In the Hollymatic the material at the very bottom did not mix well. It was extruded first and was darker before cooking and more red or brown after cooking. The stewsticks in the top of the hopper were mixed thoroughly for 15 min and was lighter and more orange after cooking.

The appearance of the stewsticks differed from the meatsticks not only by the vegetables present in the stewsticks but also by the color of the end products; the major color of stewsticks was orange (code 3) vs red

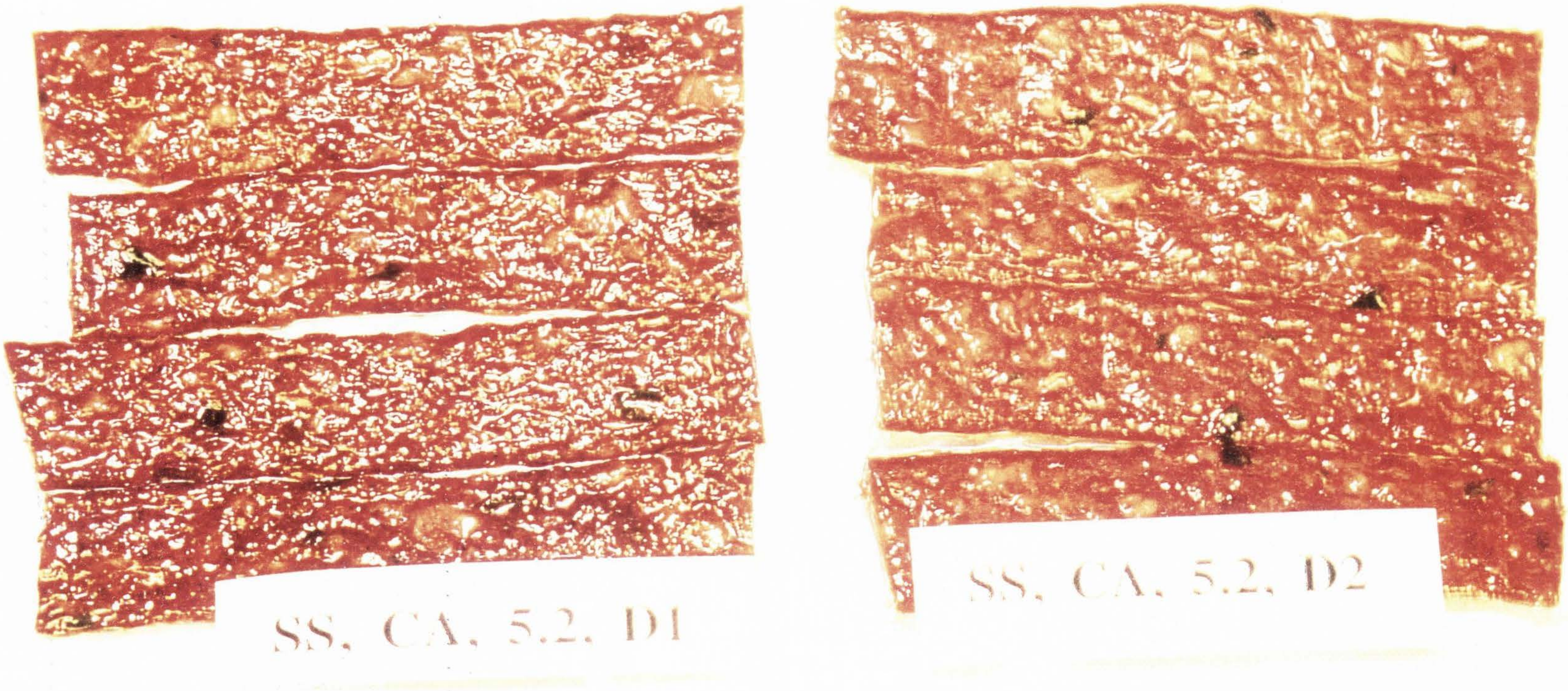


Fig. 2--Color differences of stewsticks on day 1 vs day 2.

SS = stewsticks, CA = citric acid, 5.2 = pH 5.2, 4.6 = pH 4.6.

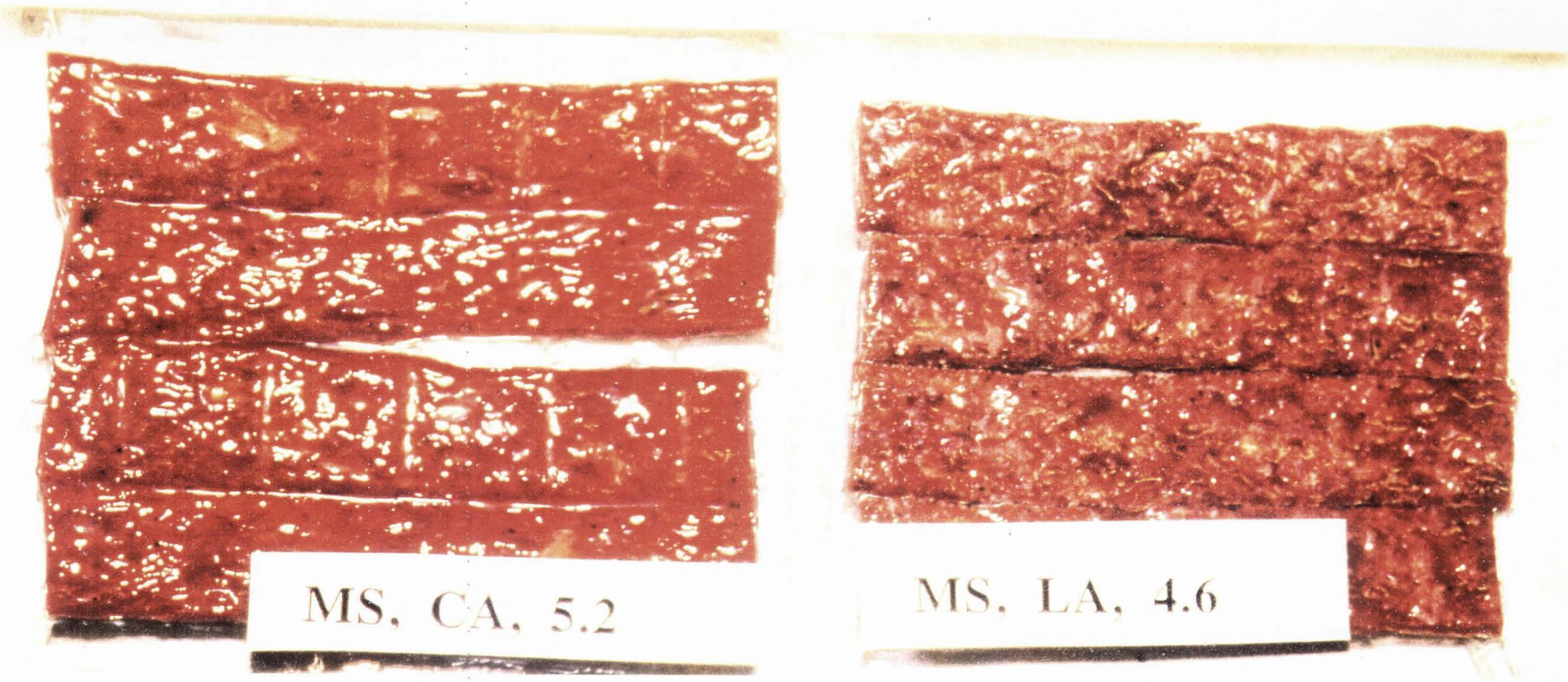


Fig. 3--Effect of pH levels on appearance of meatsticks.

MS = meatsticks, CA = citric acid, LA = lactic acid, 5.2 = pH 5.2, 4.6 = pH 4.6.

(code 1) for meatsticks. Some panelists noted that the meatsticks with lactic acid at pH 4.6 had white dots while the meatsticks with lactic acid at pH 5.2 had no white dots (Fig. 3). Another factor that adversely affected color of meatsticks and stewsticks was loss of package vacuum (Fig. 4). This caused the stick to change from a red, brown, or orange to a tan color and allowed mold to grow.

The color intensity of each sample was affected by day and stick type (Appendix B, Table B10). Color intensity was rated on a scale of 1-7 where 7 = very intense color and 1 = no color (Appendix A, Fig. A2). Day 1 samples had a more intense color score of 4.4 compared to 4.1 and 4.0 for day 2 and 3, respectively (Table 9). The stewsticks had a color intensity of 4.3 vs 4.0 for meatsticks (Table 9). Texture was affected only by stick type (Appendix B, Table B11). Panelists rated meatsticks more firm with a score of 5.1 vs 4.1 for stewsticks (Table 9). This may have been due to the meatsticks not having any vegetables added and, therefore, having higher bind and cohesiveness.

Perceived acid intensity was affected by acid type, acid level, stick type, acid level * stick type, and acid type * acid level * stick type (Appendix B, Table B12).

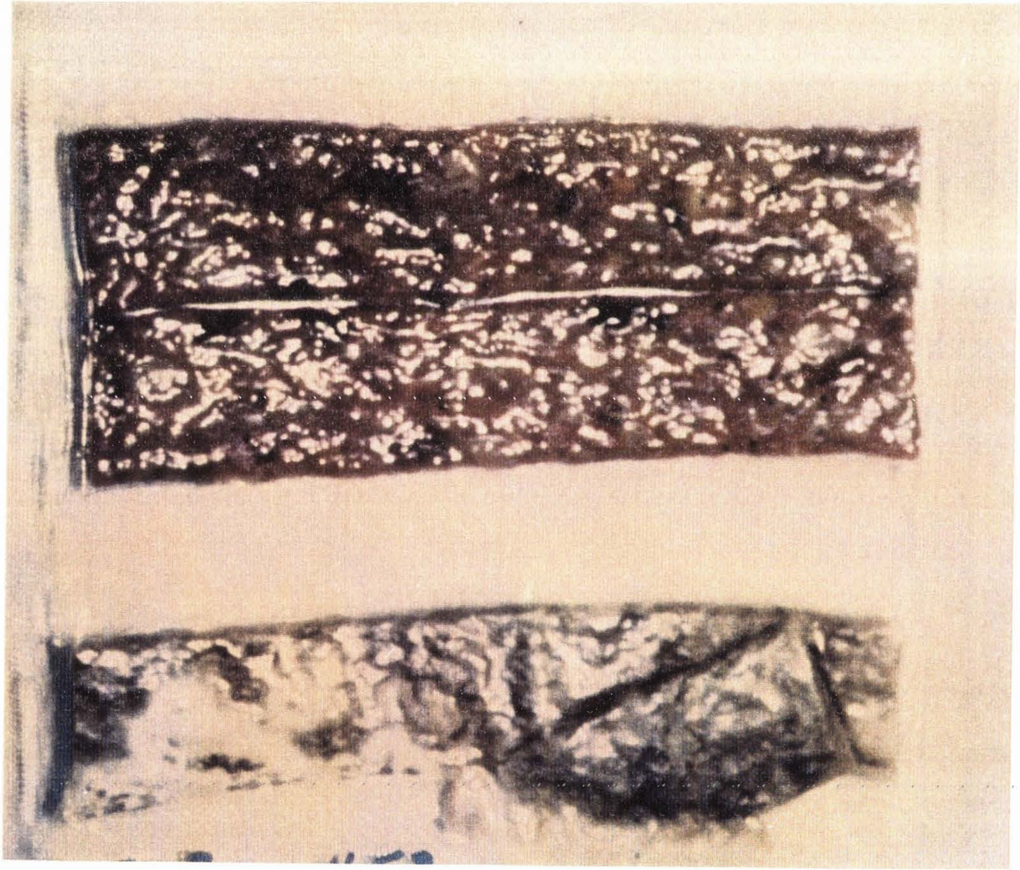


Fig. 4--Leaker effects on color and mold growth of stewsticks.

Table 9--Treatment effects on trained panel mean sensory scores (18 panelists/ session; 3 sessions)

Treatment	n	Color Intensity	Texture	Acid	Spice	Salt	Hot
D 1	144	4.4^{b}	4.7	3.9	3.8	2.5^{b}	2.5^{a}
D 2	144	4.1^{a}	4.5	4.1	3.8	2.3^{a}	3.1^{c}
D 3	144	4.0^{a}	4.6	4.0	3.9	2.3^{a}	2.9^{b}
LA	216	4.1	4.5	3.8^{a}	3.7^{a}	2.4	2.8
CA	216	4.2	4.8	4.2^{b}	3.9^{b}	2.4	2.9
4.6	216	4.1	4.5	5.1^{b}	3.7^{a}	2.4	2.7
5.2	216	4.3	4.7	2.9^{a}	4.0^{b}	2.4	2.9
SS	216	4.3^{b}	4.1^{a}	4.1^{b}	3.9^{b}	2.3^{a}	3.1^{b}
MS	216	4.0^{a}	5.1^{b}	3.9^{a}	3.8^{a}	2.4^{b}	2.5^{a}
4.6*SS	108	4.2	3.9	5.4^{c}	3.8	2.3	3.0
4.6*MS	108	3.9	5.1	4.8^{b}	3.7	2.4	2.5
5.2*SS	108	4.4	4.4	2.8^{a}	4.0	2.3	3.2
5.2*MS	108	4.1	5.1	2.9^{a}	3.8	2.4	2.6
LA*4.6*SS	54	4.1	3.6	5.3^{d}	3.7	2.3	2.8
LA*4.6*MS	54	3.8	5.1	4.5^{c}	3.4	2.5	2.4
LA*5.2*SS	54	4.4	4.2	2.6^{a}	3.9	2.2	3.2
LA*5.2*MS	54	4.2	5.0	2.9^{a}	3.9	2.4	2.7
CA*4.6*SS	54	4.4	4.3	5.5^{d}	3.9	2.3	3.2
CA*4.6*MS	54	4.0	5.2	5.2^{d}	3.8	2.4	2.6
CA*5.2*SS	54	4.4	4.5	3.0^{b}	4.2	2.3	3.3
CA*5.2*MS	54	4.0	5.2	2.9^{a}	3.9	2.4	2.5

D 1 = day one, D 2 = day two, D 3 = day three; LA = lactic acid, CA = citric acid; 4.6 = acid level of ca 4.6, 5.2 = acid level of ca 5.2; SS = stewsticks, MS = meatsticks.
^{abc} values in columns within groups with the same superscript letters are not different ($p < 0.05$).

Trained panelists rated samples made with citric acid as more acid flavored with a score of 4.17 vs 3.81 for samples made with lactic acid (Table 9). Pangborn (1963) found that at above threshold concentrations, citric acid was the least sour compared to acetic, lactic, and tartaric acids. CoSeteng et al. (1989) reported that, at equal pH and weight percent concentrations of food acids, increasing the number of carboxyl groups decreased the sourness. Relative sour intensity ratings were as follows: acetic > malic > lactic > citric. However, Hartwig and McDaniel (1995) found that pH also affected sourness ratings. They found that lactic acid was more sour than citric acid at pH 3.5 and less sour at ph 4.5. There was no difference in sourness at pH 6.5. The results of this study agree with the findings of Hartwig and McDaniel (1995) where samples with citric acid at pH 4.6 - 5.2 were rated as more sour than similar samples made with lactic acid.

In this study, panelists rated pH 4.6 samples as much more acid than samples at pH 5.2 (panel scores of 5.12 vs 2.86, respectively, for acid intensity levels; Table 9). This relationship of acid level to perceived acid intensity by trained panelists had an inverse correlation of -0.96 (Table 8). This inverse correlation is also demonstrated in Fig. 5. Panelists also perceived

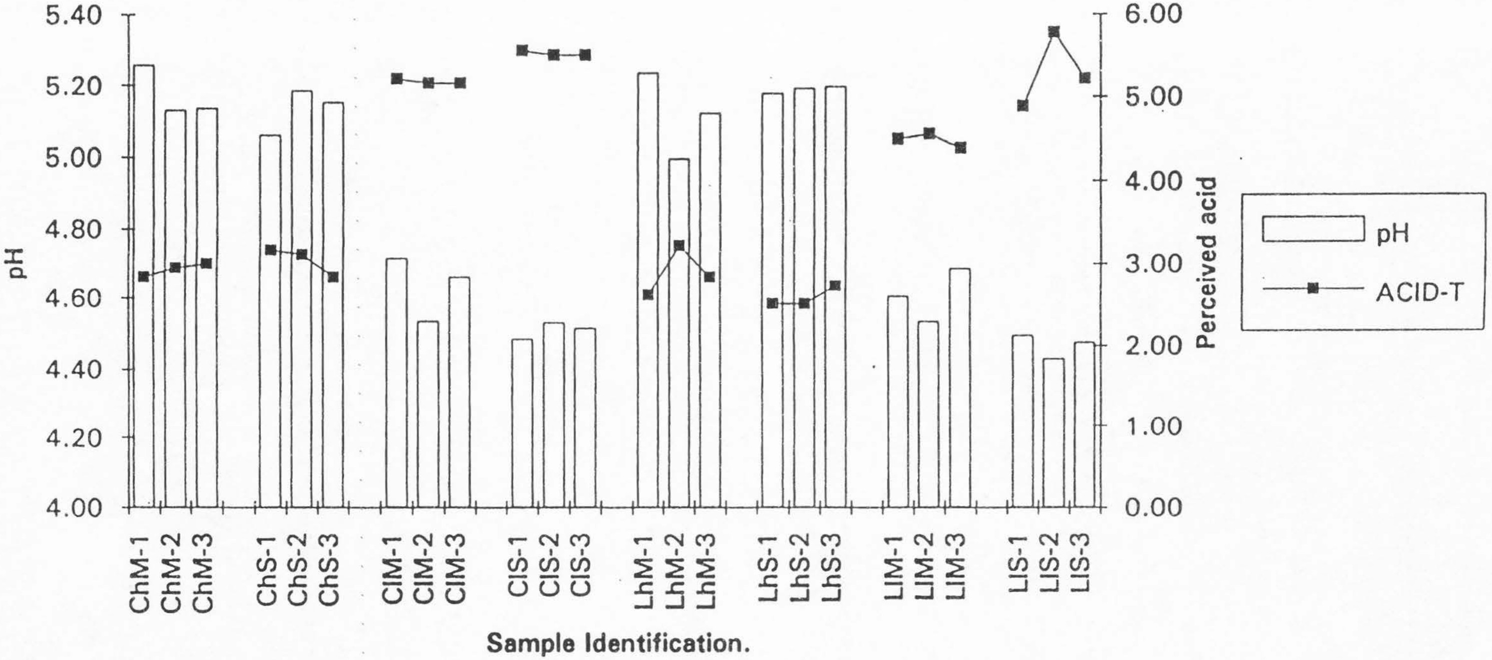


Fig. 5--Trained panel mean values for pH and perceived acid of meatsticks and stewsticks.
C = citric acid, L = lactic acid, h = pH 5.2, l = pH 4.6
M = meatsticks, S = stewsticks, 1 2 3 = day 1, 2, 3.

stewsticks as having a higher acid flavor intensity than meatsticks (4.11 vs 3.87; Table 9). Perhaps the tomato powder in stewsticks was contributing to the acid flavor. Panelists rated acid intensity of pH 5.2 * meatsticks vs stewsticks as not significantly different (2.81 vs 2.91, respectively, Table 9). However, at the lower pH, 4.6*MS were rated less acidic (4.83) than 4.6*SS (5.41). Again, the likely explanation is that tomato powder in stewsticks was contributing to their acid flavor.

Meat protein is a good buffer, so it required more lactic acid or citric acid to lower pH to 4.6 compared to stewsticks (Table 1). Meatsticks also required more acid than stewsticks to lower pH to 5.2. However, meatsticks were still perceived as less acid by the trained panel. The three-way interactions confirmed the main effects and two-way interactions previously discussed.

Spice intensity was affected by acid type, acid level, and stick type (Appendix B, Table B13). Panelists perceived samples made with citric acid as more spicy at 3.93 vs 3.72 for samples made with lactic acid (Table 9). Since the same amount of spice was added to both stewsticks and meatsticks, this difference could be related to the perceived acid level where citric acid sticks had a higher acid level than lactic acid sticks. Panelist sensory evaluation of spiciness was 3.96 for pH

5.2 samples vs 3.69 for more acid samples. There was an inverse correlation of spiciness with perceived acid since the spiciness ratings increased as the acid intensity decreased (Table 9). Spice intensity was higher for stewsticks than meatsticks (Table 9). This may have been due to some panelists associating acid intensity with spice intensity.

Salt intensity was affected by day and stick type (Appendix B, Table B14). Panelists evaluated salt intensity for day 1 as being higher than the other two days (Table 9). Since each day samples were formulated identically, there should have been no difference in these values. Meatsticks were also scored higher for salt level than stewsticks. Perhaps vegetables absorb or mask the salty flavor.

Hot flavor was affected by day and stick type (Appendix B, Table B15). Day 1 samples had a hot flavor intensity value of 2.57 vs 2.9 on day 3 and 3.1 on day 2 (Table 9). No explanation was found that would explain these values. Trained panelists rated stewsticks as hotter than meatsticks (Table 9). Again this could be perceived acid being discerned as hot flavor intensity.

Physical and chemical measurements. There was no significant treatment effect on shear values (Appendix B, Table B16). Sample pH was significantly affected by acid level (pH 4.6 or 5.2), stick type (stew vs meat), and acid level * stick type interactions (Appendix B, Table B17). The lower acid level had a measured pH of 5.15 vs 4.56 for the higher acid level, very close to the target levels of < 5.2 and < 4.6 (Table 10). The meatsticks had a mean pH of 4.88 vs 4.82 for stewsticks. Although this difference was statistically significant, the actual pH difference (0.06) is probably not of practical significance. However, preliminary experiments demonstrated that much more acid was needed to bring meatsticks to pH 5.2 compared to stewsticks (45 g lactic acid to bring meatsticks to pH 5.2 vs 25g for stewsticks; Table 1). The same pattern was seen for citric acid at pH 5.2. This may be due to higher buffer capacity of meat proteins vs vegetables in stewsticks, requiring more acid to lower pH to 5.2 in all meatsticks. The same effect was not seen at pH 4.6.

Meat type (stewsticks vs meatsticks) was the only treatment variable to significantly affect a_w values (Appendix B, Table B18). Meatsticks had a mean a_w of 0.92 vs 0.87 for stewsticks (Table 10). An explanation of the a_w difference is that the stewsticks had rehydrated vegetables added to the meat, and the meatsticks did not. The rehydrated vegetables were rehydrated using a 1:1

Table 10--Treatment effects on means of Warner-Bratzler shear, pH, a_w, and proximate analysis

Treatment	Shear	pH	a_w	Moisture	Ash	Protein	Fat	CHO
LA	9.24	4.85	0.89	38.3%	5.9%	26.4%[a]	16.5%[b]	13.3%
CA	8.71	4.86	0.90	39.5%	5.7%	28.1%[b]	14.1%[a]	13.3%
4.6	9.35	4.56[a]	0.90	37.5%[a]	5.8%	27.3%	15.7%	14.1%[b]
5.2	8.60	5.15[b]	0.90	40.3%[b]	5.8%	27.2%	14.9%	12.5%[a]
SS	9.54	4.82[a]	0.87[a]	35.5%[a]	6.1%[b]	24.4%[a]	14.1%[a]	20.6%[b]
MS	8.41	4.88[b]	0.92[b]	42.3%[b]	5.5%[a]	30.1%[b]	16.6%[b]	6.0%[a]
LA*4.6	10.01	4.54	0.89	36.9%	5.8%	27.0%[b]	17.2%	13.7%
LA*5.2	8.47	5.15	0.90	39.7%	5.9%	25.8%[a]	15.9%	12.9%
CA*4.6	8.69	4.57	0.90	38.0%	5.8%	27.6%[b]	14.3%	14.4%
CA*5.2	8.73	5.15	0.90	40.9%	5.6%	28.5%[b]	13.9%	12.2%
LA*SS	9.66	4.83	0.87	34.9%	6.1%	24.4%[a]	15.8%[b]	19.4%[b]
LA*MS	8.82	4.86	0.92	41.8%	5.7%	28.4%[b]	17.3%[c]	7.3%[a]
CA*SS	9.41	4.82	0.88	36.2%	6.0%	24.4%[a]	12.4%[a]	21.7%[b]
CA*MS	8.00	4.91	0.93	42.8%	5.3%	31.8%[c]	15.9%[b]	4.8%[a]
4.6*SS	9.43	4.48[a]	0.87	34.3%	6.1%	23.5%[a]	14.5%	21.8%
4.6*MS	9.27	4.62[a]	0.92	40.6%	5.5%	31.2%[d]	17.0%	6.3%
5.2*SS	9.64	5.16[b]	0.87	36.7%	6.0%	25.3%[b]	13.6%	19.3%
5.2*MS	7.56	5.15[b]	0.93	43.9%	5.5%	29.0%[c]	16.2%	5.8%

LA = lactic acid, CA = citric acid, 4.6 = acid level of ca 4.6,
5.2 = acid level of ca 5.2, SS = stewsticks, MS = meatsticks.
[abc] values in columns within groups with different superscript letters are different ($p < 0.05$).

ratio of water to vegetables. These vegetables were about 50-53% moisture, compared to about 62% moisture for lean meat (USDA, 1984). Therefore, the stewsticks were drier even before cooking than were the meatsticks.

Sample moisture content was affected by acid level and stick type (Appendix B, Table B19). Samples at pH 5.2 had higher mean moisture level of 40.3% compared to 37.5% for samples at pH 4.6 (Table 10). Both citric and lactic acids were encapsulated in oils, soy and palm, respectively. Samples at pH 4.6 thus had more added oil, which in part accounted for their lower moisture. This possibility is supported by the somewhat higher fat level of samples at pH 4.6 vs 5.2 (15.7 vs 14.9% fat, respectively; Table 10).

Ash values of meat and stewsticks were only significantly affected by stick type (Appendix B, Table B20). Mean ash values of stewsticks was 6.1% vs 5.5% for meat sticks (Table 10). Apparently, one of the added vegetables in stewsticks had a higher ash content than the equivalent amount of meat.

Protein content was significantly affected by acid type ($p < 0.01$), meat type ($p < 0.01$), a two-way interaction of acid type * acid level ($p < 0.05$), acid type * meat type ($p < 0.01$), and acid level * meat type ($p < 0.01$) (Appendix B, Table B21). Citric acid sticks had

28.1% protein vs 26.4% protein for lactic acid sticks (Table 10). Lactic acid has a molecular wt 90.08 vs 192.12 for citric acid. The amount of lactic acid added to product was about double that of citric acid (Table 1). Therefore, the amount added would have an inverse effect on the percent protein. This possibility is supported by the somewhat higher fat level of lactic acid vs citric acid samples (16.5 vs 14.1% fat, respectively; Table 10).

There was a positive correlation between protein levels with both moisture levels and a_w (Table 1), and corroborated in Table 10, in that the percent moisture and a_w was higher in citric acid than lactic acid samples. The protein levels of citric acid samples were also higher (Appendix B, Table B21). A significant difference between stewsticks and meatsticks was expected since stewsticks had vegetables which contain carbohydrates resulting in a decreased protein level of the stewsticks. There was no discernable reason why the mean protein level of LA*5.2 samples was lower than the other three values. Stewsticks had a lower protein than meatsticks because vegetables in stewsticks lowered the protein level of the product.

Fat levels of meat and stewsticks were only significantly affected by acid type, stick type, and the combination of acid type * stick type (Appendix B, Table B22). Mean fat values of lactic acid samples were 16.5%

vs 14.1% for citric acid samples (Table 10). As previously mentioned there was twice as much lactic acid added as citric acid due to the difference in molecular wt. Therefore, there was twice as much encapsulation oil added for lactic acid samples as for citric acid samples. Meatsticks had a mean fat level of 16.6% vs 14.4% fat for stewsticks. This lower fat level was one of the parameters hoped for in the development of the stewsticks. The two-way combination of acid type * meat type further verified that the type of stick and the amount of acid added affect the fat percentage of the sticks (Tables 1, 10).

Mean carbohydrate (CHO) levels of meat and stewsticks were only significantly affected by acid level, stick type, and the combination of acid type * stick type (Appendix B, Table B23). The mean CHO value of high acid samples was 14.1% vs 12.5% CHO for the low acid samples (Table 10). The high acid samples had more citric or lactic acid added, therefore, more carbohydrates since both acids are carbohydrates. Stewsticks had a mean carbohydrate value of 20.6% vs 6.0% for meatsticks. This obviously was due to the higher carbohydrate level associated with vegetables in stewsticks. Meatsticks' carbohydrate level was due to the peppers, fennel, and acids. The two-way-combination of acid level * meat type verified the above results that the high acid samples and the type of stick were a determining factor in carbohydrate percentages (Table 1, 10).

Consumer panel correlation coefficients. Appearance was positively correlated to texture, flavor, and overall acceptability, with correlation coefficients of 0.61, 0.50, and 0.64, respectively (Table 11). This would indicate that as appearance values increased, texture, flavor, and overall acceptability scores of the samples also increased (Fig. 6). Texture was positively correlated to flavor and overall acceptability with correlation coefficients of 0.65 and 0.76, respectively (Table 11; Fig. 7). Flavor was highly correlated to overall acceptability with a coefficient of 0.90 (Table 11). Thus, flavor was the largest determining factor in overall acceptability as shown in Fig. 8.

Trained panel correlation coefficients. For trained panel sensory scores, the only correlation coefficient that was greater than 0.50 was acid intensity vs perceived acid level with a correlation coefficient of -0.63 (Table 12).

Correlation coefficients among physical and chemical values. Shear values were negatively correlated (-0.52) with water activity (Table 13). Thus, as shear increased, water activity would generally decrease. Water activity

Table 11--Correlation of all data from consumer panel

	Acid Type	pH Level	Stick Type	Appearance	Texture	Flavor
Acid Type						
pH Level	0.01					
Stick Type	0.01	0.00				
Appearance	0.14	0.14	0.20			
Texture	0.05	0.09	0.25	0.61		
Flavor	0.02	0.20	0.31	0.50	0.65	
overall	0.04	0.19	0.29	0.64	0.76	0.90

Table 12--Correlation of all data from trained panel

	Acid Type	pH Level	Stick Type	DAY	Color Intensity	Texture	Perceived Acid	Spice	Salt
Color Intensity	0.02	0.08	-0.13	-0.15					
Texture	0.13	0.06	0.37	-0.03	0.24				
Perceived Acid	0.10	-0.63	-0.07	0.01	-0.03	-0.07			
Spice	0.08	0.10	-0.06	0.06	0.26	0.07	-0.06		
Salt	0.00	0.00	0.07	-0.07	0.20	-0.01	0.04	0.26	
Hot	0.04	0.06	-0.21	0.11	0.07	-0.10	0.08	0.36	0.10

Table 13--Correlation of all data from measured panel

	Shear	pH	Aw	Moisture	Ash	Protein	Fat
pH	-0.21						
Aw	-0.52	0.17					
Moisture	-0.41	0.33	0.92				
Ash	0.29	-0.07	-0.63	-0.69			
Protein	-0.02	0.12	0.43	0.43	-0.35		
Fat	-0.05	-0.15	0.23	0.18	0.08	0.41	
Carbohydrate	0.30	-0.20	-0.76	-0.78	0.46	-0.84	-0.58

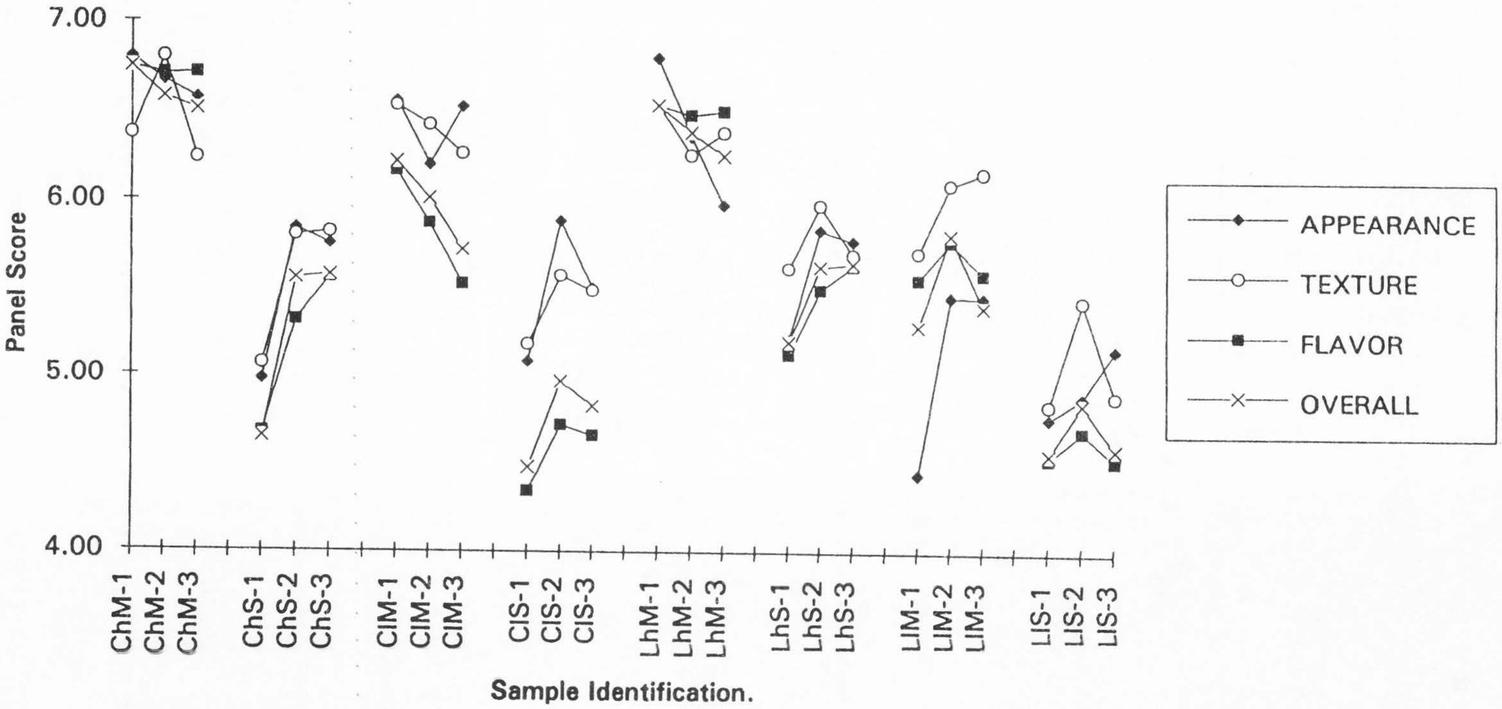


Fig. 6--Consumer panel mean scores for appearance, texture, flavor, and overall acceptability.
C = citric acid, L = lactic acid, h = pH 5.2, l = pH 4.6
M = meatsticks, S = stewsticks, 1 2 3 = day 1, 2, 3.
Panel score 9 = like extremely, 1 = dislike extremely.

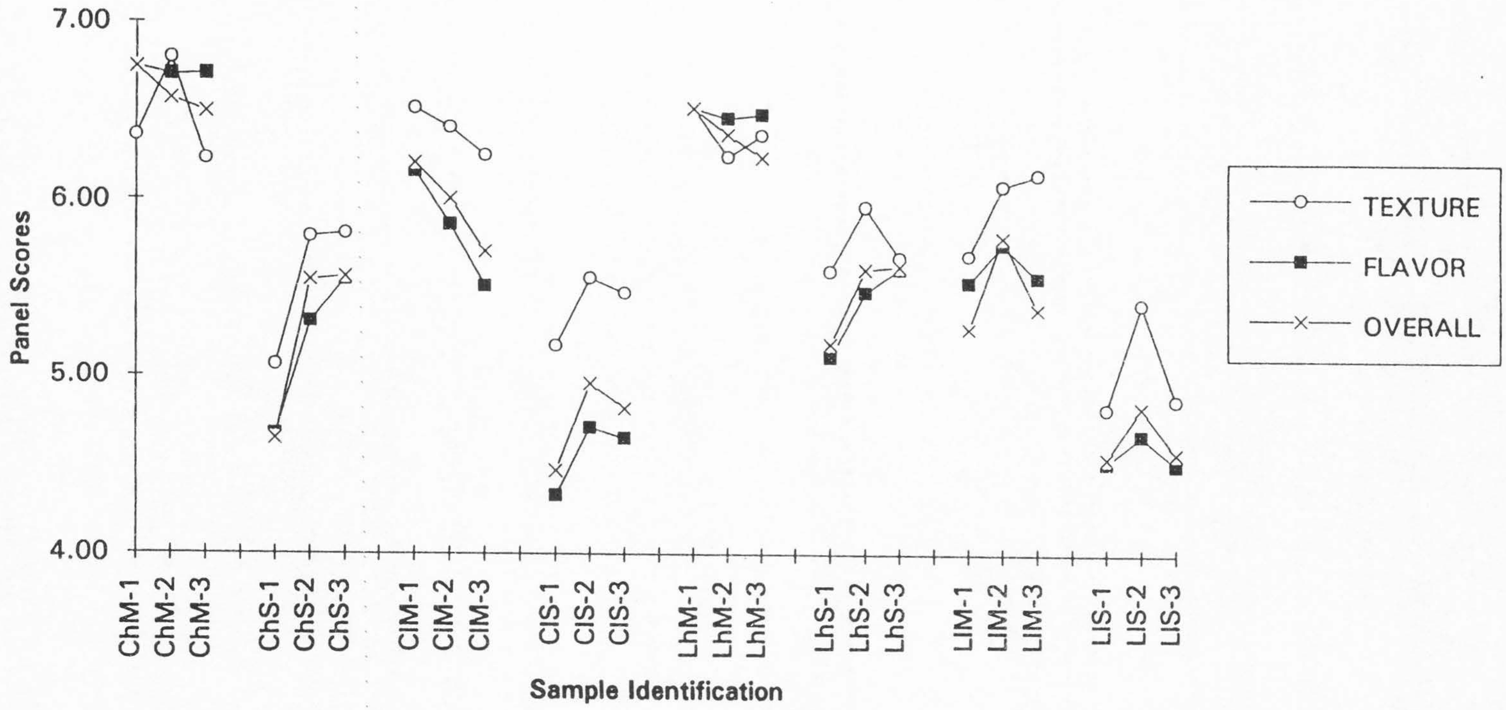


Fig. 7--Consumer panel mean scores for texture, flavor, and overall acceptability.
C = citric acid, L = lactic acid, h = pH 5.2, l = pH 4.6
M = meatsticks, S = stewsticks, 1 2 3 = day 1, 2, 3.
Panel score 9 = like extremely, 1 = dislike extremely.

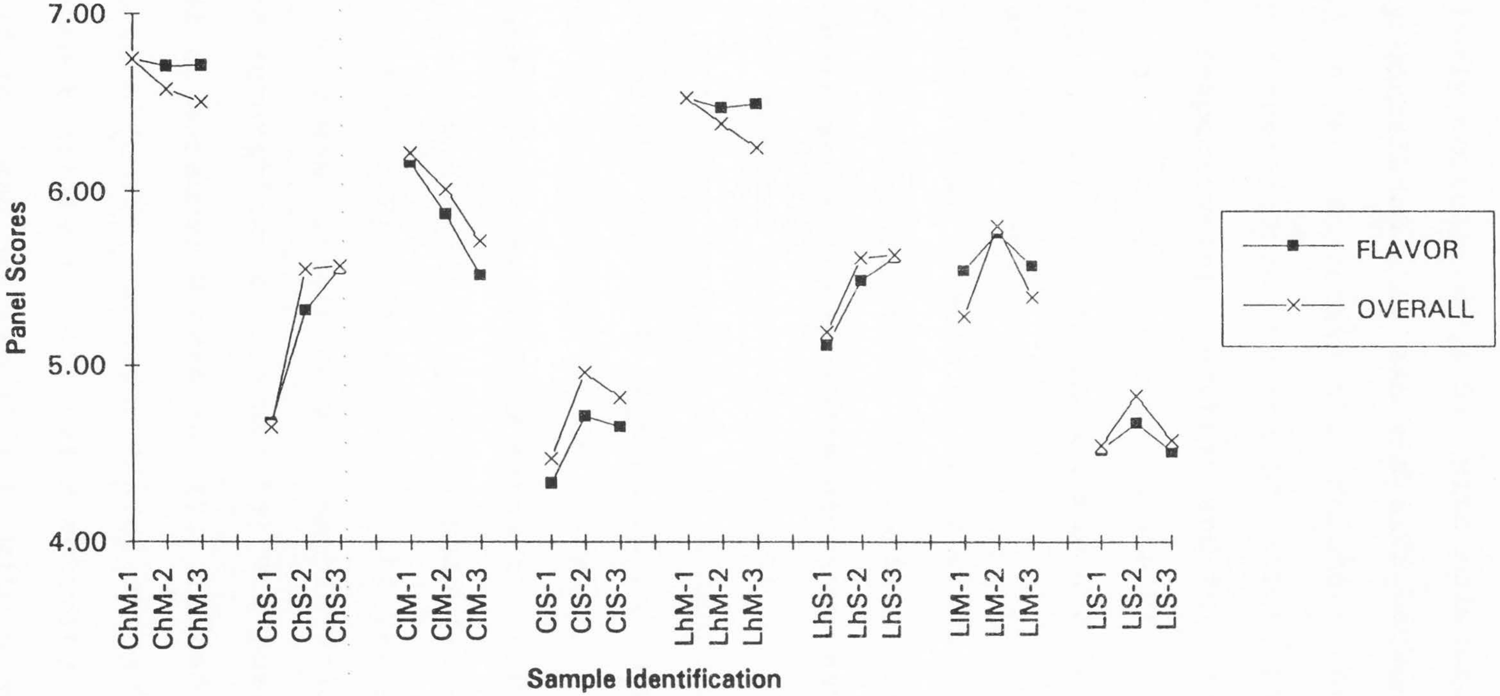


Fig. 8--Consumer panel mean scores for flavor and overall acceptability.
C = citric acid, L = lactic acid, h = pH 5.2, l = pH 4.6
M = meatsticks, S = stewsticks, 1 2 3 = day 1, 2, 3.
Panel score 9 = like extremely, 1 = dislike extremely.

was positively correlated (0.92) with moisture and negatively correlated with ash and with carbohydrates (-0.63 and -0.76, respectively). Moisture levels were negatively correlated to ash and to carbohydrates (-0.69 and -0.78, respectively). Protein and fat were negatively correlated to carbohydrates with values of -0.84 and -0.58, respectively. Thus, as protein and fat increased, carbohydrates decreased.

Correlation coefficients of means of data from consumer panel, trained panel, and physical and chemical values. Correlation coefficients among sensory values and chemical and physical measurements of stewsticks and meatsticks are shown in Table 8. As a general rule the square root of the correlation coefficient may be interpreted as the variability in one measure that is due to the change in the associated measure. For example, perceived acid was negatively correlated (-0.96) with acid level (pH 4.6 vs 5.2). Thus, 92% of the variability in perceived acid was associated with sample acid level. Stick type (meatsticks or stewsticks) was positively correlated to consumer scores (0.81), trained panel texture scores (0.77), consumer flavor scores (0.81), overall acceptability (0.77), water activity (0.76), moisture (0.76), and protein (0.80), with a negative correlation to color (-0.96) and carbohydrates (-0.95).

Day had no correlation of any significance with any other treatment.

Appearance scores of the consumer panel were highly positively correlated to texture (0.82), flavor (0.79), overall acceptability (0.86), and moisture (0.78). Thus, the more the panelists liked the appearance of the sticks, the higher they rated texture, flavor, and overall acceptability. The more favorable scores were related to the greater moisture content in the sticks.

Consumer panel texture scores were positively correlated to flavor (0.90), overall acceptability (0.93), water activity (0.80), and moisture (0.87) and negatively correlated to color (-0.75) and carbohydrates (-0.85). Flavor of the stick was highly correlated to overall acceptability, color, moisture, and carbohydrates. Thus, when the panelists rated flavor higher, they also rated overall acceptability higher and color lower (more of red than of orange). There was a higher value for moisture and a lower value for carbohydrates with an increase in flavor ratings.

Overall acceptability of the sticks was positively correlated to the moisture of the sticks at 0.88 and negatively to CHO at -0.84. Thus, there was a higher moisture and a lower CHO content in the sticks that the panelists rated high for overall acceptability.

The color of the sticks was highly negatively correlated to texture (-0.90) and protein (-0.80) and positively correlated to carbohydrates (0.88). As panelists rated color higher, they also rated samples lower for texture. Since meatsticks were rated by panelists as a red color (1) and stewsticks as an orange color (3), a high rating for color would designate stewstick. Thus stewsticks had lower texture scores, less protein, and a higher carbohydrate level.

Texture was positively correlated to protein level (0.78).

Trained panel acid intensity scores were negatively correlated to the measured pH at -1.00. This means that every time the measured pH increased, the acid intensity ratings by the trained panel decreased.

Trained panel scores for spiciness, saltiness, and hot flavor intensity were not correlated to other measures.

Water activity was highly correlated to moisture (0.91) and negatively to carbohydrate (-0.80). Since a_w and moisture are positively correlated, water activity can be approximated from moisture (Fig. 9). Moisture levels also were negatively correlated with carbohydrate levels (-0.80). As would be expected, protein levels were negatively correlated with carbohydrate levels (-0.90).

The physical and chemical measurements (Table 10) were used to create a nutrition label for stewsticks and meatsticks (Figs. 10 and 11, respectively). These labels showed that the addition of vegetables caused some nutrients to decrease while others increased. The nutrients that decreased were fat, saturated fat, cholesterol, and protein. The nutrients that increased were CHO, dietary fiber, sugars (from vegetables), vitamin A, vitamin C, and calcium. Iron remained about the same.

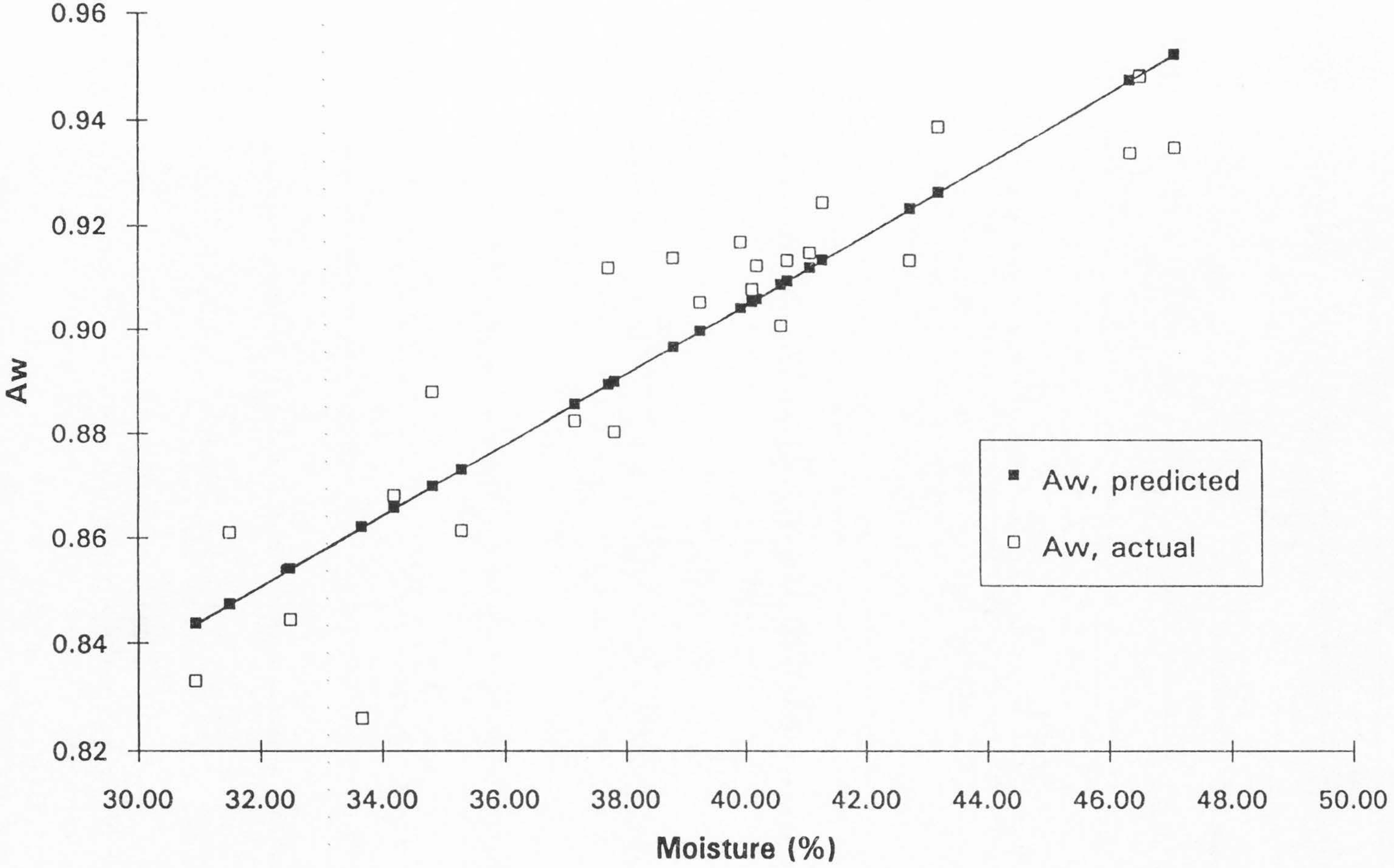


Fig. 9--Scatterplot of water activity vs moisture of stewsticks and the regression line.

Nutrition Facts		
Serving size 2 ounces (57g)		
Servings per container 1		
Amount Per Serving		
Calories 183		Calories from Fat 99
		% Daily Value
Total Fat	11 g	17%
Saturated Fat	4 g	16%
Cholesterol	90 mg	30%
Sodium	1171 mg	49%
Total Carbohydrate	4 g	1%
Dietary fiber	0 g	
Sugars	0 g	
Protein	17 g	
Vitamin A 2%	Vitamin C 1%	
Calcium 3%	Iron 27%	

Fig. 10--Nutrition label of stewsticks acidified with lactic acid to pH 5.2.

Nutrition Facts		
Serving size 2 ounces (57g)		
Servings per container 1		
Amount Per Serving		
Calories 224	Calories from Fat 84	
		% Daily Value
Total Fat	9 g	14%
Saturated Fat	3 g	15%
Cholesterol	75 mg	25%
Sodium	1213 mg	51%
Total Carbohydrate	20 g	7%
Dietary fiber	2 g	
Sugars	3 g	
Protein	15 g	
Vitamin A 11%	Vitamin C 32%	
Calcium 6%	Iron 28%	

Fig. 11--Nutrition label of meatsticks acidified with lactic acid to pH 5.2.

CONCLUSIONS

Consumer panelists had no preference for lactic vs citric acid in meatsticks or stewsticks. However, the acid level (pH 4.6 or 5.2) influenced consumer panel acceptability scores with preference for samples at pH 5.2. The highest rated product was MS*5.2*LA or CA. Stewsticks, because of the added vegetables, had less fat, less protein, and increased carbohydrate levels. The addition of lactic acid at pH 4.6 resulted in white spots on the cooked meatsticks or stewsticks. There was less citric acid added than lactic acid to obtain the desired pH because citric acid has three carboxylic acid groups per molecule vs one carboxylate group per lactic acid molecule.

The trained panel did very well in that they correctly discerned a very high inverse correlation of perceived acid to the pH of the stewsticks. As expected, flavor was highly correlated (0.90) to overall acceptability.

Compared to meatsticks, the addition of vegetables to stewsticks caused a reduction of fat (11 g to 9 g) and cholesterol (90 mg to 75 mg). Vegetable addition increased dietary fiber (2 g to 4 g), carbohydrates (4 g to 20 g), vitamins (Vit A 2% to 11% and Vit C 1% to 32%), and calcium (3% to 6%). This addition of vegetables to meat decreased the less desirable nutrients (fat and cholesterol) while increasing the desirable nutrients (carbohydrates, dietary fiber, natural sugars, vitamin A, vitamin C, and calcium).

The addition of vinegar or unencapsulated acids resulted in a flaccid uncohesive stick that did not bind. Therefore, acid encapsulation is necessary for acidification of this product. The biggest cause of color deterioration was due to poor packaging. Air contact caused meat pigment oxidation and allowed mold growth. Meatsticks were preferred over stewsticks. Forty-six percent of the panelists rated meatsticks as "like moderately" or higher compared to twenty-five percent for stewsticks. Thus, there appears to be potential for commercial manufacture of both products.

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APPENDICES

Appendix A

Sensory Evaluation Forms

Meatsticks and Stewsticks Evaluation

Name ____________________________ Date ___________________

Please evaluate the following samples in the order listed below. Use the numbers from the scale on the right that best describe each sample characteristic

9 Like Extremely
8 Like Very Much
7 Like Moderately
6 Like Slightly
5 Neither Like Nor Dislike
4 Dislike Slightly
3 Dislike Moderately
2 Dislike Very Much
1 Dislike Extremely

Attribute	453	648	035	239	426	775	887	506
Appearance								
Texture								
Flavor								
Overall Acceptability								

Comments:____

____

Fig. A1--Ballot used by consumer panelists.

Meatsticks and Stewsticks Evaluation

Name__________________ Date____________

Please evaluate the meat and stew sticks for the following attributes and feel free to use any number for each attribute described.

1. Major Color
   1 Red 2 Brown 3 Orange

2. Color Intensity
   7 Very intense color
   6
   5 Moderately intense color
   4
   3 Slight intense color
   2
   1 No color

3. Texture
   7 Very firm
   6
   5 Moderately firm
   4
   3 Slightly firm
   2
   1 Not firm

4. Acid Intensity
   7 Very acidic
   6
   5 Moderately acidic
   4
   3 Slightly acidic
   2
   1 Not acidic

5. Spice Intensity
   7 Very spicy
   6
   5 Moderately spicy
   4
   3 Slightly spicy
   2
   1 Not spicy

6. Salt Intensity
   7 Very salty
   6
   5 Moderately salty
   4
   3 Slightly salty
   2
   1 Not salty

7. Hot Flavor Intensity
   7 Very hot
   6
   5 Moderately hot
   4
   3 Slightly hot
   2
   1 Not hot

	Attribute	887	775	426	035	648	506	453	239
1	Major color								
2	Color Intensity								
3	Texture								
4	Acid Intensity								
5	Spice Intensity								
6	Salt Intensity								
7	Hot Flavor Intensity								

Comments:

Fig. A2--Ballot used by trained panelists.

Appendix B

Tables of Analysis of Variance

Table B1--Analysis of variance of consumer panel scores for appearance of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
gender	2	18.73	5.08	< 0.05
Error	1853	3.68		
Total	1855			

Table B2--Analysis of variance of consumer panel scores for texture of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
gender	2	31.71	10.43	< 0.01
Error	1853	3.04		
Total	1855			

Table B3--Analysis of variance of consumer panel scores for flavor of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
gender	2	4.72	1.14	
Error	1853	4.14		
Total	1855			

Table B4--Analysis of variance of consumer panel scores for overall acceptability of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
gender	2	11.26	3.21	< 0.05
Error	1853	3.50		
Total	1855			

Table B5--Analysis of variance of consumer panel scores for appearance of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	17.57		
acid type	1	129.20	13.04	< 0.01
acid level	1	146.00	14.74	< 0.01
stick type	1	271.65	27.43	< 0.01
acid type*acid level	1	17.57	1.77	
acid type*stick type	1	37.29	3.77	
acid level*stick type	1	18.79	1.90	
acid type*acid level*stick type	1	4.05	0.41	
Error	14	9.90		
sampling	1832			
Total	1855			

Table B6--Analysis of variance of consumer panel scores for texture of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	15.59		
acid type	1	13.37	3.37	
acid level	1	52.09	13.11	< 0.01
stick type	1	350.25	88.14	< 0.01
acid type*acid level	1	15.59	3.92	
acid type*stick type	1	3.15	0.79	
stick type	1	4.73	1.19	
acid type*acid level*stick type	1	1.46	0.37	
Error	14	3.97		
sampling	1832			
Total	1855			

Table B7--Analysis of variance of consumer panel scores for flavor intensity of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	4.98		
acid type	1	1.40	0.33	
acid level	1	298.30	69.27	< 0.01
stick type	1	719.70	167.13	< 0.01
acid type*acid level	1	4.98	1.16	
acid type*stick type	1	13.31	3.09	
acid levelstick type	1	2.36	0.55	
acid type*acid level*stick type	1	1.45	0.34	
Error	14	4.31		
sampling	1832			
Total	1855			

Table B8--Analysis of variance of consumer panel scores for overall appearance of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	10.98		
acid type	1	10.11	5.19	< 0.05
acid level	1	238.33	122.29	< 0.01
stick type	1	544.38	279.31	< 0.01
acid type*acid level	1	10.98	5.63	< 0.05
acid type*stick type	1	20.41	10.47	< 0.01
acid level*stick type	1	1.00	0.51	
acid type*acid level*stick type	1	0.10	0.05	
Error	14	5.20		
sampling	1832			
Total	1855			

Table B9--Analysis of variance of trained panel scores for color of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	0.52	0.69	
acid type	1	1.12	1.51	
acid level	1	0.59	0.80	
stick type	1	208.30	280.12	< 0.01
acid type*acid level	1	0.23	0.31	
acid type*stick type	1	3.34	4.49	
acid level*stick type	1	1.33	1.79	
acid type*acid level*stick type	1	0.01	0.01	
Error (a)	14	0.74		
judge	17	1.05	4.15	< 0.01
judge*acid type	17	0.28	1.10	
judge*acid level	17	0.19	0.76	
judge*stick type	17	1.88	7.47	< 0.01
judge*acid type*acid level	17	0.13	0.53	
judge*acid type*stick type	17	0.27	1.09	
judge*acid level*stick type	17	0.28	1.09	
judge*acid type*acid level*stick type	17	0.12	0.46	
Error (b)	272	0.25		
TOTAL	431			

Table B10--Analysis of variance of trained panel scores for color intensity of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	7.31	6.10	<0.05
acid type	1	0.28	0.23	
acid level	1	3.89	3.25	
stick type	1	11.67	9.73	< 0.01
acid type*acid level	1	1.95	1.62	
acid type*stick type	1	0.39	0.33	
acid level*stick type	1	0.06	0.05	
acid type*acid level*stick type	1	0.06	0.05	
Error (a)	14	1.20		
judge	17	1.05	1.28	
judge*acid type	17	0.28	0.34	
judge*acid level	17	0.19	0.23	
judge*stick type	17	1.88	2.30	
judge*acid type*acid level	17	0.13	0.16	
judge*acid type*stick type	17	0.27	0.33	
judge*acid level*stick type	17	0.28	0.34	
judge*acid type*acid level*stick type	17	0.12	0.14	
Error (b)	272	0.82		
TOTAL	431			

Table B11--Analysis of variance of trained panel scores for texture of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	1.27	0.45	
acid type	1	12.00	4.24	
acid level	1	3.00	1.06	
stick type	1	100.10	35.43	< 0.01
acid type*acid level	1	0.59	0.21	
acid type*stick type	1	2.37	0.84	
acid level*stick type	1	6.26	2.21	
acid type*acid level*stick type	1	0.59	0.21	
Error (a)	14	2.83		
judge	17	1.05	1.34	
judge*acid type	17	0.28	0.35	
judge*acid level	17	0.19	0.24	
judge*stick type	17	1.88	2.40	
judge*acid type*acid level	17	0.13	0.17	
judge*acid type*stick type	17	0.27	0.35	
judge*acid level*stick type	17	0.28	0.35	
judge*acid type*acid level*stick type	17	0.12	0.15	
Error (b)	272	0.78		
TOTAL	431			

Table B12--Analysis of variance of trained panel scores for acid intensity of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	1.36	1.85	
acid type	1	13.73	18.64	< 0.01
acid level	1	553.50	751.63	< 0.01
stick type	1	6.02	8.18	< 0.05
acid type*acid level	1	1.23	1.66	
acid type*stick type	1	0.02	0.03	
acid level*stick type	1	12.34	16.75	< 0.01
acid type*acid level*stick type	1	5.56	7.55	< 0.05
Error (a)	14	0.74		
judge	17	1.05	0.75	
judge*acid type	17	0.28	0.20	
judge*acid level	17	0.19	0.14	
judge*stick type	17	1.88	1.36	
judge*acid type*acid level	17	0.13	0.10	
judge*acid type*stick type	17	0.27	0.20	
judge*acid level*stick type	17	0.28	0.20	
judge*acid type*acid level*stick type	17	0.12	0.08	
Error (b)	272	1.39		
TOTAL	431			

Table B13--Analysis of variance of trained panel scores for spice intensity of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	1.41	3.03	
acid type	1	4.90	10.57	< 0.01
acid level	1	7.79	16.81	< 0.01
stick type	1	2.37	5.12	< 0.05
acid type*acid level	1	0.59	1.28	
acid type*stick type	1	0.45	0.98	
acid level*stick type	1	0.23	0.50	
acid type*acid level*stick type	1	1.33	2.88	
Error (a)	14	0.46		
judge	17	1.05	0.87	
judge*acid type	17	0.28	0.23	
judge*acid level	17	0.19	0.16	
judge*stick type	17	1.88	1.56	
judge*acid type*acid level	17	0.13	0.11	
judge*acid type*stick type	17	0.27	0.23	
judge*acid level*stick type	17	0.28	0.23	
judge*acid type*acid level*stick type	17	0.12	0.10	
Error (b)	272	1.21		
TOTAL	431			

Table B14--Analysis of variance of trained panel scores for salt intensity of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	2.96	6.18	<0.05
acid type	1	0.00	0.00	
acid level	1	0.00	0.00	
stick type	1	3.17	6.61	< 0.05
acid type*acid level	1	0.28	0.58	
acid type*stick type	1	0.19	0.39	
acid level*stick type	1	0.00	0.00	
acid type*acid level*stick type	1	0.00	0.00	
Error (a)	14	0.48		
judge	17	1.05	1.67	
judge*acid type	17	0.28	0.44	
judge*acid level	17	0.19	0.30	
judge*stick type	17	1.88	3.01	
judge*acid type*acid level	17	0.13	0.21	
judge*acid type*stick type	17	0.27	0.44	
judge*acid level*stick type	17	0.28	0.44	
judge*acid type*acid level*stick type	17	0.12	0.19	
Error (b)	272	0.63		
TOTAL	431			

Table B15--Analysis of variance of trained panel scores for hot flavor intensity of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
day	2	15.84	5.48	<0.05
acid type	1	1.69	0.58	
acid level	1	2.84	0.98	
stick type	1	38.52	13.32	< 0.01
acid type*acid level	1	3.17	1.10	
acid type*stick type	1	1.02	0.35	
acid level*stick type	1	0.67	0.23	
acid type*acid level*stick type	1	0.39	0.14	
Error (a)	14	2.89		
judge	17	1.05	0.78	
judge*acid type	17	0.28	0.21	
judge*acid level	17	0.19	0.14	
judge*stick type	17	1.88	1.39	
judge*acid type*acid level	17	0.13	0.10	
judge*acid type*stick type	17	0.27	0.20	
judge*acid level*stick type	17	0.28	0.20	
judge*acid type*acid level*stick type	17	0.12	0.09	
Error (b)	272	1.35		
TOTAL	431			

Table B16--Analysis of variance of shear values of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
acid type	1	5.0670	0.84	
acid level	1	10.1250	1.68	
stick type	1	22.6690	3.77	
acid type*acid level	1	11.2810	1.87	
acid type*stick type	1	1.4170	0.24	
acid level*stick type	1	16.8200	2.80	
acid type*acid level*stick type	1	0.6610	0.11	
Error	64	6.0180		
Total	71			

Table B17--Analysis of variance of pH values of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
acid type	1	0.0040	0.98	
acid level	1	4.2721	1037.98	< 0.01
stick type	1	0.0432	10.50	< 0.01
acid type*acid level	1	0.0037	0.89	
acid type*stick type	1	0.0070	1.70	
acid level*stick type	1	0.0660	16.04	< 0.01
acid type*acid level*stick type	1	0.0120	2.92	
Error	40	0.0041		
Total	47			

Table B18--Analysis of variance of a^w values of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
acid type	1	0.0010	2.04	
acid level	1	0.0003	0.53	
stick type	1	0.0311	60.75	< 0.01
acid type*acid level	1	0.0003	0.53	
acid type*stick type	1	0.0000	0.00	
acid level*stick type	1	0.0004	0.80	
acid type*acid level*stick type	1	0.0001	0.29	
Error	40	0.0005		
Total	47			

Table B19--Analysis of variance of moisture content of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
acid type	1	0.0020	2.45	
acid level	1	0.0125	15.39	< 0.01
stick type	1	0.0695	85.84	< 0.01
acid type*acid level	1	0	0	
acid type*stick type	1	0.0000	0.03	
acid level*stick type	1	0.0004	0.44	
acid type*acid level*stick type	1	0.0000	0.01	
Error	58	0.0008		
Total	65			

Table B20--Analysis of variance of ash content of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
acid type	1	0.0000	1.16	
acid level	1	0.0000	0.11	
stick type	1	0.0004	12.05	< 0.01
acid type*acid level	1	0.0000	0.26	
acid type*stick type	1	0.0000	0.76	
acid level*stick type	1	0.0000	0.01	
acid type*acid level*stick type	1	0.0001	3.85	
Error	43	0.0000		
Total	50			

Table B21--Analysis of variance of protein content of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
acid type	1	0.0043	11.37	< 0.01
acid level	1	0.0000	0.09	
stick type	1	0.0496	130.16	< 0.01
acid type*acid level	1	0.0016	4.31	< 0.05
acid type*stick type	1	0.0045	11.81	< 0.01
acid level*stick type	1	0.0061	15.92	< 0.01
acid type*acid level*stick type	1	0.0003	0.85	
Error	56	0.0004		
Total	63			

Table B22--Analysis of variance of fat content of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
acid type	1	0.0090	28.01	< 0.01
acid level	1	0.0011	3.44	
stick type	1	0.0099	30.77	< 0.01
acid type*acid level	1	0.0004	1.16	
acid type*stick type	1	0.0015	4.52	< 0.05
acid level*stick type	1	0.0000	0.04	
acid type*acid level*stick type	1	0.0000	0.01	
Error	58	0.0003		
Total	65			

Table B23--Analysis of variance of carbohydrate content of meatsticks and stewsticks

TREATMENT	DF	MS	F	p
acid type	1	0.0000	0.01	
acid level	1	0.0028	5.99	< 0.05
stick type	1	0.2526	545.67	< 0.01
acid type*acid level	1	0.0006	1.27	
acid type*stick type	1	0.0071	15.32	< 0.01
acid level*stick type	1	0.0012	2.56	
acid type*acid level*stick type	1	0.0011	2.35	
Error	40	0.0005		
Total	47			

Appendix C

Means of Consumer Panel, Trained Panel,

Table C1--Means of chemical and physical measures of meatsticks and stewsticks

Code	pH	Aw	Moisture	Ash	Protein	Fat	Carbohydrate	Shear
LhM-1	5.24	0.94	47.09%	4.92%	27.59%	13.76%	6.64%	7.77
LhM-2	5.00	0.91	42.76%	5.30%	29.66%	17.36%	4.93%	9.32
LhM-3	5.12	0.92	41.30%	7.28%	23.79%	18.14%	9.49%	5.90
LlM-1	4.61	0.91	40.13%	5.54%	29.19%	18.86%	6.28%	11.20
LlM-2	4.54	0.91	40.21%	5.34%	30.25%	16.38%	7.82%	9.63
LlM-3	4.69	0.92	39.94%	5.55%	29.75%	18.09%	6.67%	8.23
LhS-1	5.18	0.83	33.68%	6.33%	26.07%	16.15%	17.76%	13.37
LhS-2	5.19	0.91	39.27%	5.19%	23.69%	14.69%	17.15%	7.20
LhS-3	5.20	0.88	37.82%	6.23%	23.65%	12.68%	19.62%	7.27
LlS-1	4.50	0.86	31.49%	6.27%	25.32%	18.91%	18.00%	9.20
LlS-2	4.43	0.86	35.30%	6.18%	23.30%	16.20%	19.01%	10.80
LlS-3	4.48	0.87	34.20%	6.21%	22.26%	14.61%	22.72%	10.13
ChM-1	5.26	0.91	40.72%	5.95%	33.11%	15.48%	4.73%	10.07
ChM-2	5.13	0.93	46.37%	4.67%	30.62%	15.23%	3.11%	5.63
ChM-3	5.14	0.95	46.53%	4.77%	29.13%	15.00%	4.57%	6.65
ClM-1	4.72	0.91	38.81%	5.88%	34.10%	17.99%	3.21%	9.23
ClM-2	4.54	0.92	41.10%	5.35%	34.46%	15.38%	3.71%	8.60
ClM-3	4.66	0.94	43.22%	5.12%	29.12%	14.54%	8.00%	7.87
ChS-1	5.06	0.83	30.95%	6.77%	27.44%	13.10%	21.75%	9.83
ChS-2	5.19	0.90	40.61%	5.53%	26.06%	12.38%	15.42%	7.90
ChS-3	5.15	0.88	37.17%	6.04%	25.05%	11.32%	20.41%	12.30
ClS-1	4.49	0.84	32.49%	6.21%	22.85%	12.73%	25.72%	10.23
ClS-2	4.53	0.91	37.72%	5.54%	21.31%	12.10%	23.32%	7.20
ClS-3	4.52	0.89	34.83%	5.99%	23.90%	12.97%	22.31%	9.00

C = citric acid, L = lactic acid, h = pH 5.2, l = pH 4.6, M = meatsticks, S = stewsticks,
1 2 3 = day 1, 2 or 3, SHEAR = Warner-Bratzler shear (3/stick)

Table C2--Means of consumer panel scores and trained panel scores of meatsticks and stewsticks

Code	Appearance-C	Texture-C	Flavor-C	Overall-C	Color-T	Intensity-T	Texture-T	Acid-T	Spice-T	Salt-T	Hot-T
ChM-1	6.80	6.37	6.75	6.75	1.28	4.11	5.44	2.83	3.83	2.78	1.94
ChM-2	6.67	6.80	6.71	6.58	1.28	3.78	4.61	2.94	3.83	2.11	2.50
ChM-3	6.57	6.23	6.71	6.51	1.17	4.17	5.44	3.00	4.00	2.44	2.94
ChS-1	4.98	5.06	4.67	4.65	2.17	4.72	4.67	3.17	4.22	2.39	3.11
ChS-2	5.84	5.80	5.32	5.55	2.67	4.22	4.50	3.11	4.00	2.33	3.17
ChS-3	5.75	5.82	5.56	5.57	2.22	4.28	4.39	2.83	4.28	2.22	3.61
ClM-1	6.56	6.53	6.17	6.22	1.44	4.11	5.56	5.22	3.83	2.72	2.44
ClM-2	6.20	6.42	5.87	6.01	1.11	4.17	5.17	5.17	3.61	2.11	3.00
ClM-3	6.52	6.26	5.52	5.71	1.22	3.61	5.00	5.17	3.83	2.33	2.39
ClS-1	5.08	5.18	4.33	4.47	2.33	4.33	4.56	5.56	3.89	2.33	2.28
ClS-2	5.88	5.57	4.71	4.96	2.78	4.33	3.94	5.50	3.94	2.33	3.67
ClS-3	5.49	5.48	4.65	4.82	2.61	4.39	4.28	5.50	3.89	2.11	3.56
LhM-1	6.80	6.53	6.53	6.53	1.22	4.72	4.72	2.61	3.56	2.50	2.00
LhM-2	6.36	6.25	6.47	6.38	1.17	4.28	5.33	3.22	4.06	2.61	3.33
LhM-3	5.97	6.38	6.49	6.25	1.28	3.56	4.89	2.83	4.17	2.17	2.67
LhS-1	5.20	5.61	5.11	5.19	2.28	4.72	4.89	2.50	3.78	2.39	2.67
LhS-2	5.83	5.97	5.49	5.62	2.94	4.11	3.67	2.50	3.72	2.06	3.78
LhS-3	5.77	5.69	5.62	5.64	2.78	4.39	4.00	2.72	4.06	2.22	3.11
LlM-1	4.43	5.70	5.54	5.28	1.11	4.11	4.83	4.50	3.50	2.61	2.39
LlM-2	5.45	6.09	5.76	5.80	1.06	3.94	5.11	4.56	3.44	2.33	2.78
LlM-3	5.44	6.16	5.57	5.39	1.22	3.39	5.22	4.39	3.33	2.50	1.89
LlS-1	4.75	4.82	4.52	4.54	3.00	4.44	3.11	4.89	3.44	2.39	2.94
LlS-2	4.87	5.42	4.67	4.83	2.78	3.94	3.94	5.78	3.61	2.11	2.83
LlS-3	5.14	4.87	4.51	4.57	2.67	4.00	3.83	5.22	3.94	2.28	2.72

C = citric acid, L = lactic acid, h = pH 5.2, l = pH 4.6, M = meatsticks, S= Stewsticks,
1, 2, 3 = day 1, 2 or 3, -C = consumer panel, -T = trained panel.