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9. ABSTRACT

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EFFECT OF SODIUM ALKALIS AND SALTS ON pH AND FLAVOR OF SOYMILK

ABSTRACT

Sodium hydroxide, sodium carbonate and sodium bicarbonate were added to soymilk made by the "boiling-water grind" process. NaOH caused a rapid increase in pH; Na_2CO_3 a moderate increase and $NaHCO_3$ a slight increase in pH. After sterilization in bottles the pH of the soymilks containing alkali decreased, with the decrease least with the $NaHCO_3$ treatment and greatest with the NaOH treatment. The pH of the untreated soymilk did not change during sterilization. An experienced taste panel showed greater acceptability for soymilk adjusted to pH 7.0–7.5 with NaOH but noted a soapy flavor and gave lower scores for milks with pH greater than 7.5. Soymilks adjusted to pH 7.0–7.5 with Na_2CO_3 or $NaHCO_3$ were disliked by the panel. We theorized that the improved acceptability with NaOH could be due to the increase in sodium ion concentration rather than the change in pH. Soymilks prepared with Na_2CO_3, $NaHCO_3$, $NaNO_3$, Na_2SO_4, Na acetate and Na citrate additions at the same levels as that amount of NaOH required to raise the pH to 7.2 were given approximately the same scores by the panel as the NaOH-treated sample even when the pH was not in the range of 7.0–7.5. This evidence supports the theory that the sodium ion concentration is the effective mechanism in improving the flavor of soymilk rather than the change in pH.

INTRODUCTION

SOYMILK is the aqueous extract of dry, mature soybeans. It is made by grinding the beans with water and filtering off the insoluble residue. The product is a milky-looking liquid that usually contains about 80% of the protein and about 60% of the fat of the whole bean. The basic process has been known in the Orient for about two milleniums.

Since soymilk is relatively easy to prepare, and has a protein content and quality that approximates that of cow's milk, it has been the subject of considerable interest to those organizations that wish to make a low-cost protein beverage available to those areas of the world where protein malnutrition is a problem. Unfortunately soymilk has a strong, characteristic "beany" flavor that makes it unacceptable to non-Oriental populations. The poor acceptability of soymilk has thwarted efforts to introduce this nutritionally valuable beverage to low-income populations.

Wilkens et al. (1967) found that the off-flavors of soymilk were not present in the dry soybean but were formed during the processing and that grinding the beans in boiling water prevented the formation of the strong beany flavors. They attributed this result to the rapid heat-inactivation of the lipoxidase in the soybean precluding its attacking the unsaturated fatty acid chains in the soybean oil to form a number of lower molecular weight compounds that have objectionable flavor impact. Many of the volatiles found in soymilk prepared by the conventional grinding at ambient temperatures have been isolated and identified (Mattick and Hand, 1969; Wilkens and Lin, 1970).

Soymilk made correctly by the boiling-water grind method is free of the strong beany flavors; it has a faint, pleasant cereal-like flavor. Since the objectionable flavor can be eliminated it seems that soymilk should be reconsidered as a low-cost protein beverage for developing countries. Steinkraus et al. (1968) and Bourne (1970) extended the new process to a pilot plant operation in the Philippines and studied factors that would affect the widespread acceptance of soymilk in a tropical country.

There is a common belief that the use of a mild alkali such as sodium bicarbonate improves the eating quality of cooked common dry beans, although it is not always clear whether the improvement is in the flavor, the texture, or both (e.g., Buckeye Cookery, 1883; Snyder, 1936). The use of alkali seems to be partly effective in improving the organoleptic quality of conventional cold-grind soymilk because there are frequent references to the use of sodium bicarbonate (baking soda) in recipe books that describe how to make soymilk (e.g., Monahan and Pope, 1915).

Badenhop and Hackler (1970) studied the effects of soaking soybeans in sodium hydroxide solutions on various aspects of soymilk quality using the boiling-water grind technique to prepare the soymilk. They found that as the pH of the soymilk increased from 6.55 (water soak) to 9.18 (soak in 0.097N NaOH) the protein efficiency ratio (PER) decreased from 2.41 to 1.70, niacin increased from 3.96 mg/100g at pH 6.55 to 4.98 at pH 8.04 and declined to 3.69 at pH 9.18. They also noted that a taste panel composed of Americans preferred the flavor of soymilk of pH 7.37 (soybeans soaked in 0.048N NaOH) over samples with higher or lower pH.

Steinkraus et al. (1968) studied some effects of alkali on soymilks in the Philippines using a Filipino taste panel. They found with soymilk prepared from Taichung variety of soybeans the panel was unanimous in preferring milk made from beans that had been soaked in 0.1% NaOH to those soaked in water. However, with the Hsieh-Hsieh variety the panel was evenly divided in preference between soymilks made from water-soaked and 0.1% NaOH-soaked beans. They further noted that the taste panel was unanimous in preferring soymilk containing 0.15% $NaHCO_3$ to those containing no sodium bicarbonate. In a subsequent study, Puertollano et al. (1970) examined the effect of changes in formulation of soymilk on its acceptability by Filipino school children. They reported that soaking soybeans in 0.1% NaOH prior to the boiling water grind process gave a soymilk with a slight, but not significantly higher acceptability over the soymilk that had been prepared from beans soaked in water only. They also noted that adult Filipinos noted a "soapy" flavor in soymilk made from beans soaked in 0.1% NaOH and concluded that the questions of alkali additions and flavor of soymilks required further study.

Khaleque et al. (1970) soaked soybeans in solutions of Na_2CO_3, $NaHCO_3$, NaOH, Na_2SO_3, Na_2HPO_4, Na_3PO_4, NaCl and a mixture of $Na_2S_2O_5$ plus NH_4OH in concentrations of 0.2–0.8M and then made soymilk from the soaked beans. They concluded that soymilk made from beans that had been soaked in 0.4M Na_2CO_3 had the lowest level of beany flavor. These authors questioned the lipoxidase theory of beany flavor formation because all their soymilks had some beany flavor. However, it seems that they did not achieve a temperature sufficiently high enough to inactivate the lipoxidase. They soaked 100g dry soybeans in solution, removed the skins, and then ground the beans in a blender with 250 ml of boiling water. After grinding, the volume was made to 700 ml. Since the soaked weight of the beans would have been about 200g, the mixture of beans at ambient temperature and 250 ml of boiling water would have a temperature considerably below the minimum of 80°C required to prevent beany flavor formation. A strong beany flavor would have developed in the grinding operation under these conditions, and subsequent heating and dilution would not remove it completely. This is confirmed by their results; they found that all samples had the beany flavor.

Koski and Smith (1972) describe a process for making soymilk in which the soy ingredient was defatted flakes. The flakes are extracted in a sodium hydroxide solution with a pH of about 12, then the solution is brought back to a pH of 7–8 by adding an acid such as citric acid. The use of alkali in this case is presumably to assist in solubilizing the protein rather than to produce a bland flavor.

This experiment reports on studies on the effect of alkali additions to the bland-flavored soymilk made by the boiling-water grind process, using an experienced taste panel of eight young adult Filipinos to evaluate the products.

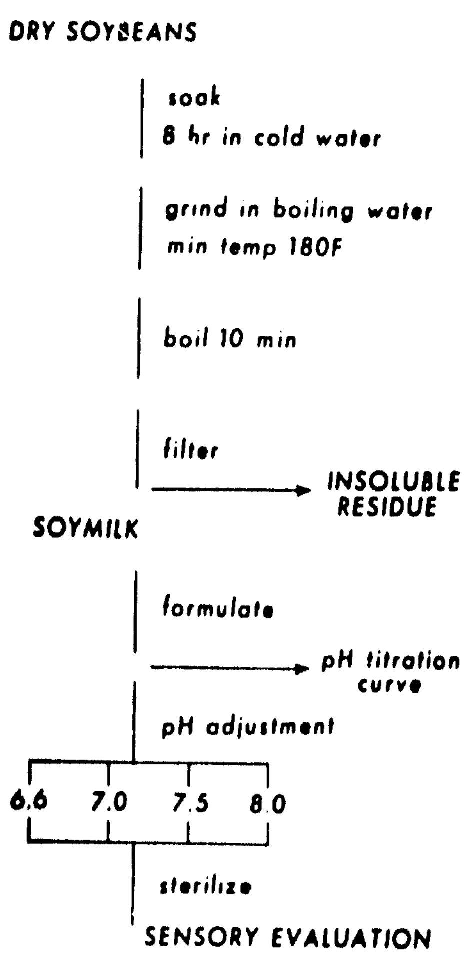

Fig. 1–Schematic representation of experimental procedure.

EXPERIMENTAL

Preparation of soymilk

Soybeans of the Biyeloxi 256 variety, obtained from the Philippine Bureau of Plant Industry were soaked for approximately 8 hr in plain water at ambient temperature, then drained, washed in fresh water and drained again. A Rietz Disintegrater fitted with a stainless steel screen with 0.032 in. perforations was preheated by passing a quantity of boiling water through it. Small quantities of soaked beans and boiling water were metered into the grinder at frequent intervals using almost all of the required water. A food-grade silicone antifoam spray was used to control foaming. Great care was taken to maintain the temperature of the bean-water slurry above 80°C at all times during the grinding operation because previous experience had shown that if the temperature falls below 80°C for even a short period of time some beany flavor will be present. The slurry was then boiled with constant stirring in a steam-jacketed kettle for 10 min, after which the total weight was adjusted to give a bean:water ratio of 1:10 by adding that small amount of water necessary to give the correct final weight (1 kg of dry beans yields 11 kg of slurry). The resulting slurry was filtered through a plate-and-frame filter press. The insoluble residue was discarded and the soymilk was formulated by adding 7% sugar and 20 ppm of a commercial essence of a vanilla. This was the basic product that was used in all subsequent tests.

pH titration curve

300 ml samples of soymilk were titrated with 1.25N solutions of NaOH, $NaHCO_3$ and Na_2CO_3, using a glass electrode pH meter. The sample was stirred continuously be means of a magnetic stirrer during the titration.

Effect of alkali and heat

A row of 600 ml beakers was set up with 300 ml of soymilk in each beaker. A calculated amount of alkali (based on the pH titration curve) was added to each beaker to raise the pH by approximately 0.2 units over the preceding beaker. Sodium hydroxide and sodium carbonate were added in the form of 1.25N solutions. Sodium bicarbonate was added as a dry powder because the volume of solution needed to achieve the desired pH level would have caused excessive dilution of the soymilk. The pH of each sample was measured after the alkali addition. Approximately 210 ml of each sample were transferred to a 7-fl oz bottle, sealed with a crown seal, and sterilized in steam in a retort using a process of 12 min at 121.1°C (250°F). The pH of the sterilized products was measured the following day.

Flavor study

Based on the results of the work mentioned above, calculated amounts of the three alkalis were added to soymilk to give pH values of 7.0, 7.5 and 8.0 after sterilization in the bottle. The actual pH was measured just before presentation to the panel. The samples were stored for approximately 2 wk at ambient temperature before submission to the panel. Figure 1 is a schematic representation of the preparation method.

The panelists were mostly young adult Filipinos with approximately equal numbers of each sex. The members of the panel had had considerable previous experience with tasting soymilks. A 9-point hedonic scale was used; a score of 1 = dislike extremely, a score of 5 = neither like nor dislike, and a score of 9 = like extremely.

When the results with the three sodium alkalis suggested that pH was not the cause of flavor improvement, we studied the effect of adding sodium salts (nitrate, sulfate, acetate and citrate) at levels that would give sodium ion concentrations of 1.50, 2.62 and 3.75 milliequivalents in the soymilk. Sodium chloride was not used because it was found that the salty flavor of the chloride ion would mask any effects of the sodium ion.

RESULTS & DISCUSSION

FIGURE 2 shows the pH titration curves for the three alkalis. As would be expected from the relative strengths of the alkalis, NaOH gave the most rapid increase in pH, followed by Na_2CO_3 and $NaHCO_3$ in that order. The addition of only 3.5 ml of the NaOH solution raised the pH of the soymilk to 10. Five ml of the Na_2CO_3 solution were required to raise the pH to about 9.0 after which further additions gave only a slight increase in pH. The highest pH obtainable with Na_2CO_3 addition was about 9.5. The $NaHCO_3$ raised the pH very slowly; about 30 ml of solution were required to raise the pH to 8.0

and further additions had negligible effects on the pH. A mixture of 100 ml of 1.25N $NaHCO_3$ and 300 ml of soymilk showed a pH of 8.2.

Figures 3, 4 and 5 show the effect of the combination of alkali addition and a heat process of 12 min in live steam at 121.1°C (250°F). The pH of the alkali-treated soymilks fell as a result of the heat treatment but there was no change in pH as a result of the heat treatment of the alkali-free soymilks. For NaOH the pH decrease became larger as the amount of added NaOH increased up to a maximum of about 2.5 ml of NaOH solution when the pH difference was 1.0 pH unit. The pH difference remained constant at 1.0 unit with additions greater than 2.5 ml of NaOH solution. A similar effect was found with the addition of Na_2CO_3; the pH after sterilization was lower than before sterilization, and the increase became greater as the amount of added Na_2CO_3 increased to about 4.5 ml of the solution when the pH difference was 0.9 unit. With further additions of Na_2CO_3, the pH difference remained at 0.9 pH unit. The $NaHCO_3$-treated soymilks showed a small drop in pH after sterilization. The addition of 5 ml of $NaHCO_3$ solution gave a pH difference of 0.16 unit, and the difference remained at this level with all greater additions. It is likely that the reactivity of the alkali on some constituent of the soymilk is responsible for this type of behavior. For example, at pH 7.5 before heat sterilization the following decreases were observed after sterilization: for NaOH, a fall of 0.45 to give a pH of 7.05; for Na_2CO_3, a fall of 0.40 to give a final pH of 7.10; and for $NaHCO_3$, a fall of 0.15 to give a final pH of 7.35. Some representative pH difference figures are shown in Table 1.

The results of the acceptability score vs pH after sterilization are shown in Figure 6. For NaOH-treated milks there was an increase in the acceptability score at pH 7.0 and 7.5 over the untreated soymilk but this was followed by a marked decrease in acceptability at pH 8.0. For Na_2CO_3-treated soymilks the acceptability decreased with every increase in pH; there was no initial increase in acceptability similar to that shown by the NaOH. The $NaHCO_3$-treated soymilk showed no initial increase in acceptability; the acceptability decreased and at a much faster rate than for the Na_2CO_3 treatments. The panelists noted that flavors described as "bitter," "soapy" and "sticky after-taste" were present in the soymilks at the higher pH values. Some curdling of the soymilk was observed in the sample that had its pH raised to 7.5 by the addition of $NaHCO_3$

The data in Figure 6 could lead to the conclusion that Na_2CO_3 and $NaHCO_3$ are completely unsuited for flavor improvement of soymilk. It will now be shown that such a conclusion is both superficial and incorrect.

If the acceptability of soymilk were a function of pH, then the flavor score should be the same regardless of which alkali was used to adjust the pH. The evidence in Figure 6 leads to the conclusion that the flavor acceptability of soymilk is not

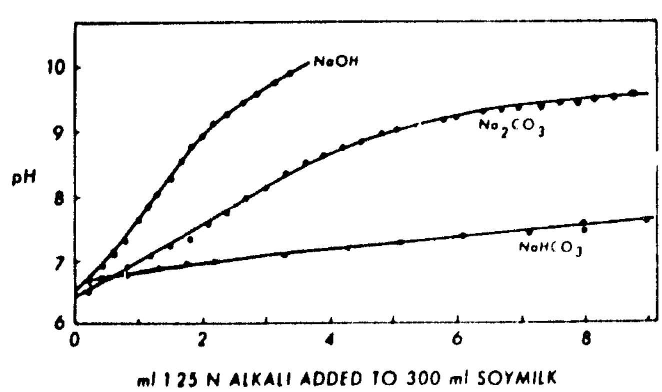

Fig. 2–pH titration curves for three alkalis and soymilk.

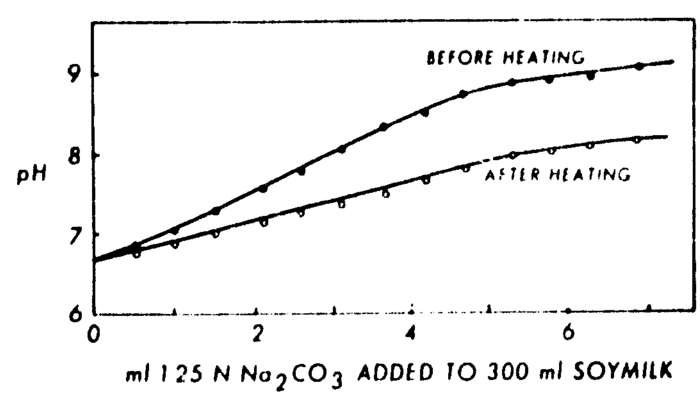

Fig. 4–Effect of heat processing on pH values of Na_2CO_3-treated soymilk.

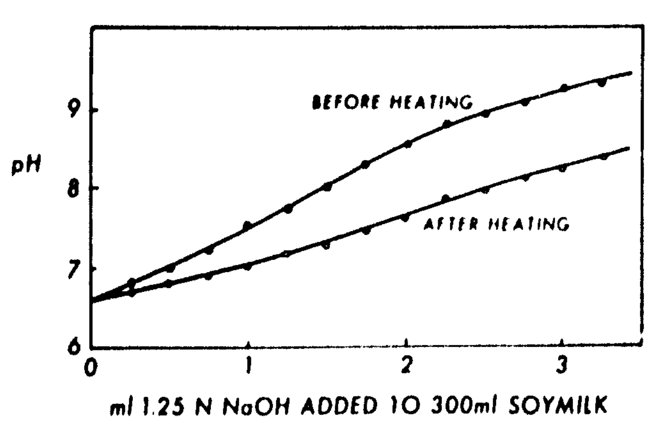

Fig. 3–Effect of heat processing on pH values of NaOH-treated soymilk.

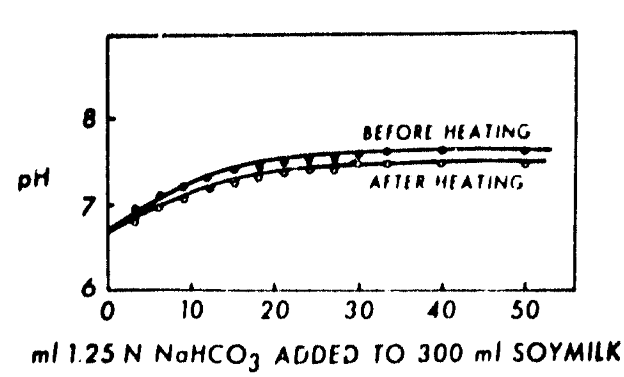

Fig. 5–Effect of heat processing on pH values of $NaHCO_3$-treated soymilk.

related directly to the pH since at each pH there are widely different acceptability scores, depending on which particular alkali was used to adjust the pH.

A question then arises as to the factor responsible for the observed changes in flavor of soymilk as the result of alkali additions. One significant factor is the amount of each alkali required to achieve a given pH. It requires 1.0 ml of NaOH, 1.8 ml of Na_2CO_3, and 7 ml of $NaHCO_3$ solutions (1.25N) to raise the pH of 300 ml of soymilk to pH 7.0 after sterilization. We hypothesized that the sodium ion concentration could be the key factor in these flavor studies. The added sodium ion concentrations from the NaOH-treated soymilks of pH 7.0, 7.5 and 8.0 are respectively 1.50, 2.62 and 3.65 milliequivalents; therefore, we made a new series of alkali-treated soymilks in which 1.50, 2.62 and 3.65 milliequivalents of sodium ion were added to soymilks, with the sodium being provided respectively by NaOH, Na_2CO_3 and $NaHCO_3$. An additional series of experiments was run in which the same levels of sodium ion were added to the soymilk with the sodium supplied by four salts: $NaNO_3$, Na_2SO_4, Na acetate and Na citrate.

The results for the addition of three alkalis at equal sodium ion concentrations are shown in Figure 7. The striking feature here is the similarity in acceptability scores for all alkalis. In each case there is an increase in acceptability at the 1.50 and 2.62 milliequivalent sodium ion levels, followed by a decrease at the 3.65 milliequivalent level. This evidence supports the hypothesis that it is the sodium ion concentration that affects the flavor of soymilk rather than the pH.

Figure 8 shows the effect on acceptability of the same three levels of sodium ion concentration in soymilk with the sodium supplied by four sodium salts. The sodium citrate and sodium sulfate gave curves that are similar to those obtained with the alkalis. The nitrate and acetate salts appeared to have no effect on the acceptability scores at the levels tested.

An analysis of variance of the pooled data shown in Figures 7 and 8 shows that the differences in acceptability between sodium ion concentrations is highly significant (1% level on the F-test), while the differences between sodium compounds is not significant.

This evidence is interpreted as an indication that the sodium ion is the principal causative factor in the effects of sodium alkalis or sodium salts on the flavor of the bland-tasting soymilks that are made by correctly using the boiling-water grind method of preparation. Although not conclusive, it seems probable that the anion associated with the sodium ion may have a secondary effect. It should be noted that in the case of the alkalis the flavor improvement decreased in a reverse sequence to the alkali strength. The invarying acceptability of the nitrate and acetate with change in concentration is unexplained. The higher score for the sodium citrate, although not significant in this experiment, suggests that the citrate ion may exert an improvement in the flavor in addition to the improvement given by the sodium ion. Additional

Table 1—Effect of heat and alkali on pH of soymilk

pH before heating	pH after heating		
	NaOH	Na_2CO_3	$NaHCO_3$
6.60	6.60	6.60	6.60
7.00	6.80	6.82	6.84
7.50	7.05	7.10	7.35
8.00	7.25	7.35	–
8.50	7.60	7.60	–
9.00	8.00	8.10	–
9.50	8.50	–	–

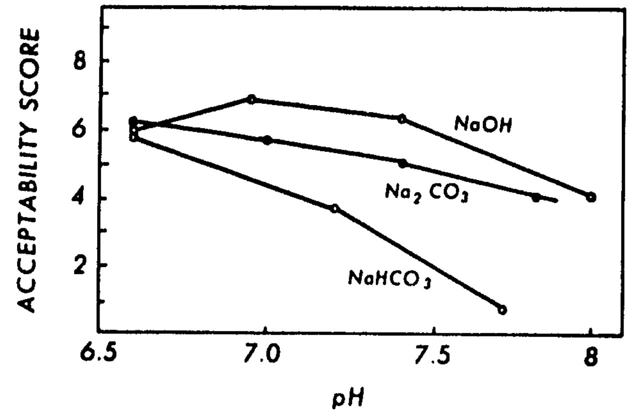

Fig. 6—Acceptability scores and pH values of soymilks treated with NaOH, Na_2CO_3 and $NaHCO_3$.

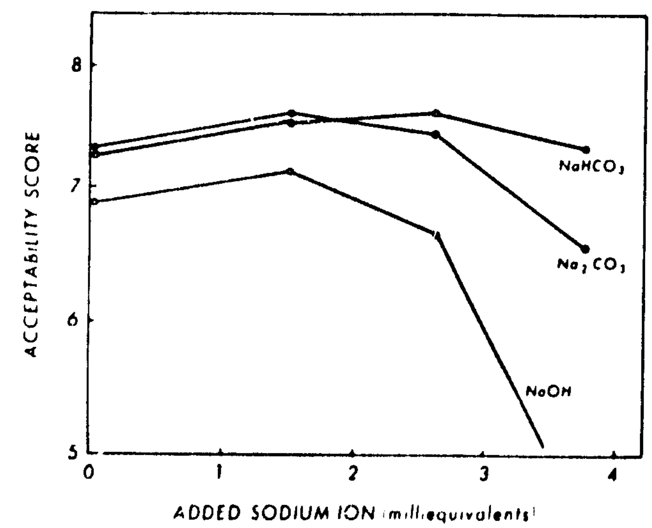

Fig. 7—Acceptability scores and added sodium ion concentration of soymilks treated with NaOH, Na_2CO_3 and $NaHCO_3$ (the final point for the NaOH curve lies outside the graph)

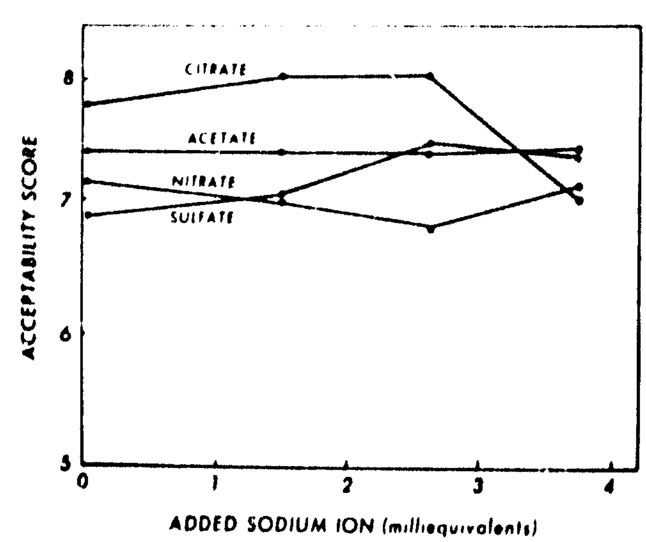

Fig. 8—Acceptability scores and added sodium ion concentration of soymilks treated with $NaNO_3$, Na_2SO_4, Na citrate and Na acetate.

studies are needed to determine the cause of the anomalous behavior of the nitrate and acetate ions, and whether the effect of the citrate ion is additive or synergistic to the sodium ion.

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