To the Graduate Council:

I am submitting herewith a thesis written by Catherine Bomoh Ebah entitled "Development of Yogurt with Sweet Potato as an Ingredient." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

J. L. Collins, Major Professor

We have read this thesis
and recommend its acceptance:

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DEVELOPMENT OF YOGURT WITH SWEET POTATO AS AN INGREDIENT

A Thesis

Presented for the

Master of Science

Degree

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CATHERINE BOMOH EBAH

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DEDICATION

The author wishes to dedicate this work to her fiancé, Djedji Anthony Guy for his love, encouragement, unending patience, faith, understanding, and support in the decision she was making in her difficult times.

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ABSTRACT

The objectives of this study were to establish critical parameters in the processing of yogurt with sweet potato as an ingredient and to determine the effect of sweet potato on sensory, physical, chemical, and nutritional attributes of the yogurt.

Sweet potato level, sugar level, and incubation time had a significant effect on the production of lactic acid in the yogurt. When the percentage of sugar was increased at a given level of sweet potato and period of incubation, acidity production in the yogurt was relatively low. An increased in level of sweet potato caused a lowering of acidity for all levels of sugar at a given period of incubation. Percentage of sweet potato and sugar had an inhibitory effect on the activity of the starter culture. The predicted periods of times necessary to reach 0.85% titratable acidity in yogurt with 5% sugar and with 12, 14, 16, and 18% sweet potato were 6.25, 6.42, 6.50, and 7.25 hours, respectively.

The amount of gelatin had a significant effect on firmness of the yogurt, but sweet potato had no effect. As gelatin was increased, firmness of the yogurt was increased until the gelatin content was increased to 3 g per 500 g of yogurt.

The expert panel found that amount of gelatin and percentage of sweet potato had no effect on the yogurt

attributes of flavor, body and texture, and appearance and color. Panelists scored the samples significantly different for each of the attributes.

From the hedonic panel, gender of the panelists, the type of yogurt preferred by the panelists, the frequency of buying yogurt by the panelists and the willingness to buy the sweet potato yogurt if made commercially available had significant effects on the scores given by the panel. Panelist preferred yogurt of 16 and 18% sweet potato over the yogurt with 14% sweet potato.

As level of sweet potato was increased, the percnetages of moisture and fat were decreased and the percentage of carbohydrate was increased. At 14% sweet potato, yogurt had 81.3% moisture, 8.5% gat, and 66.3% carbohydrate. At 18% sweet potato, yogurt had 79.7% moisture, 4.9% fat, and 69.8% carbohydrate (DWB). Sweet potato contributed dietary fiber to the yogurt. Level of sweet ptoato did not affect the percentages of protein (mean 19.0%), ash (mean 3.9%), and total dietary fiber (mean 2.43%) (DWB). Caloric content was decreased as the level of sweet potato was increased. The calculated values indicated that yogurt with 14% sweet potato had 1,726 kjoules energy, and yogurt with 18% sweet potato had 1,651 kjoules energy (DWB).

Percentage of sweet potato affected the level of vitamin C and pro-vitamin A of the yogurt. As percentage of sweet potato was increased, the vitamin contents were increased to 0.41 mg for vitamin C and to 1,252 retinol

equivalents of vitamin A per 100 g sample (DWB). Level of sweet potato did affect the level of riboflavin (mean 0.41 mg) and niacin (mean 0.62 mg) per 100 g sample (DWB). However, the vitamin level of the experimental samples was higher than that for yogurt reported in the literature, except for vitamin C.

As percentage of sweet potato was increased, the amounts of calcium and zinc in the yogurt were decreased. The levels of six other minerals were not affected by level of sweet potato.

Percentage of sweet potato affected the levels of fructose, glucose, sucrose, and lactose of the yogurt but did not affect the level of maltose.

Levels of sweet potato and sugar affected the Hunter color, L, "a" and "b", values of the yogurt. Time of incubation had only an effect on L and "b" values. As level of sweet potato was increased, the yogurt developed a darker and more red and yellow color. The yogurt with the higher sugar level was darker, less red and more yellow. As time of incubation was increased, the yogurt became lighter, less red, and more yellow.

During fermentation, the bacterial culture increased at approximately 0.44 log CFU/g each hour.

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CHAPTER I

INTRODUCTION

The per capita consumption of the sweet potato root in the United States has declined from 13.3 kg in 1919 to 1.9 kg in 1983 (Anonymous, 1984). The decline has inspired researchers to develop products of sweet potato which will be beneficial to producers and consumers. These new products should meet the acceptability and nutritional requirements of potential consumers.

Currently, total consumption of dairy products is declining. In 1950, Americans consumed a mean 174.2 kg of dairy products, while in 1983 each American consumed only 139.3 kg (FDA, 1985). The decrease in consumption is a result of the concern regarding health risks and diets, relating to the fact that many dairy products are high in fat content. In 1983, a survey by the United States Department of Agriculture showed that 3 of 5 households made dietary changes for reasons of health and nutrition. The survey also revealed that weight control was the leading reason for the decrease in dairy product consumption. Even though consumption of dairy products has declined over the past 30 years, this food group still accounts for about 20 percent of the food consumed by the average American. Furthermore, increases have occurred in the consumption of

low fat dairy products such as low fat milk, currently leading in sales, and yogurt, second in sales. Yogurt consumption increased from 0.05 kg per person in 1955 to 1.44 kg per person in 1983, according to statistics of Food and Drug Administration reports. Since the amount of yogurt being sold in the United State has increased markedly during the past several years and since the per capital consumption of the orange flesh sweet potato has continued to decline, one possible method of increasing consumption of this vegetable is to use it as an ingredient in an existing food product that is increasing in consumption. Yogurt may be one compatible product for such use of sweet potato.

The orange flesh sweet potato is an excellent source of certain food nutrients, including provitamin A (Picha, 1985b) and vitamin C (Toma and Tabekhia, 1979). It also provides an appreciable amount of riboflavin, niacin, pantothenic acid (Crosby, 1964; Edmond and Ammerman, 1971), thiamine, calcium, and iron (Elkins, 1979; Fitzgerald, 1976). The sweet potato should provide certain other nutrients not present in yogurt, including dietary fiber. Preliminary investigations indicated that yogurt with added sweet potato possessed excellent culinary attributes.

The objectives of this experiment were first to establish critical parameters in the processing of yogurt with sweet potato as an ingredient; and second to determine the effect of sweet potato on sensory, physical, chemical, and nutritional attributes of yogurt.

CHAPTER II

REVIEW OF LITERATURE

A. Classification of Yogurt

The word "yogurt" originated from the turkish word 'jugurt.' This product is known by different names in different countries. It is a traditional food in the Balkan and the Middle East countries.

A review of Tamine and Deeth (1980) reported that yogurts are classified according to their chemical composition, method of manufacture, flavor, and the nature of post-incubation. In many countries standards have been proposed for the chemical composition of yogurt. The proposed standards are based on three levels of fat: low, intermediate, and high (FAO/WHO, 1973). The use of such standards for classification is considered necessary to allow consumers to choose yogurt of a particular caloric content.

There are two important types of yogurt based on the methods of manufacture and the physical structure of the coagulum. They are the set and the stirred types. The set type is yogurt that has been fermented in the retail container and consists of continuous semi-solid mass of product. The stirred type is formed in bulk and the gel structure is broken before it is cooled and packaged.

Flavoring is also a method to differentiate many types of yogurt. Flavored yogurt can be divided into three classes: plain, fruit, and flavored. Plain or natural yogurt has a sharp acid flavor which is often covered by addition of sugar. The fruit type is made by adding fruit to the product in the form of preserves, puree, or jam. When sugar and other sweetening agents, synthetic flavoring, and coloring are added to the natural yogurt, it is referred to as flavored yogurt.

Lesser known types of yogurt exist also. Concentrated and condensed yogurt contains approximately 24% total solids with different rheological properties compared to regular yogurt. Frozen yogurt, soft or hard, has a physical structure similar to ice cream but a chemical composition similar to yogurt. Frozen yogurt requires high percentages of sugar and stabilizers. Dried yogurt is made by sun drying, spray-drying, or freeze-drying. Drying causes some loss of flavor compounds and destroys the starter bacteria.

The caloric content of yogurt varies depending on the type. Plain yogurt has approximately 250-335 kjoules/100 g. When fruit is added, the caloric content is raised to approximately 420 kjoules/100g. This high caloric level can be reduced considerably by adding stabilizers and thickening agents as ingredients to boost the consistency. Tamime and Grabs (1979) reported that a typical low calorie yogurt contained about 9% milk solids-not-fat, 1% fat, and 0.5 -

1.0% stabilizer (carrageenan) - gelatin mixture (1:1;w/w) which can be used to reduce the caloric value to approximately 170 kjoules/100g. Recently, the enzyme B-D-galactosidase has been used in yogurt manufacture to produce a low-lactose yogurt. The enzyme hydrolyzes lactose and produces a sweeter product without addition of sugar.

Obviously, yogurt of the different types differ in chemical composition, microbiological content (viable or inactive starter culture), biochemical characteristics, and organoleptic properties. Therefore, it is very difficult to find a common definition for yogurt covering all these types. For this reason yogurts are categorized according to some basic properties. The most suitable classification is based on physical properties of this product. These different physical states indicate the product types: viscous, liquid yogurt; semi-solid, condensed yogurt; solid, soft or hard frozen yogurt; and powdered yogurt.

B. Nutritional Value and Therapeutic Effect of Yogurt

For years, the nutritive and health values of fermented dairy products have been regarded only as subjects based on folklore, lacking scientific support for such claims (Speck and Katz, 1980). According to a review by Deeth and Tamime (1981), Metchnikoff at the beginning of this century attributed the longevity of Bulgarians and their good health to consumption of large quantities of yogurt. He also

believed that yogurt was an effective tool to cure a range of organic illnesses (dryness of skin to atherosclerosis). The purported claims for beneficial effects of fermented dairy products have prompted researchers to attempt to verify the claims. More recently, many studies have been conducted to determine the benefits of food containing lactic acid bacteria when consumed by humans. The subject of debate today is whether fermentative bacteria cause any significant compositional changes in fermented dairy products with respect to nutrients. The major change in dairy products resulting from fermentation is the production of lactic acid from lactose (Deeth and Tamime, 1981). Acid production contributes to flavor and inhibits growth of undesirable microorganisms in the finished product. Furthermore, it has been suggested that lactic acid improves the digestibility of casein and aids in retention of calcium in the intestine (Tamime and Deeth, 1980). According to Tamime (1977), lactose in yogurt is more digestible than that of milk. The efficient digestibility of lactose in rats has been attributed to their high intestinal lactase activity (Goodenough and Kelyn, 1976). Lactase released from lysed starter cells in the intestinal tract enables lactose intolerant people to consume fermented dairy products without any subsequent ill effects (Kilara and Shahani, 1976; Speck and Katz, 1980). Lactic acid bacteria cause some small degree of proteolysis in fermented dairy

products, leading to changes in physical structure, production of flavor compounds, and improvement of protein digestibility (Breslaw and Kleyn, 1973, Tamime and Deeth, 1980). On the other hand, the contribution of cellular proteins by starter bacteria to the overall nutrient profile of the finished product should not be overlooked (Shahani and Chandan, 1979).

The extent of fat alteration in fermented dairy products has been debated in the literature. Alm (1982) reported that insignificant changes occurred in the composition of fat due to fermentation, but Formisano et al. (1975) found that such changes do occur and can be significant.

Conflicting reports exist about the vitamin content of fermented dairy products. Studies show that some starter bacteria require certain vitamins for normal growth during the fermentation process while other starter bacteria are capable of synthesizing B-complex vitamins such as folic acid and niacin (Deeth and Tamime, 1981). The extent of biosynthesis and utilization of vitamins by starter bacteria is dependent on the strain used, the quantity of inoculum, and the fermentative conditions (Shahani et al., 1974).

Antimicrobial activity, hypocholestermic effect, antitumor, and antibiotic properties are a few of the many beneficial therapeutic effects attributed to fermented dairy products.

C. Effect of Fermentation in Yogurt Manufacture

Effect of fermentation on protein digestibility and amino acid composition

Lactic acid bacteria are usually considered weakly proteolytic, but they cause a significant degree of proteolysis in many fermented dairy products, including yogurt. Proteolysis leads to changes in physical structure of the product and contributes to production of flavor compounds (Tamime and Deeth, 1980). Of twelve strains of lactic bacteria studied for proteolytic activity in a medium containing 1% casein, Streptococcus lactis and Streptococcus diacetilactis were found to exhibit the highest proteolytic activity. Some species of Streptococcus and Leuconostoc bacteria preferentially attack B-casein. Simultaneously, the alpha and kappa-casein fractions were weakly hydrolyzed.

The biological value of protein in fermented dairy products is assumed to be superior to that in milk, due to partial hydrolysis of protein and conversion of lactose to lactic acid. Many authors found yogurt to be more digestible than milk. Breslaw and Kleyn (1973) showed that there is a decrease in the particle size of casein and an increase in the amount of soluble protein, no increase in protein nitrogen, and an increase in free amino acids during yogurt processing. From another study these authors

concluded that yogurt protein was twice as digestible as milk protein because it takes only 3 hours for yogurt to reach more than 70% digestion compared to 6 hours for milk. Davis and Latto (1957) observed that the casein particles of ingested fermented milk were much smaller than those in native milk. This finding led the authors to speculate that the more rapid rate of digestion was due to increased surface area available for digestive enzymatic attack. Rasic and Panic (1963) showed that when yogurt is made from milk of different species of animals the respective digestibility factors were higher for yogurt than for milk. They indicated that goat's and sheep's milk had the highest digestibilities. The increased digestibility in yogurt protein compared to that of milk is related to many factors. A review by Deeth and Tamime (1981) cited research that indicated the increased digestibility of yogurt protein compared to that of milk was attributed to the softer curd. Curd modification was due to the high heat treatment used, the smaller casein curd and higher acidity, and the increase in enzymes of the digestive tract when stimulated by the curd particles in contact with the salivary glands. They also mentioned that this increased digestibility was due to the increased peptide and free amino acid contents developed by heat treatment applied in the processing and proteolysis activities by the yogurt bacteria. A review by Tamime and Deeth (1980) reported that of the two yogurt bacteria L.

bulgaricus is the more proteolytic and has the ability to hydrolyze casein to a greater extent than S. thermophilus. There is an important synergistic relationship between these two organisms in yogurt. The most intense proteolysis activity occurs during the log phase of growth of the yogurt bacteria. It then declines slowly when the stationary phase is reached. The greatest degree of proteolysis takes place between 24 to 48 hours. In yogurt the ratio of L. bulgaricus to S. thermophilus influences the amount of proteolysis. Cousin and Marth (1977a, 1977b) found that the increased proteolysis may occur in yogurt when the milk utilized is contaminated by proteolytic psychrotropic bacteria. They also found that the proteolysis was accompanied by development of undesirable flavors when milks were pre-cultured with a pseudomonas or a Flavobacterium species of bacteria.

Shahani and Chandan (1979) stated that yogurt and other fermented dairy products contain significant numbers of starter culture bacteria and that the bacteria might contribute cellular protein and constituent enzymes to the overall nutrient profile of the finish products.

Hargrove and Alford (1974) compared the growth rates and feed efficiency of rats fed fermented milk products. These diets included yogurt, acidophilus milk, buttermilk, inoculated milk, or milk acidified directly with lactic acid. Of all these experimental diets, yogurt was found to

be superior. The growth rates of rats given directly acidified milk were extremely low. This finding lead these authors to conclude that the higher growth rate and feed efficiency of rats given fermented milk diets might be related to improved bioavailability of the protein in the fermented products.

The free amino acid profile in yogurt depends on many factors which include strain of starter culture, age of yogurt (Ogai et al., 1974), ratio of Lactobacilli to Streptococci bacteria, type of milk, and method of manufacture (Luca, 1974; Ottoyalli et al., 1974). Nachev (1969) investigated 125 strains of L. bulgaricus and concluded that they could be classified into three types according to the sugars fermented and the amino acids released. One type of the bacteria ferments sugar in the presence of leucine, glutamic acid, asparagine, and proline and in the absence of aminobutyric acid, beta-alanine and tryptophan. Another type ferments sugar in the absence of glutamic acid. The remaining type ferments sugar in the presence of tryptophan. These findings can explain some of the differences in the free amino acid profiles reported. Results from four different laboratories showed that glutamic acid and proline are the two most prominent free amino acids in yogurt. Most of the other amino acids are consumed to some extent during the bacteria growth in the yogurt manufacture except proline and glutamic acid which

accumulated in yogurt. The presence of other amino acids in the final yogurt product reflected the balance between proteolysis and consumption. The total amino acid content reported in yogurt varied from 23.6 to 70 mg/100 ml. The total amino acid content increased during storage at 20°C and 4°C although the increase at the latter temperature was smaller than that at 20°C (0.2 mg/10 ml over 60 days). Incubation at 41-42°C for 2-3 hours produced higher amino acid content than incubation at 42°C at one hour followed by 5-6 hours at 30-32°C. Evidence showed that peptides are produced in yogurt but little research has been conducted to elucidate this point.

Effect of Fermentation on Fat Composition

Most researchers agree that lipolytic activity of starter bacteria is relatively low (Alm, 1982; Chandan et al., 1969: Tamime and Deeth, 1980;), but conflicting reports exist on the extent of fat alteration in fermented dairy products. Alm (1982) reported that fermentation of milk resulted in relatively small changes in fat composition; whereas, Formisono et al. (1975) found that neutral fats decreased in quantity and free fatty acids increased. Fatty acid C_{14} - C_{18}:2 were more numerous than fatty acids, C_4 -C_{12}. Furthermore, Rao and Reddy (1984) observed that fermentation of whole milk by Lactobacillus acidophilus, Lactobacillus bulgaricus, and Streptococcus thermophilus

resulted in a moderate but significant increase in the level of saturated fatty acids and oleic acid together with a decrease in the level of linoleic and linolenic acids in the triglyceride fraction. The increase in the level of free fatty acids was moderate. Tamime and Deeth (1980) found noticeable changes in fat content and free fatty acids content of yogurt after 21 days of storage. The fat content decreased by 6.6% (determined colormetrically) while the free fatty acid content increased by 30% after 21 days of storage.

Lactic starter bacteria not only might alter the composition of fatty acids in fermented dairy products, but they might also produce unusual fatty acids and alter cholesterol levels (Anonymous, 1976). However, Alm (1982) reported that unusual fatty acids of microbial origin where not detected in fermented milk.

Effect of Fermentation of Lactose to Lactic Acid

Lactose is the only carbohydrate present in milk in any appreciable quantity and is used as the available energy source by fermentative microorganisms. Production of lactic acid is the most important chemical process to occur during fermentation. Lactic acid bacteria involved in this process possess the enzyme lactate dehydrogenase for synthesis of lactic acid from lactose. The configuration of lactic acid formed can be D(-), L(+) or DL($\pm$) depending on the bacterial species and the presence of appropriate enzymes (Tamime and

Deeth, 1980). Garvie (1978) observed that Streptococcus thermophilus produced the L(+) lactic acid while Lactobacillus bulgaricus produced the D(-) isomer. Wiesner et al. (1975) reported that the percentage of lactic acid isomers in yogurt was from 45-60% L(+) lactate to 55-40% D(-) lactate. The percentage of lactic acid isomers in yogurt was reportedly affected by the incubation temperature, quantity of starter culture inoculum, ratio between coccus and rod bacteria, age of yogurt and levels of lactic acid produced (Wiesner et al., 1975).

D(-) lactic acid is less readily metabolized in the human body than the L(+) isomer and can lead to metabolic disturbances in an extremely unbalanced diet, especially in babies. The L(+) isomer is completely harmless. It was suggested that both isomers improved the digestibility of casein and aided in retention of calcium in the intestine (Deeth and Tamime, 1981). No mention was made of probable mechanisms.

Goodenough and Kleyn (1976), using a rat bioassay, reported that rats fed yogurt containing viable culture were able to digest lactose more efficiently and their intestinal lactase activity was greater than that of rats fed either pasteurized or simulated yogurt. They also demonstrated the survival of culture organisms in the stomach and the upper parts of the small intestine of rats for up to 3 hours after feeding. It was concluded that lysing of the yogurt culture

cells in the intestinal tract released lactase which hydrolyzed the lactose content of consumed dairy products (Kilara and Shahani, 1976). Thus, the lactose activity of starter culture cells should enable lactose intolerant people to consume fermented dairy products without subsequent ill effects (Speck and Katz, 1980). Accumulation of galactose in yogurt has been reported by Tamime (1977). He reported that in one strain of yogurt starter culture, galactose was utilized at a later stage during fermentation. This means that some of the L. bulgaricus strains used are capable of catabolizing galactose. In a review by Tamime and Deeth (1980), these authors reported that galactose is accumulated in fermented milk because S. thermophilus showed a tendency to utilize only glucose while L. bulgaricus metabolized glucose and galactose. It is evident that some further investigation on galactose metabolism in yogurt is needed.

Effect of Fermentation on Vitamin Composition

The vitamin content of fermented milk products as compared to raw milk from which the products are produced has been the subject of debate. Some authors have considered fermented milk products as a rich source of vitamins, while others have shown that the content of any vitamins decreased during fermentation.

Davis (1970) claimed that yogurt was a "B-vitamin

factory", but Acott and Labuza (1972) showed that, with the exception of niacin, yogurt contains lower amounts of vitamins than whole milk. Davis did not present data. Vitamins A, B_{12}, C, choline, and biotin content were, respectively, 56, 72, 71, 95, and 61% lower in plain yogurt than in whole milk. The vitamin content of fermented dairy products is also affected by such factors as heat treatment of milk, amount and type of starter culture, incubation temperature, and length of incubation and storage times.

In yogurt manufacture, milk is heated at either 85°C for 3 minutes or to 90-95°C for 5-10 min. The heat treatment of milk is essential and significantly affects the physical and chemical properties of yogurt (Tamime and Deeth, 1980). The relatively high heat treatment causes significant decreases in some vitamins such as C, B6, B_{12} and folic acid. The rate of destruction increases as temperature is increased. Also, the presence of dissolved oxygen in milk greatly enhances the sensitivity of certain vitamins to heat (Hartman and Dryden, 1974).

Studies show that during incubation some starter bacteria require certain vitamins for normal growth, while others are capable of synthesizing the necessary vitamins (Deeth and Tamime, 1981). Shahani et al. (1974) stated that the extent of biosynthesis and utilization of vitamins by starter bacteria depended on the strain used and the relative amount of inoculum as well as the conditions of

fermentation. Pelczar and Reid (1958) reported that L. bulgaricus required choline for growth. Reif et al. (1976) found that niacin and folic acid contents increased during yogurt manufacture while vitamins B_{12}, biotin, and pantothenic acid contents decreased. The optimum incubation temperature for maximum synthesis of folic acid and niacin was reported as 42°C; the folic acid content increased tenfold while the niacin content increased only slightly. Christensen (1970) attributed the rapid synthesis of folic acid to the symbiotic relationship between S. thermophilus and L. bulgaricus.

Reddy et al. (1976) studied the effect of storage on the level of vitamins in yogurt. They found that most vitamins decreased during storage. Considerable loss occurred in the amount of folic acid and vitamin B_{12} at 5°C during storage, while the amounts of biotin, niacin, and panthenic acid were fairly stable. Folic acid and vitamin B_{12} exhibited the greatest loss (28.6 and 59.5%, respectively) during a 16 day period of storage. Under similar conditions, milk lost 84.2% folic acid and 48.7% vitamin B_{12}. There was only a small loss of biotin, niacin, and pantothenic acid in yogurt during storage. The content of each vitamin decreased during yogurt fermentation because they are used as essential nutrients by the bacteria for growth while the decrease during storage at 5°C may be due to chemical decomposition.

Hypocholestermic Effect of Fermentation

Mann and Spoerry (1974) observed that the Maasai tribesmen of Africa had a fairly low cholesterol level in their blood, in spite of consuming large quantities of saturated fat and cholesterol in their diet. The low blood cholesterol was attributed to the consumption of large quantities of fermented milk. In a later study, Mann (1977) showed that yogurt contained an "anticholestermic milk factor." This factor inhibited cholesterol synthesis from acetate, which led to lower the plasma cholesterol level of rat and inhibited cholesterogensis in the liver of rats. Although the chemical nature of the anticholesterimic factor of fermented milk products has not been identified, Shahani and Chandan (1979) suggested that the presence of hydroxymethylglutaric and orotic acids in yogurt may inhibit biosynthesis of cholesterol and, consequently, lower blood cholesterol content.

Other suggestions regarding the reasons for the hypocholestermic effect of fermented milk have been made (Rao et al., 1981). Rao and Reddy (1984) ruled out the possible reduction of cholesterol content of fermented dairy products due to lactic fermentation. Harrison and Peat (1975) reported that feeding infants a milk formula supplemented with L. acidophilus lowered their blood cholesterol content. Speck (1976) suggested that the large

numbers of lactobacillus organisms in fermented milk could cause deconjugation of bile salts in the small intestine with consequent fecal excretion of bile acids and a lowering of body cholesterol. Similar effects were also found in heat-treated yogurt. Therefore, Deeth and Tamime (1981) concluded that fermented dairy products such as yogurt either contained a heat stable system or a bacterial metabolite which caused this hypocholestermic effect. Casein and calcium have been suggested as possible hypocholesterolemic factors (Carroll and Hamilton, 1975).

Antimicrobial Effect of Fermentation

Acids produced by starter bacteria during fermentation of milk not only contributed to the flavor of fermented products but also had an inhibitory effect on the growth of undesirable microorganisms in the fermented products. Acids differ in ability to inhibit microbial growth (Chung and Geopfert, 1970). The predominant acid produced by starter bacteria is lactic acid which is not as effective in inhibiting spoilage microorganisms as acetic acid. Acetic acid is produced in small concentration by some strains of starter bacteria (Speck, 1976). Shahani and Chandan (1979) reported that lactic cultures such as S. lactic, S. diacetylactis, Lenconostoc viemoris, and Lactobacillus spp. were capable of inhibiting Staphylococcus aureus, Pseudomonas putrifaciens, Escherichia coli, Clostridium

perfringens, Salmonella tennessee, Vibrio parahamolyticus, and other spoilage and pathogenic organisms. The exact nature of the inhibitory effect in each case has not been identified. Shahani and Chandan (1979) concluded that lactic acid and acetic acid as well as hydrogen peroxide in dairy products may be involved in inhibiting spoilage organisms. Hydrogen peroxide is produced by starter bacteria in minute amounts in fermented milks. Even though this substance is transient and difficult to measure, it has been found to inactivate harmful bacteria (Speck and Katz, 1980).

The production of certain antibiotics and inhibitors of microbial growth by some strains of lactic starter bacteria has been reported. Kodama (1952) found that a number of lactic streptococci also produced niacin and diplococcin. Niacin produced by selected starter cultures is used to preserve Swiss-type cheeses from spoilage by clostridia. There are many reports regarding production of antibiotics by Lactobacilli including lactobrevin by L. brevis (Kavasnikov and Sodenko, 1967); bulgarican by L. bulgaricus (Reddy and Shahani, 1971); acidophilin (Vakil and Shahani, 1965); lactocidin (Gossowics, 1947); acidophilin (Hamdan and Mikolajck, 1973), and lactolin (Kodama, 1952) by L. acidophilus. Sandine (1979) reported that antibiotics produced by Lactobacilli had inhibitory activity against Salmonella, Shigella, enteropathogenic Escherichia coli,

bacilli, and vibrio organisms *in vitro*. The amount of antibiotic produced was influenced by strain and the variation in the starter culture.

Antitumor Effect of Fermentation

The possible antitumor activity of certain lactic acid bacteria to some types of cancer has been the focus of many studies (Friend and Shahani, 1984). It has been shown that the content of bacterial enzymes, B-glucuronidase, nitroreductase and ozareductase was high in the animals fed a diet rich in red meats. These enzymes are believed to be involved in conversion of procarcinogens to proximal carcinogens. It has been reported that the supplementation of *L. acidophilus* in diets of both rats and humans lowered the activity of these enzymes (Goldin and Gorbach, 1976; 1977).

Bogdanov et al. (1978) isolated three glycopeptide cell wall fragments from *L. bulgaricus* which are called blastolysin collectively. Blastolysin has been proved to have promising biological activity against some tumors such as sarcoma-180 in mice. Activity was accessed by an increase in the period of survival of lukemias and inhibition of growth in solid tumors. The cured animals remained free of tumors. In the same study Bogdanov et al. (1978) could not demonstrate the effects of the blastolysin *in vitro*. Therefore, the authors concluded that the blastolysin activated the animals' immunological mechanisms.

Effect of Fermentation on Flavor Production

The role of the starter culture during yogurt manufacture is to produce lactic acid and develop flavor in the final product. The most important flavor components produced during yogurt manufacture are carbonyl, acetaldehyde, acetone, acetoin, and diacetyl. A review by Tamime and Deeth (1980) reported that acetaldehyde and other unidentified compounds are responsible for yogurt flavor. The production of acetaldehyde is an important factor to develop an acceptable flavor in yogurt. The symbiotic relationship existing between S. thermophilus and L. bulgaricus increased acetaldehyde production in yogurt. Hamdan et al. (1971) reported that L. bulgaricus was the main flavor producer in yogurt, while (Shankan and Davies, 1977, 1978) indicated that S. thermophilus produced more acetaldehyde than L. bulgaricus. Tamime and Deeth (1980) stated that flavor production varied according to the strain of bacteria used. Volatile fatty acids and amino acids are associated with flavor production in yogurt. The production of N-pentaldehyde and 2-heptanone by L. bulgaricus might contribute to yogurt flavor. Flavor compounds can be derived from fat, protein, or lactose but of importance are the ones formed by microbial fermentation of lactose. Acetaldehyde is produced from lactose, valine, and acetyl

phosphate by decarboxylation of pyruvate and cleavage of threonine to yield glycine and acetaldehyde. Acetaldehyde can be formed also via the activity of deoxyriboaldehyde enzyme by degrading deoxyribonucleic acid and converting thymidine to acetaldehyde. More than one metabolic pathway operates simultaneously in the production of acetaldehyde in yogurt. It should not be omitted that lactic acid produced during yogurt fermentation contributes to the flavor, producing an acidic and refreshing taste, while the carbonyl compounds are associated with the aroma and flavor of the final product. Yogurt is a relatively tart, high acid product with a characteristic flavor differing from other fermented milk products (Anonymouns, undated). The authors stated that the high acid content alone does not give the fullness and richness of yogurt flavor. They cited that the characteristic flavor of yogurt is due to a combination of lactic acid, small amounts of acetaldehyde, diacetyl, and acetic acid and that acetaldehyde accounts for nearly 90% of the volatile flavor compounds in yogurt. The complete yogurt flavor is obtained only when lactobacilli are grown in association with the moderate acid producing Streptococcus thermophilus species which produce acid at high temperature (40^{o}C - 46^{o}C). Initially, S. thermophilus facilitates lactobacillus growth by distributing dissolved oxygen in milk. Then the lactobacilli, during their growth liberate amino acids which stimulate S. thermophilus growth.

The "coccus" in addition, produces formate as a metabolic by-product which enhances the growth of the lactobacilli (Anonymous, undated).

D. Temperature and Time of Incubation for Yogurt

There are two time-temperature combinations for yogurt incubation: low temperature-overnight incubation and high temperature-short time incubation. In the former case, incubation temperature is held at 32°C for 15-16 hours. Incubation was terminated when the pH of the yogurt reached the range between 4.2 to 4.4. With higher temperature-short time incubation the yogurt mixture is incubated between 41°C to 44°C for 8 to 10 hours. In this case, incubation is terminated and the pH of the product will reach 4.3 to 4.5. Temperature and the length of incubation should be controlled carefully.

E. Nutritional Value and Chemical Composition of Sweet Potatoes

Sweet potato is the sixth largest food crop consumed in the world, providing about 2 million metric tons of protein worldwide. Very little is known about the nitrogenous content of this root. Dickey et al. (1984) investigated the potential for increasing protein content by genetic manipulation and postharvest handling practices. It appears that there is a demand for further research in this area.

Approximately 60 to 85% of the nitrogen content of the root is proteinaceous of which approximately 90% is amino or amide nitrogen. The proteins efficiency ratio of the isolated protein of component sweet potato was found to be equal to that of casein. The protein of this root is not evenly distributed. The crude protein content is slightly higher in the proximal and distal ends of the root. The crude protein is higher in tissue of the outer layer part (Bradbury et al., 1984; Purcell et al., 1976). Most of the protein of this crop is reported to be a globulin, called "ipomoein" (Jones and Gersandorff, 1931). Upon storage, ipomoein is partially converted to a polypeptide that is different from the parent globulin physically and chemically. Amino acid analysis indicated that sulfur-containing amino acids are first limiting. In some cases lysine and or tryptophan are the second limiting amino acids. (WHO, 1973; U.S.D.A., 1980; Walter and Catignati, 1981). Heat can cause a decrease in lysine bioavailability, and the magnitude of decrease depends upon the severity of the heat processing technique. The total protein contents on the dry weigh basis of the following three products are: 7.52% for baked sweet potato, 5.55% for canned sweet potato, and 7.06% for sweet potato flakes. The type of heat treatment affects the amino acid content. In baked sweet potato, lysine content was higher and serine content was lower than those in canned and flaked sweet potato and the

other items. Leucine and alanine contents were highest in the canned product. Methionine content was higher in the baked and flaked products. Baking was considered to be the least severe heat treatment with a temperature no more than 100°C. Canning was the most severe heat treatment used. Canned sweet potatoes contain 26% less total nitrogen than the baked sweet potatoes due to the amount that leaches into the syrup. Flaking involves the most severe short time heat treatment. Destruction of lysine seemed to be the major change of amino acids caused by the processing method. Both canned and flaked sweet potatoes contained more than 25% less lysine than did the baked counterpart. Tryptophan and total sulfur containing amino acids were low in all the products. Methionine was low only in the flakes.

On the fresh weight basis sweet sweet potato contained a mean 1.8% crude protein, 0.7% crude fat, 1.0% crude fiber, 68.5% water, and 28.0% carbohydrate (Cooley, 1948; Goodbody, 1984; Thompson, 1984). On the dry weight basis, the total carbohydrate content of the sweet potato root was 89.5%. This value included the sugars maltose, sucrose, and glucose and dextrin (Picha, 1985b, 1986). The concentration of carbohydrate varied among cultivars.

The sweet potato root is an excellent source of energy (114 Kcal/100 g) (Mathia, 1975). In some tropical areas, people depend on this crop for their dietary protein (Thompson, 1984). Some cultivars have more than 9% protein

(Purcell et al., 1976; Purcell and Swaisgood, 1972). The recommended dietary allowance (RDA) of protein for adult males and females are 56 g and 44 g, respectively. To meet this requirement, one must consume a large quantity of the root (Picha, 1985b). This root is an excellent source of vitamin c and provides important amounts of riboflavin, niacin, pantothenic acid (Crosby, 1964; Edmond and Ammerman, 1971; Technical Committee S-101, 1980) thiamine, calcium, and iron (Elkins, 1979; Fitzgerald, 1976). It is an excellent source of dietary fiber. Part of the dietary fiber from plant material is cellulose, hemicellose, lignin, and pectin (Eastwood and Passmore, 1984; Schneeman, 1986). Lack of fiber in a diet over a long period of time can lead to gastrointestinal tract dysfunctions and, further, to serious disease states (Burkitt and Trowell, 1975) such as diverticular disease, colon cancer, ischemic heart disease, constipation, diabetes, and other gastrointestinal tract disorders (Kelsay, 1978).

The sweet potato provides an excellent source of provitamin A (880 RE/100 g) (Mathia, 1975). Provitamin A is an essential nutrient for epithelial tissue maintenance, reproduction, growth and normal vision (Clemens and Brown, 1986). The deep orange color of this crop is the result of a high level of beta carotene (Chichester and Tanner, 1972; Martin, 1983). Researchers have demonstrated that some vitamin A active carotenoids have anti-cancer and anti-ulcer

properties. Eighty to ninety percent of the carotenoids in sweet potatoes are beta carotene (Picha, 1985b). The remaining carotenoids are precursors of vitamins and account for 10-20% of the total carotenoid content, excluding the white strains.

CHAPTER III

MATERIALS AND METHODS

A. Source of Preparation of Sweet Potato

The Jewel cultivar of sweet potato was used. This sweet potato is the moist type with orange flesh. The sweet potatoes were produced on the Plant Sciences Farm, The University of Tennessee, Knoxville, by personnel of the Plant and Soil Science Department. After harvest, the roots were cured by holding them at 30°C and 80 to 90% relative humidity for seven days Technical Committee S-101, (1980). Following the curing process, the roots were held at 16°C until used.

To prepare the roots for use, they were washed, dried, and baked at 190°C in a conventional hot air oven for 1.0 to 1.5 hours, depending on diameter of the root. After baking and cooling, the peel was removed. The flesh was comminuted with a food processor (Cuisinart brand, model DLC - L PRO, Cuisinart Inc., Greenwich, Connecticut). The processor was allowed to operate for 15 min. The puree was used immediately.

B. Source of Milk

Milk (cow's) was provided by the University of Tennessee Creamery. The milk was processed to contain 2%

butterfat and 400 units of vitamin D per quart (0.94 l), pasteurized, and homogenized. Non-fat dry milk was purchased from a local food store.

C. Source of Starter Culture for Yogurt and Gelatin

A freeze dried culture consisting of Lactobacillus bulgaricus and Streptococcus thermophilus produced by Yogurmet, Inc., Quebec, Canada was used. Plain, unflavored gelatin was purchased from a local food store.

D. Preparation of Yogurt Mixture and Method of Fermentation

A Swiss-style yogurt was prepared with ingredients combined by the following procedure. Sweet potato puree of 12, 14, 16, and 18% levels were added to milk of proportional amounts to equal 100%. A batch of 100 g was prepared. The mixture was blended in an Osterizer brand kitchen-type blender (Osterizer Co., Milwaukee, WI) at maximum speed for 6.3 minutes, then transferred to a stainless steel container (capacity) for heating. The container of mixture was placed in a boiling water bath and the mixture was stirred until it reached 82°C. The container was removed from the bath and held for three minutes. The mixture was returned to the blender jar to which gelatin at 4.4 g/100 g and granulated sugar of 4.00, 4.67, 5.33, or 6.00% were added. The combined materials

were blended for 1.8 minutes and, again poured, into the stainless steel vessel. The vessel with ingredients was placed into the boiling water bath and heated to 82°C with gentle stirring to remove occulated air (foam) that was incorporated by the blending action.

The heated mixture was proportioned into pint jars at amounts of 228 g and allowed to cool for 43°C. Then, 0.4 g yogurt starter was added to the jar, and the material was mixed at 250 revolutions per minute for 2.0 minutes with a two-blade stirrer. The jars were closed loosely with zinc-porcelain lids.

The jars with the yogurt mixture were placed into an incubator which was equipped with an internal fan for uniform air circulation and held at 43°C. Samples of the yogurt mixtures were incubated for 5.00, 5.33, 5.67 and 6.00 hours (Appendix 1). At the end of the different incubation periods, a previously designated sample was removed from the incubator and placed into an ice bath and held overnight to discontinue the fermentative activity of the bacteria. The rate of cooling was monitored by placing a thermocouple into the sample and recording the temperature overnight. After being held in the ice bath, the samples were placed in a refrigerator and held until analyzed.

E. Measurement of pH and Titratable Acidity of Yogurt

Two replications of samples of yogurt were analyzed for

pH and titratable acidity according to the AOAC (1984) method. pH was determined with a Fisher Acumet brand, model 600, pH meter. The sample consisted of a mixture of 10 g of yogurt and 40 ml boiled, deionized water. During the period of measurement the mixture was stirred constantly with a magnetic stirrer. After the pH measurement was made, the titratable acidity was determined, using 0.1 N sodium hydroxide (NaOH) titrant to reach an end-point of pH 8.1. Acidity was calculated as percentage of lactic acid, using the following formula:

$$\% \text{ lactic acid} = \frac{(\text{ml NaOH})\ (\text{N NaOH})\ (\text{meq. wt.})\ (100)}{\text{g of sample}}$$

N = normality = 0.10 N

meq. wt. = millequivalent weight = 0.09008

gram of sample = 10

The data were analyzed to determine values needed to establish parameters for the next phase of the experiment (Little and Hills, 1978). Correlation coefficients were calculated to test for linearity of the data. Acidity for each combination of sweet potato and amount of sugar was analyzed. From each set of data calculations were made to determine the period of time necessary to allow for fermentation of samples of yogurt containing 12%, 14%, 16% and 18% sweet potato to produce 0.85% lactic acid when sugar level was set at a 5% (Anonymous, Undated).

F. Evaluation of Fermentation For Different Incubation Periods

Another series of samples was prepared to ascertain whether the calculated periods of time would allow for production of 0.85% lactic acid in the yogurt. Samples of yogurt were prepared using 12, 14, 16 and 18% sweet potato, 5% sugar, 4.4 g gelatin per 1000 g yogurt mix, and 0.4 g starter preparation to 228 g of yogurt mixture to be fermented.

The periods of time for fermenting as determined from the previous experiment were the following: for 12% sweet potato, 6.25 hours; 14% sweet potato, 6.42 hours; 16% sweet potato, 6.5 hours; and 18% sweet potato, 7.25 hours.

These samples were prepared, incubated, cooled, and handled by procedures similar to those presented in Section D. Samples were analyzed for percentage of titratable acidity as presented in Section E.

G. Effect of Gelatin Concentration on Firmness of Yogurt

The series of samples was prepared to determine the effect of gelatin concentration on the firmness of yogurt. Ingredients included sweet potato at 12, 14, 16, or 18%; sugar at 5%; and starter preparation of 0.88 g and gelatin of 2.00, 2.30, 2.60, or 2.90 g gelatin per 500 g of yogurt mixture. Samples were also prepared in the same manner as the sweet potato yogurt for the flow rate measurement. In

place of sweet potato, non-fat dried milk powder was used. The total solids level of the samples and the controls was calculated to be the same among all samples. The times of incubation were the same as those presented in Section F, and the method of incubation and handling was similar to that presented in Section D. Two replications of samples and controls were prepared, and two measurements were determined on a sample and a control of each replication.

H. Firmness Measurement of Yogurt

Samples, prepared according to procedures presented in Section G, were tested for firmness with an Instron Food Testing Machine (Model 1332) (Instron Corp., Canton, Masssachusetts) (Bourne, M. C., 1978; Larmond, E., 1976). A 500 g capacity load cell was used, the crosshead speed was 10 cm per minute, and the range was set at 5. An integrator (Shimadzu Chromatopac, model C-R3A) was connected to the Instron machine as a recorder for measuring the work-force produced by the sample tested.

Firmness was determined by forcing a Cherry-Burrell Curd Tension devise (model A) (Cherry-Burrell Co., Cedar Rapids, Iowa) into the surface of the undistributed yogurt as it was being held in the jar in which it was fermented. The device was forced to a depth of 5.5 cm, and from this penetration a measurement of firmness was obtained. Firmness was considered to be the work-force as indicated by

the area under the integrator curve. The firmest samples produced the greatest values for area under the curve. Firnmess was expressed in terms of area under the curve and in units of cm^2. Temperature of the yogurt was equilibrated at approximately 5^oC for measurement.

Consistency of the yogurt was determined according to the following procedure. The yogurt was removed from the jar, placed into the mixing apparatus of the Mixograph (National Mfg. Co., Lincoln, Nebraska) and stirred for 4 minutes. Then, the sample trough of a Bostwick Consistometer (CSC Scientific Company Inc., Fairfax, Virginia) was filled and the gate was tripped to allow the yogurt to flow for 30 seconds along the channel which was marked in centimeters (Rutgus, 1958). The distance the yogurt flowed was recorded as centimeters. Samples of the greatest consistency flowed the shortest distances. Temperatures of the laboratory, the equipment, and the samples were maintained at 10^oC.

I. Sensory Evaluation of Selected Yogurt Samples - Expert Panel

Six treatments were selected as a result of the firmness measurements for evaluation by a trained panel. Accordingly, the treatments selected contained 14% sweet potato and 4.40 g gelatin; 14% sweet potato and 5.04 g gelatin; 16% sweet potato and 4.40 g gelatin; 16% sweet

potato and 5.04 g gelatin; 18% sweet potato and 4.40 g gelatin; and 18% sweet potato and 5.04% gelatin per 1000 g of yogurt mixture. Two additional samples were selected at random from among the six samples listed. These samples were prepared and used to determine the precision of the panel to evaluate similar samples. The additional samples for replication 1 were 16% sweet potato and 5.04 g gelatin and 16% sweet potato and 4.4 g gelatin. For replication 2, the additional samples were 16% sweet potato and 5.04 g gelatin and 14% sweet potato and 4.4 g gelatin.

The panel consisted of five members of the Department of Food Technology and Science trained to evaluate dairy products. The samples were presented in the sensory testing laboratory on a table, separated by ample space to allow for individual evaluation. The evaluation sheet used was the one used by dairy products judging teams to evaluate swiss-style yogurt (Appendix 2). The items evaluated were: flavor, body and texture, and appearance and color. Prior to evaluation, a training session was held where samples of the yogurt were presented to familiarize the panel members with the product. At that time appropriate terms were defined to describe the sweet potato yogurt. Following this, the panel was presented the eight samples for evaluation. The two replications were presented on separate days. After the panel had completed its evaluation, the members and the researcher conducted an open discussion of

the attributes of the samples. The consensus opinion presented indicated that the samples with 5.04 g of gelatin per 1000 g yogurt mixture were too firm, but that samples with 4.40 g gelatin were of satisfactory firmness. The panel also indicated that differences for flavor and for appearance and color existed among samples of the different percentage levels of sweet potato. Sweet potato was considered to exhibit no effect on the yogurt. Consequently, the set of three samples was selected for evaluation by a hedonic panel.

J. Sensory Evaluation of Selected Yogurt Samples-Hedonic Panel

The samples selected for evaluation by the hedonic panel contained 14, 16, and 18% sweet potato, 5% sugar and 4.4 g gelatin per 1000 g yogurt (Kramer, 1973). Evaluations occurred in the sensory evaluation laboratory. Cool, white light was used to illuminate the samples. Members of the panel consisted of faculty and staff members and students of the Institute of Agriculture, The University of Tennessee. Two replications of the samples were tested. For the first replication, 40 members evaluated the samples; and for the second replication, 63 members. Thirty-nine members evaluated samples of both replications. To qualify as a panelist, the person must not declare a dislike for yogurt.

An 8-point hedonic scale was used to evaluate the

samples of two replications for color, flavor, texture (month feel), and overall acceptability (Appendix 3). Samples were held in a refrigerator before being presented for evaluation in a paper cup of 74 ml capacity.

After evaluating the samples, each panelist was asked to provide certain information. A complilation of this information is provided in the Appendix 4.

K. Methods of Chemical Analysis-Proximate Composition

The three samples of two replications evaluated by the hedonic panel (Section J) were analyzed for proximate analysis according to AOAC (1984) methods.

Samples were prepared by freeze-drying the fresh sample in a Virtis Freeze-dryer (model FFP-15W5). The dried material was comminuted with a morter and pestle and placed in sealed glass jars over desiccant until analyzed.

Moisture was determined by the vacuum oven method at 100^{o}C. Fat content was determined by the Babcock methods (AOAC, 1984) with modifications. Nine grams of sample were used, and 9 ml of water, 2 ml butyl alcohol, and 9 ml sulfuric acid were added to the sample. The last centrifugation was 3 minutes. One drop of glymol solution was added to facilitate reading the fat content. Protein content was determined by the kjeldahl method (% N x 6.38). Ash was prepared by the dry method, using the muffle furnace at 525^{o}C overnight. Total dietary fiber was determined by

an enzymatic - gravimetric method (Alstin, 1985; Prosky et al., 1985), using the Fibertec System, module E (Tecator Company, Hoganas, Sweden).

The percentage of carbohydrate was determined by subtracting the percentage of lipid, protein, ash, and dietary fiber from 100%.

L. Caloric Content

The caloric content (gross energy) of the yogurt was measured with the Parr Adiabatic Oxygen Bomb Calorimeter (model 124) (Anonymous, 1960). Approximately 0.8 g of freeze-dried yogurt was tested, and energy was reported as Kilo calories (Kcal) per 100 g of sample on dry weight basis. The Atwater method was used to calculate the caloric values of yogurt (Watt and Merrill, 1963).

M. Vitamin Content

Beta carotent (provitamin A), thiamine, riboflavin, niacin, and ascorbic acid contents were determined on freeze-dried yogurt. Vitamin A potential was calculated from the beta carotene. A modification of a method by Holden (1985) and Bureau and Bushway (1986) was used. Thiamine, riboflavin, niacin, and ascorbic acid contents were measured according to procedures of Augustin (1984), Kamman et al. (1980), Mauro and Wetzel (1984), and Toma and Tabekhia (1979). For all the vitamin analyses, a high

pressure liquid chromatograph (HPLC) (Waters Assoc, Milford, MA, model 6000 A solvent delivery system with a V6K injector) was used. The vitamins were separated with a Waters U Bondapak C-18 column with a Z-module. Riboflavin, niacin, thiamin and ascorbic acid were detected using Waters Lambda Max (model 480) Spectrophotometer. The spectrophotometer absorbance detector was set at 254 nm. A solution of 0.005 M hexane sulfonic acid in methanol-water (36:64) with 1% glacial acetic acid was used as solvent. The flow rate used was 1.0 ml per minute. Detection of the vitamin response was correlated to vitamin concentration using a Shimadzu Chromatopac 2-channel Integrator (model C-R2 AX, INP-R2A) which was connected to the HPLC).

N. Preparation of Samples and Extraction of Vitamins

For riboflavin, niacin, thiamin and ascorbic acid extraction, 5 g samples of yogurt with 14%, 16%, and 18% sweet potato of both replicates were added to a 100 ml amber volumetric flask with 50 ml of 0.978 N sulfuric acid. The samples were mixed well, and the flasks were placed in a boiling water bath for 10 minutes. The flasks were removed and cooled. A 5 ml aliquot of a solution containing a preparation of amylases (Miles Laboratory, 2 g "clearase" in 100 ml of 2.5 M sodium acetate buffer) was added to the mixture. The flasks containing the solution were placed in a water bath at 56^{o}C and agitated slowly for one hour to

allow for digestion. Fifty ml of this solution were transferred to stainless steel centrifuge tubes, and centrifuged at 37,500 x g for 15 minutes. Ten ml of the supernatant from each sample were filtered through a 0.45 um filter. Ten ml of the filtrate were injected in triplicate into the High Performance Liquid Chromatograph (HPLC). A standard solution of these vitamins containing 0.002 mg/ml riboflavin, 0.06 mg/ml ascorbic acid, 0.04 mg/ml niacin, and 0.04 mg/ml thiamin (Sigma Chemical Co., St. Louis, Missouri) in 0.978 N sulfuric acid was prepared. Aliquots of 5, 10, 15, 20, and 25 µl of the standard solutions were injected in triplicate into the HPLC to draw the standard curves.

Beta carotene was extracted from freeze dried yogurt with 14, 16 and 18% sweet potato. The fat extraction method using the Goldfish apparatus was employed. Samples of 2 g were extracted for 4 hours with moisture free petroleum ether. Ether was evaporated from the carotenoid extract, and the residue was dissolved in 25 ml HPLC-grade hexane. The suspensions were filtered through a 0.45 um pore size filter, and 10 µl of the aliquots were injected into the HPLC. A mixture of acetone and hexane (15:85; v/v) was used as diluting solution. The flow rate was 2 ml per minute. The spectrophotometer was set at 452 nm for the measurements. A standard solution containing 0.0056 mg/ml beta carotene (Sigma Chemical CO., St. Louis, MD) was prepared in hexane. Aliquots of 5, 10, 15, 20, and 20 µl

were injected into the HPLC in triplicate for use in developing the standard curve. The provitamin A content was reported in terms of beta carotene per 100 g samples of yogurt which was converted to retinol equivalents (RE).

O. Mineral Content

Calcium, magnesium, potassium, sodium, phosphorus, zinc, iron, and copper contents were determined on samples of yogurt which contained 14, 16, and 18% sweet potato. Analyses were determined on two replicates of samples. One gram of sample was weighed into a 250 ml beaker, and 60 ml concentrated nitric acid were added. The sample was boil to near dryness and cooled. Seven ml of reagent grade perchloric acid were added to the beaker, and the beaker was covered with a watchglass until the reaction subsided. The glass was removed, and the sample was boiled to approximately one ml volume. The sample was diluted with 25 ml distilled water. Analysis was conducted by personnel of the Department of Animal Science, using an Instrumentation Laboratory, atomic absorption spectrophotometer, model 551.

P. Sugar Analysis

Sugar composition was analysed according to the modified method outline by Zugmunt (1982). Fructose, glucose, sucrose, maltose, lactose, stachyose, and raffinose contents were determined on freeze-dried yogurt. Five g

samples of yogurt with 14, 16, and 18% sweet potato of replicates 1 and 2 were mixed into 100 ml alcohol and water (1:1.v/v) and weighed. The composites were placed in 80-85°C water bath for 25 minutes and stirred occasionally. Then, mixture was cooled to room temperature and alcohol was added to the samples to bring them to the original weight. The solutions were transferred to stainless steel centrifuge tubes and centrifuged at approximately 480 x g for 10 minutes. The solutions were filtered through a 0.45 micromilipore size filter. Twenty ml of the filtrates were injected in duplicate into the HPLC. The flow rate used was 2.0 ml per minute. The column used was a carbohydrate analysis column, P/N 84038 SN (Waters Assoc., Milford, Massachusetts). A mobile phase solvent of acetonitrile (HPLC grade) and water (80:20, v/v) was used for fructose, glucose, sucrose, maltose, and lactose analyses while a (70:30 V/V) solvent was used for stachyose and raffinose analyses. Individual sugar standards of fructose, glucose, sucrose, maltose, lastose, stachyose and raffinose (Sigma Chemical Co., St. Louis, Missouri) were dried at 80°C under vacuum for 2 hours, and the standards were dissolved in water. A standard solution of the sugars was prepared to contain 5.0058 g/100 ml fructose, 5.0060 g/100 ml maltose, 5.0022 g/100 ml glucose, 10.0026 g/100 ml sucrose, 1.0044 g/20 ml lactose, 0.2513 g/25 ml stachyose and 0.5008 g/50 ml raffinose in distilled water. Aliquots of 5, 15, and 25 µl

of the standard solutions were injected in duplicate into the HPLC to determine the standard curves.

Q. Color Measurement of Yogurt

Color measurements were made on yogurt samples containing 12, 14, 16, and 18% sweet potato; 4.00, 4.67, 5.33 and 6.00% sugar; 4.4 g gelatin per 1000 g yogurt mixture and 0.4 g starter preparation per 228 g yogurt mixture (Francis and Clydesdale, 1975). Two replications of samples were incubated for 5.00, 5.33, 5.67, and 6.00 hours (Appendix 5). The Hunter Color Meter, model D25 D2M, was used. The instrument was standardized against a white tile (L = 91.03, "a" = -1.3, and "b" = 1.6). The yogurt sample was mixed and filled into the cuvette with an optical glass bottom. Readings were taken for L (lightness - darkness), "a" (redness), and "b" (yellowness).

R. Microbiologicl Analysis of Yogurt

Samples for the microbiological count were taken from the yogurt mixture before inoculation, after inoculation, and after incubation (yogurt). All analyses were conducted on samples containing 16% sweet potato, 5% sugar, 4.4 g gelatin per 1000 g yogurt mixture, and 0.4 g starter preparation per 228 g yogurt mixture. Counts were made on the baked sweet potato puree.

The Standard Method Agar (SMA) (BBL) (Microbiology

Systems, Bectom Dickinson and Co., Cockeysville, Maryland) and the de Mann Rogasa and Sharpe Agar (MRS) Difco Laboratory, Detroit, Michigan) were used for plating the samples (Busta et al., 1984). Media were prepared according to instructions of the respective suppliers.

Eleven grams of each well mixed sample were taken and quantitatively transferred to a sterile 99 ml dilution bottle (blank), containing phosphate butter at pH 7.2 and 0.5 M. Aseptic techniques were followed (Richardson, 1985).

The conposite samples were mixed in Seward Stomacher model 400 bags for 2 minutes, using a Stomacher Lab-Blender, model 400, (Seward Laboratory, England). Decimal dilutions of the samples were prepared and pour plated on SMA and MRA media. SMA plates were incubated at 32°C for 48 hours to selectively enumerate the culture organisms used in fermentation of yogurt. A high humidity was maintained by placind a pan of water in the incubator. Plates were sealed with parafilm to prevent evaporation. Thermoduric lactic and aerobic plate counts were taken for each sample (Busta et al., 1984; Richardson, 1985).

S. Statistical Methods and Experimental Design

Measurement of pH, titratable acidity, firmness, sensory evaluation, proximate composition, caloric values, vitamin content, mineral content, color measurement, and microbiological analysis were preformed following a

randomized complete block design according to Little and Hills (1978). The design for pH and titratable acidity measurement was a 4 x 4 x 4 x 2 (time x sweet potato x sugar x replication) factorial. A 4 x 4 x 2 (sweet potato x gelatin x replication) was used for the firmness analysis. The expert panel used the following factorial: 5 x 2 x 3 x 2 (panelist x gelatin x sweet potato x replication) for body and texture, and appearance and color, and a 4 x 2 x 3 x 2 (panelist x gelatin x sweet potato x replication) factorial for flavor attribute. The consumer panel used a 63 x 3 x 2 factorial (panelist x sweet potato x replication). Proximate composition, caloric, vitamin, and mineral data were analyzed following a 3 x 2 x 2 factorial (sweet potato x duplication x replication). A 4 x 4 x 4 x 2 (time x sugar x sweet potato x replication) factorial was used for color measurement. Microbiological counts were taken in replicate. No statistical analysis was preformed for microbial count.

Data from all tests were determined by analysis of variance to determine any significant differences between treatments. Models were reduced on some of the analysis by removing variables that were not significant. Significance among the means for each test was determined by the Student Newman - Kuel (SNK) mean separation technique. The statistical analysis was preformed using the Statistical Analysis System (SAS, 1985) programs available at the University of Tennessee Computing Center (UTCC).

CHAPTER IV

RESULTS AND DISCUSSION

A. Measurement of pH and Titratable Acidity

The correlation coefficient between pH and titratable acidity values (percentage of lactic acid) of sweet potato yogurt samples fermented between 300-360 minutes showed an inverse relationship (coefficients ranged between 0.9314 and 0.9999, depending upon levels sweet potato and sugar). Duitschaever (1978) reported on acid development (pH) by yogurt bacteria in unfortified low fat milk during incubation at 43°C. The pH values decreased from 6.37 at 0 minutes to 4.4 after 174 minutes. The pH value for fortified cow's milk (skim milk powder added) after 190 minutes was 4.40. Titratable acidity values were not reported in the study. Varing opinions exist as to the range in which the final pH of yogurt should fall: many researchers advise, however, that the final pH should be between 4.00 and 4.44 (Connolly, 1978; Kroger, 1973; Manus, 1973). Lactic acid content should range from 0.8 - 0.9% according to Kroger (1973). Chambers (1979) and Kroger (1973) reported that from 3 to 4 hours are needed to obtain a desirable curd formation and acid level of yogurt. This study, however, showed that in order to reach a pH and titratable acidity within the range suggested in literature,

it was necessary to increase the time approximately two fold. The data suggest the presence of the factor which acts to suppress the production of the lactic acid within the initial 3 to 4 hour period of incubation of sweet potato yogurt.

The analysis of variance for the titratable acidity values for the four levels of sweet potato, four levels of sugar, six incubation times, and two replications is presented in Table 1. There were significant differences in the titratable acidity values of the sweet potato yogurt samples as affected by sweet potato level, sugar level, and incubation time. There was a significant difference between replications.

The effects of level of sweet potato and time of incubation on percentage of titratable acidity of the yogurt samples are shown in Figures 1, 2, 3, and 4. For yogurt with 12% sweet potato, titratable acidity at 4% sugar and after 300 minutes incubation was 0.70%, and after 360 minutes incubation was 0.70%, and after 360 minutes, 0.88% (Figure 1). When the sugar level was raised to 6%, acidity reached a lower percentage. After incubation of 300 minutes, acidity was increased to 0.46%, and after 360 minutes, 0.71%.

When the level of sweet potato was increased to 14% acidity developed to 0.60% in yogurt with 4% sugar and after 300 minutes incubation. Extended the time to 360 minutes

TABLE 1

SUM OF SQUARES FROM THE ANALYSIS OF VARIANCE FOR TITRATABLE ACIDITY OF SWEET POTATO YOGURT AS AFFECTED BY LEVELS OF SWEET POTATO, SUGAR AND PERIODS OF INCUBATION

Source	d.f.	Sums of squares
Sweet potato level	3	2.71**
Sugar level	3	6.16**
Incubation time	5	6.98**
Replication	1	0.06**
Error	563	1.77

**Significant at 0.01 level.

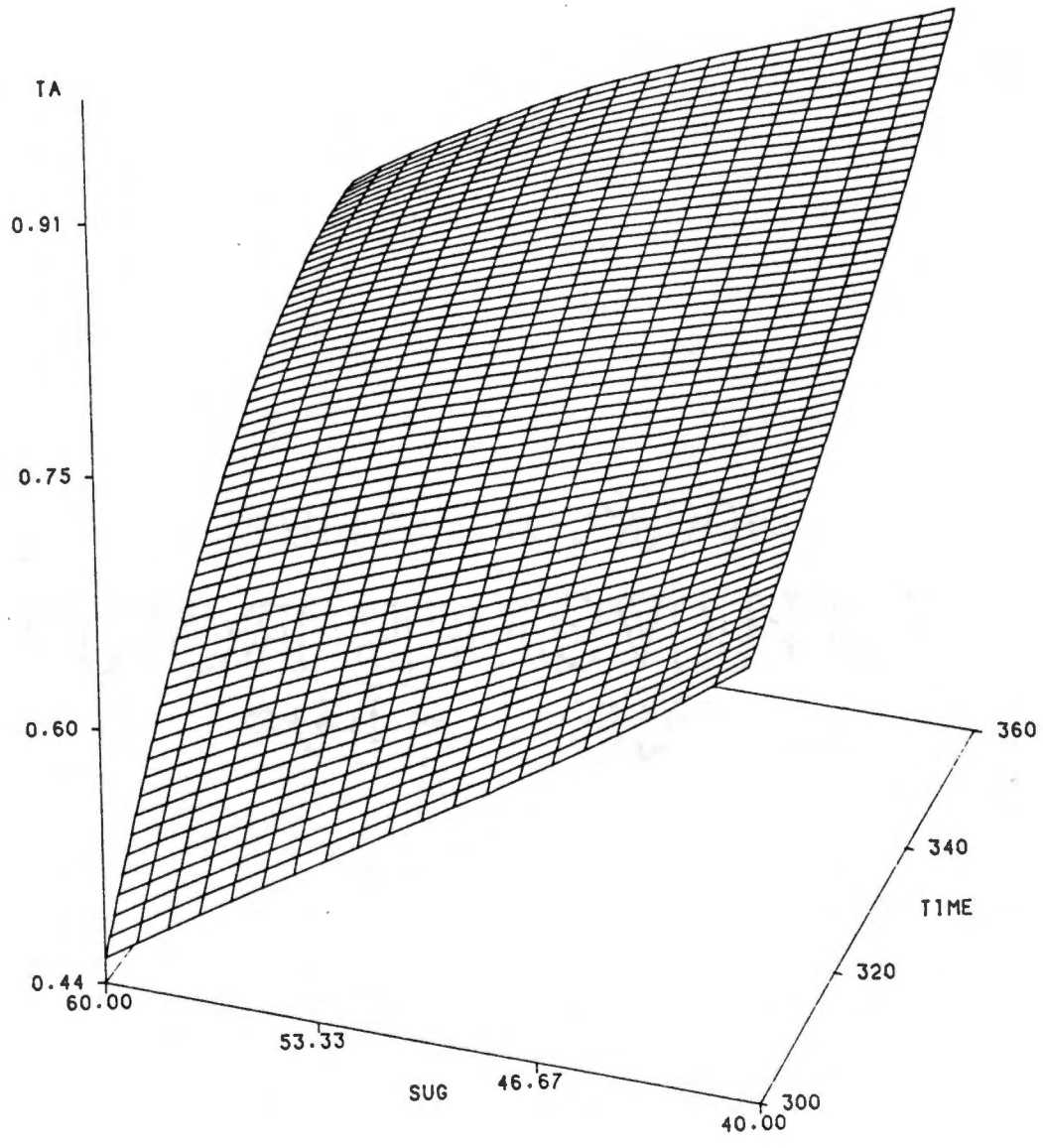


Figure 1. Titratable Acidity of Yogurt with 12% Sweet Potato as Affected by Level of Sugar and Time of Incubation. TA = % Titratable Acidity as Lactic Acid; SUG = Grams Sugar Per 1000 g Yogurt

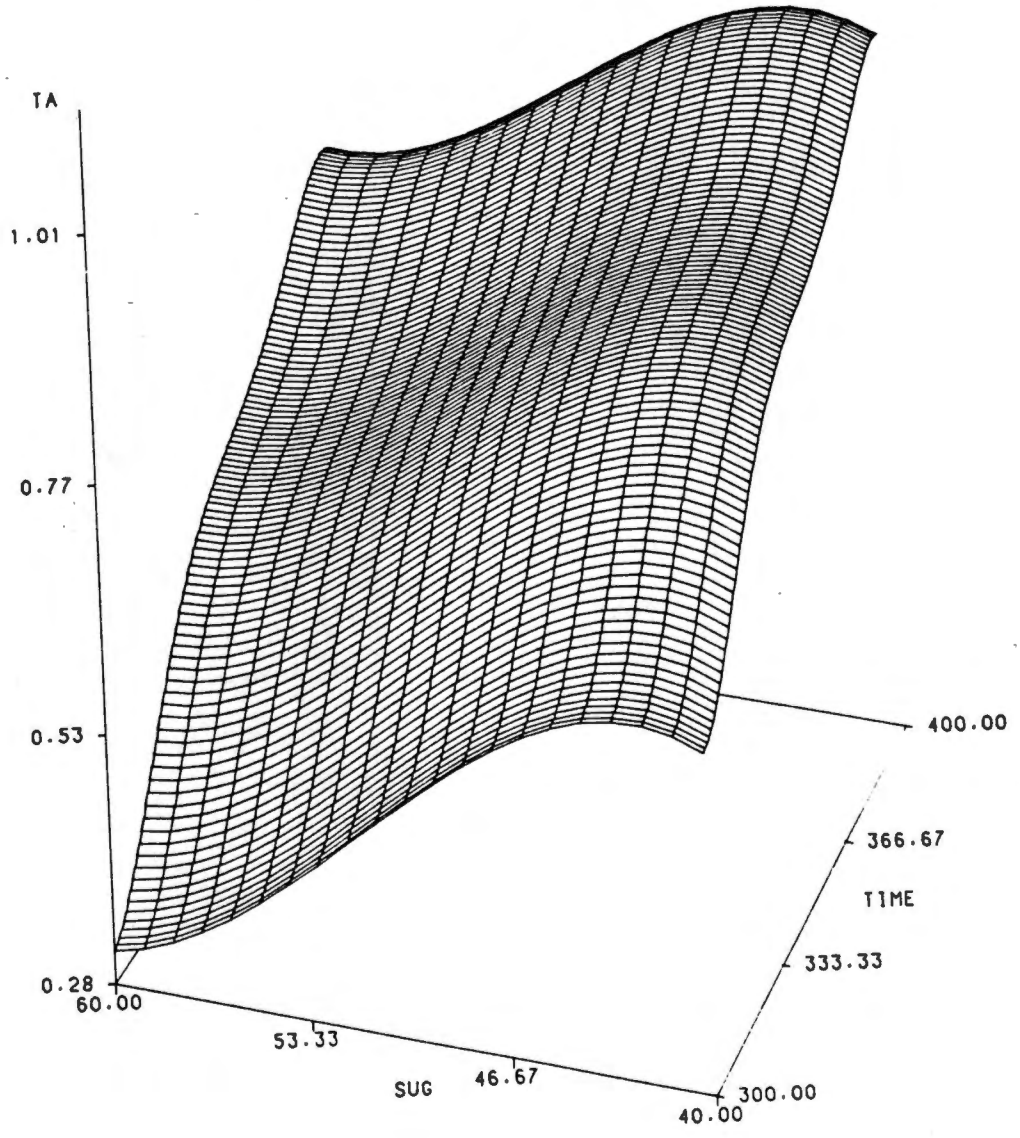


Figure 2. Titratable Acidity of Yogurt with 14% Sweet Potato as Affected by Level of Sugar and Time of Incubation. TA = % Titratable Acidity as Lactic Acid; SUG = Grams Sugar Per 1000 g Yogurt

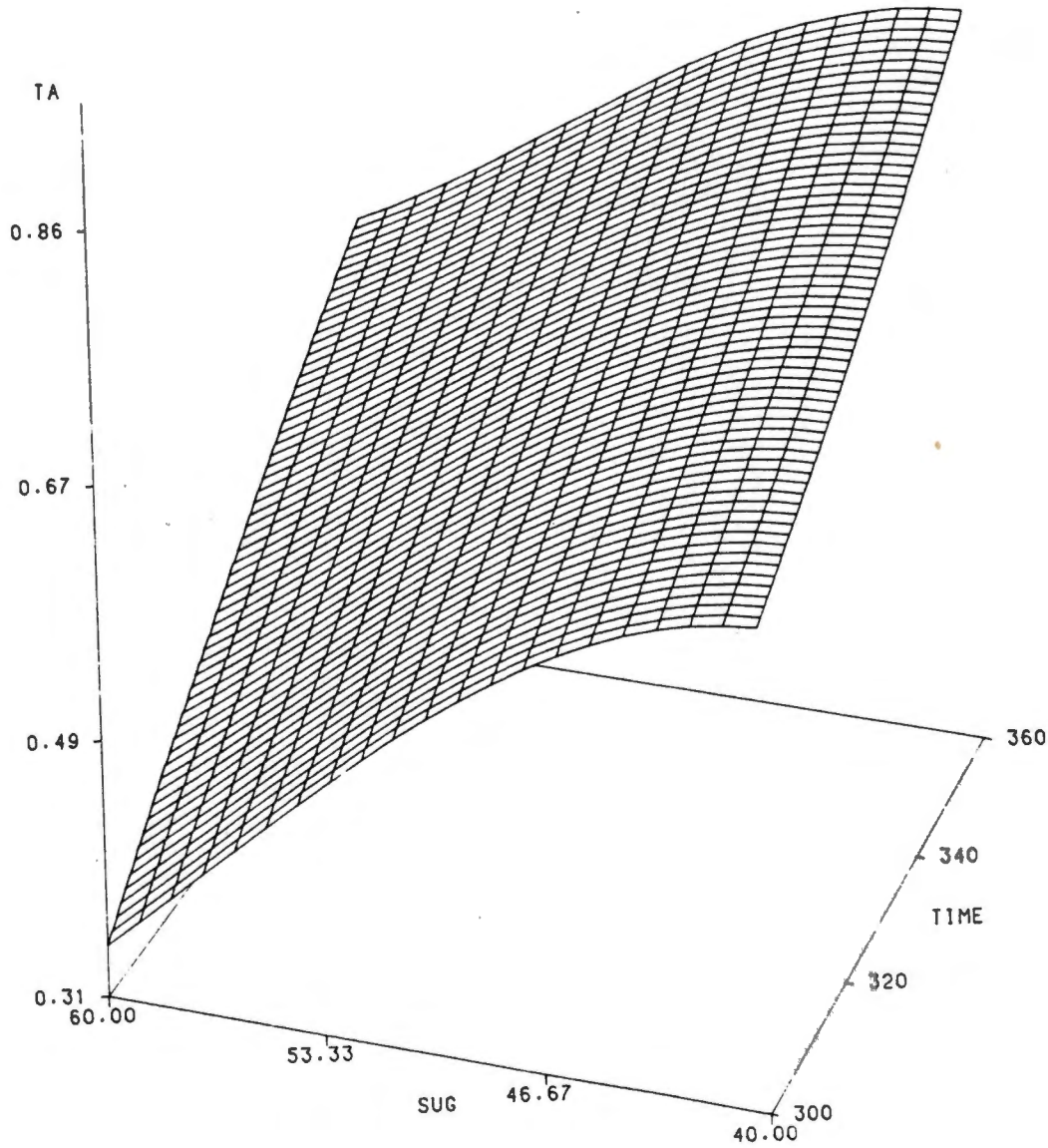


Figure 3. Titratable Acidity of Yogurt with 16% Sweet Potato as Affected by Level of Sugar and Time of Incubation. TA = % Titratable Acidity as Lactic Acid; SUG = Grams Sugar Per 1000 g Yogurt

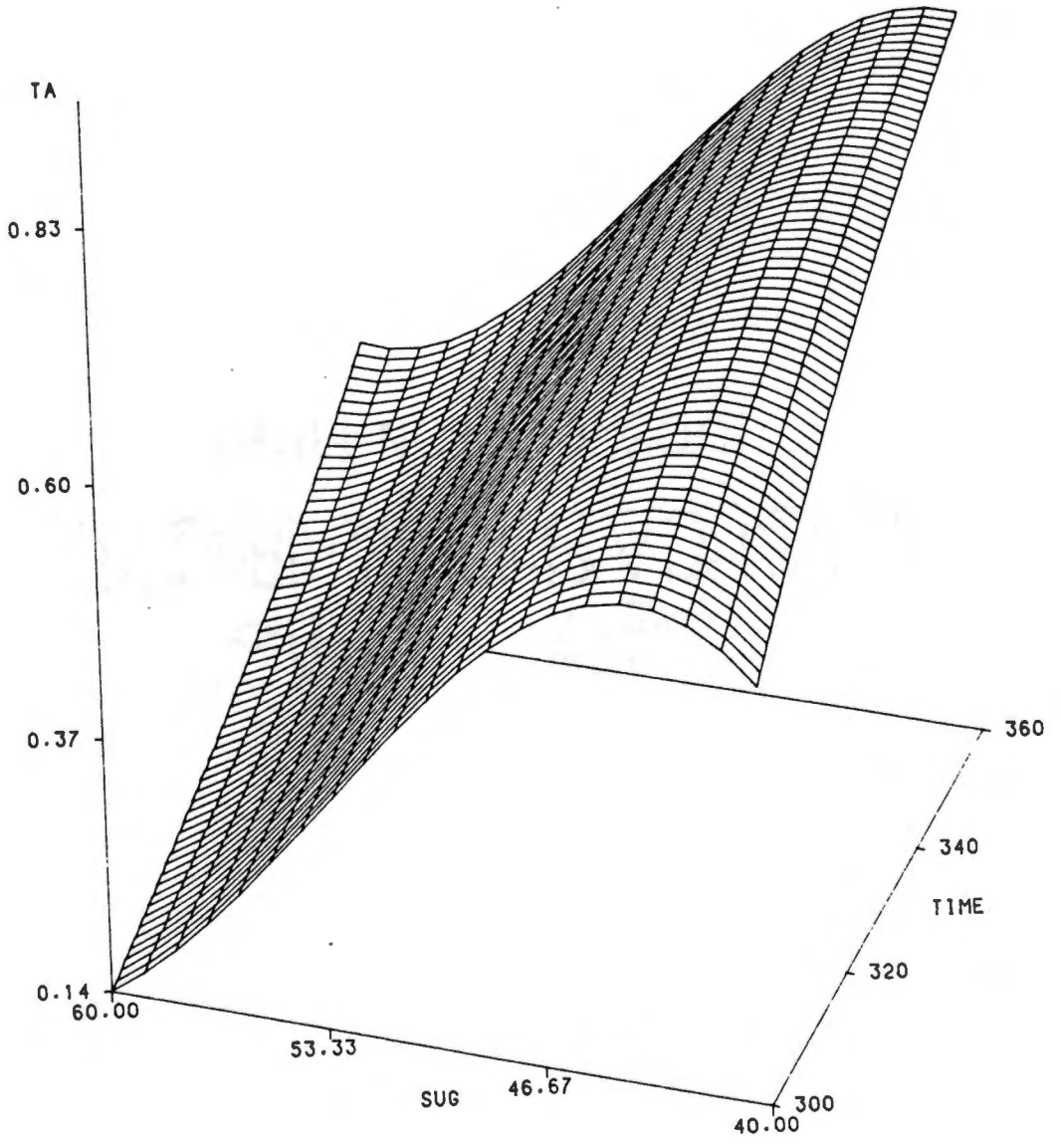


Figure 4. Titratable Acidity of Yogurt with 18% Sweet Potato as Affected by Level of Sugar and Time of Incubation. TA = % Titratable Acidity as Lactic Acid; SUG = Grams Sugar Per 1000 g Yogurt

increased acidity to less than 0.85% (Figure 2). Incubation time was increased from 360 to 400 minutes to obtain acidity up to 0.85%. Thus after 400 minutes, acidity at 4% sugar was 0.96, and 6% sugar, 0.68%

At 16% sweet potato, yogurt which contained 4% sugar developed 0.60% acidity after 300 minutes incubation and 0.83% after 360 minutes (Figure 3). By increasing the sugar to 6%, acidity increased to a lower level. With incubation of 300 minutes, acidity reached 0.39% and with 360 minutes, 0.60%.

Yogurt with the highest level of sweet potato of 18% developed the lowest levels of acidity. At 4% sugar, acidity was 0.51% after 300 minutes incubation and 0.75% after 360 minutes (Figure 4). Sugar at 6% had a very pronounced effect on limiting acid development. After 300 minutes incubation acidity had reached 0.14 and after 360 minutes, only 0.41%. Overall, at a given percentage of sweet potato and sugar, the percentage acidity increased as time of incubation was increased. When the percentage of sugar was increased at a given level of sweet potato and period of incubation, the production of acidity decreased. An increase in level of sweet potato caused a lowering of acidity for all levels of sugar at a given period of incubation. Meiklejohn et al. (1978), reporting on the phenomenon of seasonal inhibition of growth of yogurt cultures, stated that inhibition occurred when the product

remained above pH 4.6 after 5 hours of incubation at 42°C. The inhibitory effect on the starter bacteria seemed to be associated with the use of materials to increase the total solids content to about 25%. The authors also found that the concentration of sugar in the yogurt mixture played some role in the phenomenon of culture inhibition. The researchers reserved that when the sugar level was lowered to 8%, the inhibitory effect ceased. At 10% sugar there was a reduced degree of inhibition. At 22% total solids inhibition could be overcome even with a sucrose level of 12%.

Results of this study are in agreement with those of the literature. Percentages of sweet potato and sugar seemed to have had an inhibitory effect on the starter culture activity. When percentages of sweet potato and sugar were increased, gelation of the yogurt mixture was decreased; under extreme conditions gelation did not occur. Thus, the starter culture could not grow properly in such a saturated medium. The inhibitory effect of the higher solids content can be overcome by lowering the level of total solids of the yogurt mixture. This change can be accomplished by reducing the amount of sweet potato or the amount of sugar. Reducing the amount of sweet potato in the yogurt might yield a product with a less desirable body and texture, and appearance and color. Consequently, a reduction of the level of sugar to the minimum required for

adequate fermentation might be a plausible solution to overcome the inhibitory effect on the starter culture. For these reasons, the sugar level of additional samples was set at 5% for the purpose of predicting time of incubation necessary to reach 0.85% total acidity. The times of incubation for yogurt with 12, 14, 16, and 18% sweet potato were generated from the following equations:

Equation of 12% sweet potato was

$$Y = -3.43 - 0.0086Z + 0.023X - 0.000029X^2$$

Equation of 14% sweet potato was

$$Y = -3.06 - 0.012Z + 0.021X - 0.000024X^2$$

Equation for 16% sweet potato was

$$Y = -0.19 - 0.013Z + 0.0048X - 0.00000129X^2$$

Equation for 18% sweet potato was

$$Y = -0.48 - 0.21Z + 0.0084X - 0.0000067X^2$$

Z = Percent sugar X = Time (minutes)

Y = Percent titratable acidity

The predicted periods of times necessary to reach 0.85% titratable acidity in yogurt with 12, 14, 16, and 18% sweet potato were 6.25, 6.42, 6.50, and 7.25 hours, respectively. The percentage of acidity produced from test samples containing 12, 14, 16, and 18% sweet potato were 0.857, 0.886, 0.871, and 0.894, respectively. The increase in the period of time of incubation at the high percentages of sweet potato was expected due to the inhibitory effect of the higher percentage of total solids on the starter culture.

B. Effect of Gelation and Sweet Potato Levels on the Firmness of Yogurt.

The analysis of variance for the effect of four levels of sweet potato, four levels of gelatin, and two replications on the firmness of yogurt is presented in Table 2. The amount of gelation had a significant effect (1% level) on the yogurt firmness, but the percentage of sweet potato and replication did not have an effect on firmness.

The average firmness values of the yogurt samples are in Table 3. The mean value of all the samples as affected by sweet potato was 294 cm^2. The firmness values of yogurt showed an increase as a level of gelatin was increased. Firmness values for yogurt with 2.52 and 3.18 g gelatin were not significantly different. Firmness of yogurt with 2.20 of gelatin was significantly lower than firmness of yogurt at all higher levels of gelatin.

Figure 5 shows the predicted effect of gelatin on the sweet potato yogurt firmness. As the level of gelatin (data for all levels of gelatin combined) was increased, the firmness value increased until gelatin reached approximately 3.0 g, beyond which no increase occurred. At 3.0 g gelatin the predicted force was 315 cm^2.

The Bostwick consistometer values are presented in Appendix 6. A wide variation occurred in the values among

TABLE 2

SUM OF SQUARES FROM THE ANALYSIS OF VARIANCE FOR FORCE MEASUREMENT (FIRMNESS) OF SWEET POTATO YOGURT AS AFFECTED BY LEVELS OF SWEET POTATO AND GELATIN

Source	d.f.	Sum of squares Force
Sweet potato level	3	3993.18NS
Gelatin level	3	52546.95**
Replication	1	208.41NS
Error	24	29713.93

*Significant at 0.05 level.

NS Not significant.

TABLE 3

MEAN FIRMNESS MEASUREMENT ON THE SWEET POTATO YOGURT[+]

	Firmness force (cm^2)
----------% sweet potato----------	
12	285.02[a]
14	303.49[a]
16	293.54[a]
18	273.09[a]
----------g gelatin----------	
2.20	225.80[b]
2.52	303.02[a]
2.85	288.56[a]
3.18	337.76[a]

[+] Level of sugar in the yogurt was 5%.

[a-b] Means within a column and an independant variable followed by the same letters are not significantly different at the 0.05 level.

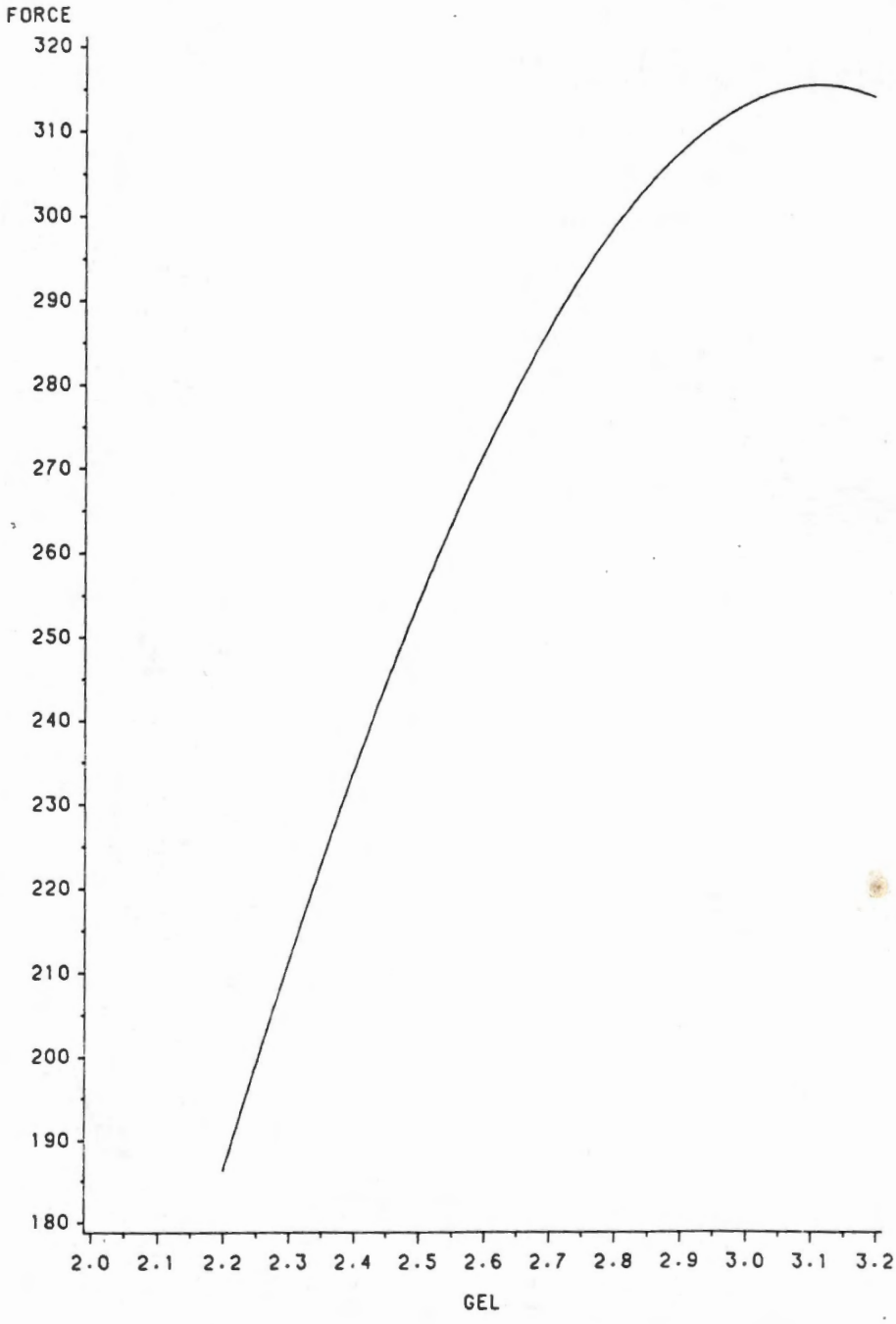


Figure 5. Predicted Firmness (Work-force in cm^2) of Yougrt with Sweet Potato (Composite Data for 12, 14, 16, and 18% Sweet Potato) and Difference Levels of Gelatin; Sugar at 5% GEL = Gelatin

the yogurt samples. This might be due to variation in heating time during the processing steps. During heating the temperature was allowed to reach 82°C, but the duration of heating time was not consistant due to the heating of samples in batch amounts. This condition could have lead to some experimental errors. Neilson (1975) and Rasic and Kurmann (1978) reported that physical properties of yogurt were influenced by milk composition and manufacturing conditions. The authors indicated that variables affecting physical properties included heat treatment applied to milk, protein content and acidity of milk, homogenization treatment, aspects of the bacterial culture, mechanical handling of the coagulum, and the presence of stablizers. Heating of milk to temperatures to exceed normal pasteurization temperatures (72°C for 16 seconds) is known to improve the consistency of yogurt (Parnell-Clunies et al., 1986). However, there is a considerable controversy regarding the temperature-time relationship necessary to yield the product with acceptable stability. This finding seemed to be applicable to this study. It is important to mention that due to the properties of both milk and sweet potato, each processing step should be carried out with extreme care to obtain a desirable end product of excellent texture. Parnell-Clunies et al. (1986) reported that the flow behavior of yogurt can be described as non-Newtonian. Such values are often invalid for comparative use since

shear rates are rarely compatable between different studies. Shear rates are influenced by multitude of variables such as the physical and chemical characteristics of the ingredients and the methods and preparation and processing the yogurt.

C. Sensory Evaluation-Expert Panel

The analysis of variance of values for flavor, body and texture, and appearance and color of sweet potato yogurt as determined by a panel of trained panelist are shown in Table 4. Neither the amount of gelatin nor the percentage of sweet potato had a significant effect of the attributes of yogurt, according to the panel. There were differences among the mean scores of the panelists for each of the attributes. The interaction of the levels of gelatin and sweet potato was significant at the 0.05% level for appearance and color.

The mean value for flavor, body and texture, and appearance and color as assigned by the trained panelist are presented in Table 5. Levels of sweet potato and gelatin had no effect on scores for any of the three attributes. The mean scores as affected by levels of sweet potato or gelatin were 7.64 flavor, 3.87 for body and texture, and 3.83 for appearance and color. Accordingly, the samples were determined to have flavor between "good" and "acceptable" catagories (footnote, Table 5), and body and texture, and appearance and color between "very good" and

TABLE 4

SUM OF SQUARES FROM THE ANALYSIS OF VARIANCE OF VALUES FOR FLAVOR, BODY AND TEXTURE, AND APPEARANCE AND COLOR OF SWEET POTATO YOGURT AS ASSIGNED BY THE TRAINED PANEL

	Sum of Squares					
	Flavor		Body and Texture		Appearance and color	
Source	d.f.	ss	d.f.	ss	d.f.	ss
Panelists (p)	3[a]	10.23*	4	15.27**	4	7.33**
Replication (R)	1	0.19 NS	1	1.07 NS	1	0.00 NS
Gelatin (G)	1	0.021 NS	1	0.07 NS	1	0.27 NS
Sweet Potato (SP)	2	0.29 NS	2	1.03 NS	2	2.23 NS
G X SP					2	3.03*
Error	40	46.25	51	23.50	49	17.47

[a]One panelist not included because of lack of repeatability.

*Significant at the 0.05 level.

**Significant at the 0.01 level.

NS Not significant.

TABLE 5

MEAN VALUES FOR FLAVOR, BODY AND TEXTURE, AND APPEARANCE AND COLOR OF SWEET POTATO YOGURT AS ASSIGNED BY TRAINED PANEL

Attribute	% Sweet Potato			Gelatin, g		Panelist				
	14	16	18	4.40	5.04	1	2	3	4	5
Flavor+	7.75[a]	7.56[a]	7.63[a]	7.63[a]	7.67[a]	7.75[ab]	8.33[a]	7.08[b]	7.42[ab]	+++
Body & Texture++	3.80[a]	3.75[a]	4.05[a]	3.83[a]	3.90[a]	4.08[d]	3.42[d]	3.67[d]	4.75[c]	3.42[d]
Appearance and Color++	3.65[a]	3.75[a]	4.10[a]	3.77[a]	3.90[a]	3.25[d]	3.92[cd]	3.67[cd]	4.25[c]	4.08[c]

+ 1 = criticism, 10 = no criticism of flavor

++ 1 = criticism, 5 = no criticism

+++ Panelist not included because of lack of repeatability.

[a-b]Means within a row and an independent variable followed by the same letters are not different at the 0.05 level.

[c-d]Means within a row for the independent variable panelist followed by the same letters are not different at the 0.01 level.

"good" categories. The mean scores of individual panelists for each of the three quality attributes were significantly different, indicating that additional training might have been beneficial

The significant interaction between levels of sweet potato and gelatin as it affected appearance and color is probably of minor importance (Table 4). However, the mean scores do indicate a trend for more desirable appearance and color when the level of sweet potato was lowest (14%) and level of gelatin was highest (5.4 g).

D. Consumer Panels

Appendix 4 presents information concerning the panelist who participated in the study. The percentage of male and female members of the panel was 52.4 and 47.6%, respectively. Ages of the panelists were such that 30.2% were 18 - 24 years old; 47.6%, 25 - 34; 15.9%, 35 - 44 years old; 1.6%, 45 - 54 years old; and 4.8%, 55 years old or older. Eighty-one percent of the panelists preferred flavored yogurt, 6.3% preferred plain yogurt, and 12.7% had no preference for either one. The frequency of which panelists consumed yogurt was 22.2% weekly, 39.7% monthly, 38.1% yearly. The rates at which panelists purchased flavored yogurt were as follows: 95.2% had purchased flavored yogurt while 4.8% had not purchased flavored yogurt. The panelists were asked if they would buy the

sweet potato yogurt if it were available for purchase, and 22.2% responded "no;" 73%, "yes;" and 4.8%, "maybe." Age and purchase characteristics were discarded from the analysis of variance because there was an unproportional inequality in the sample groups. The only criteria used in selecting a panelist to evaluate the yogurt samples was that the person not dislike yogurt.

Table 6 presents the analysis of variance of scores assigned by the hedonic ("consumer") panel for selected samples of sweet potato yogurt. Gender of the panelists had a significant (0.05% level) influence on scores assigned for flavor and acceptability but did not have an influence on scores of texture and color. The individual preference groups (catorgized according to preference for flavored yogurt) of panelists reacted significantly different (0.01% level) from each other when evaluating sweet potato yogurt samples (Table 6). The frequency at which the panelist purchased yogurt influenced their evaluation of the yogurt. Significant differences were found for flavor (0.05% level), and for texture, color, and acceptability (0.01% level).

The male panelists gave higher scores for flavor and acceptability of the yogurt than the female panelists, but the scores for texture and color were not different between gender of panelists (Table 7). Panelists who preferred plain flavored yogurt tended to give the highest scores for the attrtibutes while panelists who had no flavor

TABLE 6

SUM OF SQUARES FROM THE ANALYSIS OF VARIANCE OF EVALUATIONS OF FLAVOR, TEXTURE, COLOR, AND ACCEPTABILITY OF SWEET POTATO YOGURT AS ASSIGNED BY THE "CONSUMER" PANEL[+], [++]

Source	d.f.	Sum of squares			
		Flavor	Texture	Color	Acceptability
Gender	1	5.42*	0.68NS	1.60NS	3.80*
Preference group	2	15.32**	11.30**	12.22**	16.15**
Frequency to purchase	2	7.48*	18.78**	23.00**	9.85**
Willingness to purchase	2	104.40**	19.40**	42.27**	89.48**
Error	293	366.23	275.06	304.84	254.54

[+]Samples consisted of 14, 16, and 18% sweet potato, 5% sugar, and 4.40 g gelatin.

[++]Refer to Appendix 7 for terms under source.

*Significant at the 0.05 level.

**Significant at the 0.01 level.

NS Not significant.

TABLE 7

MEAN VALUES FOR FLAVOR, TEXTURE, COLOR, AND ACCEPTABILITY OF SWEET POTATO YOGURT AS ASSIGNED BY THE "CONSUMER" PANEL

	Flavor	Texture	Color	Acceptability
		Gender		
Male	6.20^{a}	6.59^{a}	6.26^{a}	6.29^{a}
Female	5.94^{b}	6.74^{a}	6.18^{a}	6.09^{b}
		Preference		
Plain	6.62^{a}	6.71^{c}	6.52^{c}	6.67^{c}
Flavored	6.06^{ab}	6.72^{c}	6.24^{cd}	6.20^{cd}
No preference	5.82^{b}	6.28^{d}	5.92^{d}	5.90^{d}
		Frequency		
Weekly	6.33^{c}	6.62^{d}	6.33^{c}	6.38^{c}
Monthly	6.33^{c}	7.02^{c}	6.63^{c}	6.48^{c}
Yearly	5.61^{d}	6.29^{d}	5.68^{d}	5.74^{d}
		Buy		
No	4.92^{d}	6.14^{d}	5.48^{d}	5.11^{d}
Yes	6.40^{c}	6.82^{c}	6.43^{c}	6.50^{c}
Maybe	5.87^{d}	6.60^{cd}	6.13^{c}	6.07^{c}

$^{a-b}$Means within a row and an in dependent variable followed by the same letters are not different at the 0.05 level.

$^{c-d}$Means within a row and an independent variable followed by the same letters are not different at the 0.01 level.

Scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = like slightly, 6 = like moderately, 7 = like very much, 8 = like extremely.

preferences tended to give the lowest scores. Panelists who purchased yogurt on a weekly or monthly basis gave higher scores for flavor, color, and acceptability than panelist who purchased yogurt on a yearly basis. Texture scores of the group which purchased yogurt monthly were higher than scores of the other two groups among which no difference was found. Panelist who stated "yes" or "maybe" to the probability of purchasing sweet potato yogurt tended to give the higher scores for all the attributes of the samples. For the most part, scores given by panelists as they were variously grouped placed the sweet potato yogurt samples between the "like slightly" and the "like moderately" catorgies. The yogurt with 16 and 18% sweet potato was more acceptable than yogurt with 14% sweet potato.

E. Proximate Composition

The analysis of variance for the proximate composition of the sweet potato yogurt samples is shown in Table 8. Replication had no effect for any of the components. The level of sweet potato had a significant effect on the moisture content (0.05 level) and the fat and carbohydrate contents (0.01 level).

The means for protein, fat, ash, dietary fiber, carbohydrate, and moisture are presented in Table 9. The mean moisture content (80.18%) of yogurt with 16% and 18% sweet potato was lower (0.05 level) than that of yogurt with

TABLE 8

SUM OF SQUARES FROM THE ANALYSIS OF VARIANCE FOR PROXIMATE COMPOSITION OF THE SWEET POTATO YOGURT

Source	d.f.	Sum of squares					
		Protein	Fat	TDF[+]	Ash	Carbohydrate	Moisture
Sweet potato level	2	0.00859NS	13.351381**	0.0950NS	0.054NS	12.870**	2.391*
Replication	1	0.00002NS	0.000004NS	0.0024NS	0.021NS	0.009NS	0.231NS
Error	2	0.00170	0.000016	0.0169	0.017	0.058	0.052

[+]Total dietary fiber.

*Significant at 0.05 level.

**Significant at 0.01 level.

NS Not significant.

TABLE 9

MEAN PROXIMATE COMPOSITION OF
THE SWEET POTATO YOGURT

Sweet Potato, %	Proximate Composition (g/100 g DWB[+])					
	Protein	Fat	Ash	TDF[++]	Carbohydrate	Moisture
14	18.99[a]	8.54[c]	3.94[a]	2.26[a]	66.28[d]	81.27[a]
16	19.08[a]	7.22[d]	3.93[a]	2.48[a]	67.28[d]	80.62[b]
18	19.02[a]	4.93[e]	3.73[a]	2.56[a]	69.76[c]	79.73[b]

[+]DWB indicates values are reported on a 100% dry weight basis.

[++]Total dietary fiber.

[a-b]Means within each column followed by the same letters are not significantly different at the 0.05 level.

[c-e]Means within each column followed by the same letters are not significantly different at the 0.01 level.

14% (81.27%) sweet potato. These moisture contents were lower than the moisture content (89.0%) of yogurt reported in the literature which was made with partially skimmed milk (Watt and Merrill, 1963). Increasing the percentage of sweet potato increased the proportion of solids, and therefore, caused a decrease in moisture content.

The mean values for yogurt were 3.7% protein, 1.333% fat, 0.47% ash, 0.75% dietary fiber, and 13.21% carbohydrate on a 100 g edible portion basis. Values reported by Watt and Merrill (1963) showed that yogurt prepared from partially skimmed milk contained 3.4% protein, 1.7% fat, 0.7% ash, 0.0% dietary fiber, and 5.2% carbohydrate on a 100 g edible portion basis. The sweet potato added a considerable amount of dietary fiber to the yogurt which did not exist in yogurt made from partially skimmed milk. The sweet potato contained a mean 2.43% dietary fiber (DWB).

F. Caloric Content

The analysis of variance for the caloric content for both the calculated and the measured methods are presented in Table 10. Sweet potato level had an effect on the calculated (0.01 level) and the measured (0.05 level) values.

The mean caloric values for the yogurt samples are presented in Table 11. The mean caloric content as calculated ranged between 412.6 Kcal (1726 Kjoules) at 14%

TABLE 10

SUM OF SQUARES FROM THE ANALYISIS OF VARIANCE OF THE CALORIC VALUES OF SWEET POTATO YOGURT

Source	d.f.	Sum of squares	
		Calculated	Measured
Sweet potato level	2	332.05**	40.93*
Replication	1	0.19NS	0.21NS
Error	2	0.49	0.89

*Significant at 0.05 level.

**Significant at 0.01 level.

NS Not significant.

TABLE 11

MEAN ENERGY CONTENT: CALCULATED AND MEASURED VALUES[+]

Sweet Potato, %	Caloric values (Kcal/100 g) (DWB[++]) Calculated	Measured
14	412.6[c]	447.2[a]
16	405.2[d]	445.3[a]
18	394.5[e]	440.9[b]

[+]To convert Kcal to Kjoule, use the following equation: KJoule = Kcal X 4.184.

[++]DWB indicates the values are reported on a 100% dry weight basis.

[a-b]Means within each column followed by the same letters are not significantly different at the 0.05 level.

[c-e]Means within each column followed by the same letters are not significantly different at the 0.01 level.

sweet potato to 394.5 Kcal (1651 Kjoules) at 18% sweet poato DWB. For the measured values, the mean caloric content ranged from 447.2 Kcal (1971 Kjoules) at 14% sweet potato to 440.9 Kcal (1845 Kjoules) at 18% sweet potato. As the level of sweet potato was incresed, the proportional amount of fat was decreased, and, therefore, the caloric content was decreased also. On the edible basis the mean calculated caloric value was 78.8 Kcal (330 Kjoules), and the mean measured caloric value was 86.6 Kcal (362 Kjoules). Caloric values reported by Watt and Merrill (1963) were 50 Kcal (209.2 Kjoules) per 100 g edible yogurt made from partially skimmed milk. The caloric content of sweet potato baked in the skin was 141 Kcal (589.9 Kjoules) for a 100 g edible portion (Watt and Merrill, 1963). The increase in caloric content of the sweet potato yogurt was due to the caloric contribution of the sweet potato.

G. Vitamin Content-Water Soluble

The analysis of variance of the effect of sweet potato on the amount of water soluble vitamins in yogurt are presented in Table 12. The presence of sweet potato had a significant effect on the vitamin C content (0.05 level) but no effect on the contents of riboflavin and niacin. Replication was not significant.

The mean values for riboflavin, niacin, and vitamin C are shown in Table 13. The mean amount of riboflavin and

TABLE 12

SUM OF SQUARES FROM THE ANALYSIS OF VARIANCE FOR VITAMIN CONTENT OF SWEET POTATO YOGURT

Source	d.f.	Sum of squares			
		Riboflavin	Niacin	Vitamin C	Carotene
Sweet potato level	2	0.00000023 NS	0.00000135 NS	0.00000112*	0.000183**
Replication	1	0.00000001 NS	0.00000002 NS	0.00000003 NS	0.0000007
Error	3	0.00000039	0.00000078	0.00000006	0.0000042

*Significant at the 0.05 level.

**Significant at the 0.01 level.

NS Not significant.

TABLE 13

MEAN VITAMIN CONTENT OF SWEET POTATO YOGURT

% Sweet Potato	Sum of squares: Riboflavin (mg/100 g DWB[+])	Niacin (mg/100 g DWB[+])	Vitamin C (mg/100 g DWB[+])	Vitamin A: IU[++]	Vitamin A: RE[+++]
14	0.408[a]	0.622[a]	0.303[b]	9717.0[c]	971.0[c]
16	0.378[a]	0.562[a]	0.311[b]	11308.0[b]	1131.0[b]
18	0.431[a]	0.689[a]	0.408[a]	12518.0[a]	1252.0[a]

[+]DWB indicates values are reported on a 100% dry weight basis.

[++]IU = International Units.

[+++]RE = Retinol Equivalents.

[a-c]Means within each column followed by the same letters are not significantly different at the 0.05 level.

niacin was 0.406 and 0.624 mg/100 g yogurt (DWB), respectively. Yogurt with 18% sweet potato had a higher level (0.05 level) of vitamin C than yogurt with 14 and 16% sweet potato, among which there was no difference. The amount of riboflavin, niacin, and vitamin C in yogurt made from partially skimmed milk was 1.0, 0.1, and 0.2 mg/100 g of edible portion (Watt and Merrill, 1963). Riboflavin and niacin levels in sweet poato yogurt were higher than those reported in the literature.

Only the content of vitamin C was lower than that reported in the literature. Ascorbic acid (vitamin C) is easily destroyed during processing. Considering the fact that milk and sweet potato are fair sources of vitamin C, the destruction of this vitamin could have taken place during the heating and blending steps in the preparation of the yogurt. Exposure to oxygen and prolonged heating in the presence of the oxygen are detrimental to the stability of vitamin C. Probably the loss of vitamin C had already occurred before production of lactic acid occurred, a condition under which vitamin C would have been more stable.

Thiamine content of sweet potato yogurt was very low and was not reported. Literature reported 0.04 mg and 0.09 mg amounts of thiamine of 100 g of edible portion of yogurt made from partially skimmed milk and from baked sweet potato, respectively (Watt and Merrill, 1963).

H. Vitamin Content-Vitamin A from Beta-Carotene

The analysis of variance of the beta-carotene content is presented in Table 12. Percentage of sweet potato had a significant (0.01 level) effect on beta-carotene content of the yogurt. The vitamin A content (as calculated from beta-carotene values) increased as the level of sweet potato was increased (Table 13). The vitamin A value as reported by Watt and Merrill (1963) for yogurt made from partially skimmed milk was 70 International Units .

I. Mineral Content

The analysis of variance for mineral content of sweet potato yogurt is shown in Table 14. The level of sweet potato yogurt had an effect (0.05 level) only for calcium and zinc. Replication was significant for magnesium.

The means for the minerals are shown in Table 15. The amounts of calcium and zinc decreased as the percentage of sweet potato was increased. The level of sweet potato did not change the amount of the other minerals. The mineral composition of yogurt made from partially skimmed milk was as follows on a 100 g edible portion basis: 120 mg calcium, 14 mg magnesium, 143 mg potassium, 52 mg sodium, 94 mg phosphorus, and 400 ug zinc, respectively (Renner, 1983; Watt and Merrill, 1963). Iron and copper were found in trace amounts. The mean mineral content of a 100 g edible portion of sweet potato yogurt was 100.6 mg calcium, 13.7 mg

TABLE 14

SUM OF SQUARES FROM THE ANALYSIS OF VARIANCE FOR MINERAL CONTENT OF THE SWEET POTATO YOGURT

Source	d.f.	Mean of squares							
		Calcium	Magnesium	Potassium	Sodium	Phosphorus	Zinc	Iron	Copper
Sweet potato level	2	2010.05*	1.00NS	85.37NS	515.64NS	401.84NS	37994.92*	153493.90NS	4779.14NS
Replication	1	79.79NS	5.01*	275.40NS	42.51NS	14.54NS	779.53NS	61327.26NS	4142.77NS
Error	2	20.68	0.50	91.17	27.43	336.12	643.27	209641.68	21970.45

*Significant at the 0.05 level.

NS Not significant.

TABLE 15

MEAN MINERAL CONTENT OF THE SWEET POTATO YOGURT

% Sweet Potato	Calcium	Magnesium	Potassium	Sodium	Phosphorus	Zinc	Iron	Copper
	(mg,100 g DWB+)					(µg,100 g DWB+)		
14	538.38[a]	68.89[a]	1050.99[a]	303.42[a]	479.50[a]	2113.69[a]	1271.3[a]	570.8[a]
16	521.60[b]	68.00[a]	1049.51[a]	304.25[a]	465.71[a]	1996.16[b]	890.2[a]	502.4[a]
18	493.98[c]	68.83[a]	1042.35[a]	284.18[a]	460.01[a]	1920.26[c]	1002.3[a]	527.5[a]

+DWB indicates that the values are reported on a 100% dry weight basis.

a-cMeans within each column followed by the same letters are significantly different at the point 0.05 level.

magnesium, 58.0 mg sodium, 90.0 mg phosphorus, and 400 µg zinc. These values are similar to values of the literature. Other minerals of the sweet potato yogurt on the edible basis had amounts of 200.0 mg potassium, 204.4 µg iron, 103.7 µg.

J. Sugar Content

The analyis of variance for sugar content of the sweet potato yogurt is presented in Table 16. Percentage of sweet potato had a significant effect on the amounts of fructose, glucose, and lactose at the 0.05 level and on the amount of sucrose at the 0.01 level. Sweet potato had no effect on maltose content.

The means of the sugar content for the sweet potato yogurt are shown in Table 17. The amounts of fructose, glucose, sucrose, and lactose in the yogurt with 14% sweet potato was lower than those from yogurt with 16 and 18% sweet potato, among which no difference was found. The sugar content of yogurt with 14% sweet potato was lower than the sugar content of yogurt with 16 and 18% sweet potato for all sugars except lactose. This finding seems to be erroneous and probably is the result of error in sampling techniques. The total sugar content of the yogurt with 14, 16 and 18% sweet potato was 9.45, 38.13, and 38.07 g/100 g yogurt (DWB). The sugar content of yogurt with 14, 16, and 18% sweet potato on a 100 g edible portion was 1.77 g, 7.39

Table 16

SUM OF SQUARES FROM THE ANALYSIS OF VARIANCE FOR THE SUGAR COMPOSITION OF THE SWEET POTATO YOGURT

Source	d.f.	Sum of Squares				
		Fructose	Glucose	Sucrose	Maltose	Lactose
Sweet potato level	2	46478.76*	1111327.95*	15773008.19**	192499.50NS	3211253.34*
Replication	1	1578.53NS	43.90NS	18133.50NS	102727.86NS	0.50NS
Error	2	1485.09	36594.45	9772.34	4201190.88	1062.19

*Significant at 0.05 level.

**Significant at 0.01 level.

NS Not significant.

TABLE 17

MEAN SUGAR COMPOSITION OF THE SWEET POTATO YOGURT

% Sweet Potato	Mean sugar (mg/100 g DWB+)				
	Fructose	Glucose	Sucrose	Maltose	Lactose
14	33.6[b]	110.5[b]	781.8[d]	8245.0[a]	284.5[b]
16	1069.2[a]	4348.0[a]	18599.0[c]	6060.0[a]	8125.2[a]
18	810.4[a]	4944.0[a]	17370.3[c]	6990.0[a]	7960.0[a]

+DWB indicates values are on a 100% dry weight basis.

[a-b]Means within each column followed by the same letters are not significantly different at the 0.05 level.

[c-d]Means within each column followed by the same letters are not significantly different at the 0.01 level.

g, and 7.72 g, respectively. The total sugar content of yogurt made from partially skimmed milk as reported by Watt and Merrill, (1963) was 5.2 g for a 100 g edible portion. Total sugar content of yogurt with 16 and 18% sweet potato was 1.42 and 1.48% times higher than that of the literature.

The major sugars of baked sweet potato (conventional oven or microwave cooked) are maltose, sucrose, glucose, and fructose (Picha, 1985a). The author also reported that the Jewel cultivar of sweet potato had a balanced sugar composition and that maltose was the most abundant sugar in baked roots of all cultivars. The second sugar in abundance was sucrose, followed by the monosaccharides. Consequently, the baked sweet potato made an important contribution to the sugar content of the yogurt. Attempts to evaluate stachyose and raffinose contents were made, but neither of the two sugars was detected.

K. Color Measurement

The sum of squares for the analysis of variance of the effect of levels of sweet potato and sugar and of time of incubation are presented in Table 18. Levels of sweet potato and sugar had significant (0.01 level) effects on Hunter L, "a," and "b" values. Time of incubation affected Hunter L (0.05 level) and "b" (0.01 level) values. Replication was significant (0.01 level) for the three color attributes.

TABLE 18

SUM OF SQUARES FROM THE ANALYISIS OF VARIANCE FOR HUNTER COLOR MEASUREMENT OF YOGURT WITH 12, 14, 16, AND 18% SWEET POTATO

Souce	d.f.	Sum of Squares L	"a"	"b"
Sweet potato level	3	1056.07**	258.60**	546.00**
Sugar level	3	67.77**	7.18**	141.28**
Time	3	6.73*	1.46NS	48.67**
Replication	1	21.80**	197.23**	104.81**
Error	245	190.48	124.20	392.44

*Significant at the 0.05 level.

**Significant at the 0.01 level.

NS Not Significant.

The mean Hunter color values of the yogurt samples are shown in Table 19. As the level of sweet potato was increased, the yogurt developed a darker (lower L values) and more red (higher "a" values) and yellow color (higher "b" values). The yogurt with the highest level of sugar of 6.0% was darker, less red, and more yellow than yogurt with the lowest level of sugar of 4.0%. As the time of incubation was extended from 300 minutes to 360 minutes, the yogurt became lighter, less red, and more yellow. While the various factors had significant effects on color of the yogurt, the changes in color were rather small. From a visual observation the yogurt exhibited a vivid yellow color.

L. Microbiological Analysis

Table 20 shows the microbiological count for sweet puree and yogurt with 16% sweet potato as determined with the MRS and SMA methods. The sweet potato puree had a mean 2.89 log CFU/g count for MRS medium and a mean 3.97 log CFU/g count for SMA medium. These data indicate that lactic acid organisms were probably the dominant initial microflora in the sweet potato puree, but other microorganisms were present.

On the MRS medium, the initial count on the yogurt (before inoculation) was very low or almost absent. This condition was due to the absence of starter culture in the

TABLE 19

MEAN COLOR MEASUREMENTS OF YOGURT WITH 12, 14, 16, AND 18% SWEET POTATO

	Hunter color values [+]		
	L	"a"	"b"
time (minutes)			
300	73.80[b]	5.93[a]	32.30[b]
320	74.13[ab]	5.85[a]	32.70[b]
340	74.09[ab]	5.76[a]	33.34[a]
360	74.24[a]	5.75[a]	33.31[a]
% Sweet Potato			
12	76.73[a]	4.99[c]	30.48[c]
14	74.75[b]	5.35[b]	33.10[b]
16	73.69[c]	5.40[b]	34.19[a]
18	71.10[d]	7.54[a]	33.89[a]
% Sugar			
4.00	74.70[a]	5.97[a]	31.99[b]
4.67	74.42[a]	5.98[a]	32.41[b]
5.33	73.73[b]	5.75[ab]	33.45[a]
6.00	73.42[b]	5.58[b]	33.82[a]

[+]Hunter L (100 = white, 0 = black); "a" (+ "a" = redness, - "a" = greenness); "b" (+"b" = yellowness, - "b" = blueness). Increasing values for "a" and "b" indicate an increase in the intensity of color.

[a-b]Means within each column followed by the same letters are not different at the 0.05 level.

TABLE 20

LOGARITHMIC (BASE 10) MICROBIAL COUNTS ON BAKED SWEET POTATO PUREE AND YOGURT WITH 16% SWEET POTATO, USING MRS AND SMA AGARS+

Time of sampling	Replication	Log CFU/gm MRS	Log CFU/gm SMA
Sweet potato puree	1	2.91	4.02
	2	2.81	3.93
----------yogurt----------			
Before inoculation	1	<1.0 EST	1.30 EST
	2	<1.0 EST	1.84 EST
After inoculation	1	5.60	3.30 EST
	2	5.50	3.60 EST
After fermentation	1	8.30	<1.0 EST
	2	8.14	<1.0 EST

+MRS = Mann Rogasa Sharpe Agar
SMA - Standard Methods Agar

mixture and to the heat treatment given the milk and sweet potato mixture during the preparatory steps. For the milk-sweet potato mixture after inoculation, the mean count increased to 5.55 log CFU/g. During fermentation, bacteria of the starter culture increased to a mean 8.22 log CFU/g. This increase represented an approximate mean of 0.44 log CFU/g each hour. The mean count of S. thermophilus and L. bulgaricus was reported by Kroger (1976) in fresh yogurt to range from 7.41 to 9.62 log CFU/g with increases during storage at 7°C. The finding of this study compared favorably to the reported values. Bills et al. (1972) and Kroger and Fram (1975) reported a large number of microorganisms present in fresh yogurt, but little work has been published demonstrating the actual numbers of microorganisms in the product or the effects of storage on their viability.

Counts on the SMA medium probably represent thermoduric organisms, lactics, microbacterium, bacillus, or other spore forming organisms since the sweet potato yogurt had been heated to 82°C. The initial count was a mean 1.57 log CFU/g before inoculation and a mean 3.45 log CFU/g after inoculation. After fermentation the microbial count on SMA medium was very low or almost absent. This finding showed that the yogurt had a high percentage of lactic acid and the lactic organisms predominated. The pH of the sweet potato yogurt was approximately 4.30 with 0.88% lactic acid.

CHAPTER V

SUMMARY

The objectives of this experiment were to establish critical parameters necessary in the processing of yogurt with sweet potato as an ingredient and to determine the effect of sweet potato on sensory, physical, chemical, and nutritional attributes of the yogurt.

Production of lactic acid in the sweet potato yogurt was related to percentages of sweet potato and sugar and to the periods of incubation. Within each level of sweet potato production of lactic acid decreased as the percentage of sugar was increased from 4 to 6% and as time of incubation was increased from 300 to 360 minutes. The lowest percentage of sweet potato and the lowest percentage of sugar produced the highest percentage of lactic acid at any specific time of incubation. The predicted periods of time to incubate yogurt with 5% sugar and 12, 14, 16, and 18% sweet potato were 6.25, 6.42, 6.50, and 7.25 hours, respectively.

The amount of gelatin affected firmness of the yogurt, but levels of sweet potato had no effect. At 3.0 g gelatin per 500 g yogurt the mean predicted force was 315 cm^2. The flow rates of the yogurt as measured by the Bostwick Consistometer were not consistant.

The trained panelist did not find differences for flavor, body and texture, and appearance and color of selected samples of yogurt as influenced by amount of gelatin and percentage of sweet potato. The mean scores for flavor, body and texture, and appearance and color were 7.65 (10 indicated no criticism of the attribute), 3.87 and 3.83 (5 indicated no criticism of the attribute) for yogurt with 14, 16, and 18% sweet potato, respectively. For the effect of gelatin on flavor, body and texture, and appearance and color the mean scores were 7.65, 3.86, and 3.83, respectively. The panelists described the yogurt samples as "good" to "acceptable."

Hedonic (consumer) panel evaluated the samples for flavor, texture, color, and acceptability. For flavor and acceptability, the male panelists gave the samples a higher scores than the female panelists. The mean scores assigned by panelists who preferred plain yogurt or flavored yogurt were not different from each other. Panelists who consumed yogurt monthly or yearly preferred the sweet potato yogurt over panelist who consumed yogurt at weekly intervals. Of the 63 panelists who participated, 73% stated a willingness to buy the sweet potato yogurt. This group of panelist gave higher scores to the samples than the group of panelist who expressed little or no desire to purchase the yogurt. The scores placed the samples between "like very much" and "liked moderately" categories. Yogurt with 16 and 18% sweet potato was evaluated as most acceptable.

Percentage of sweet potato had a significant effect on moisture, fat, and carbohydrate contents, but not the content of the other components, of the yogurt. Yogurt with 18% sweet potato had the lowest percentage of moisture due to the higher level of sweet potato. Mean values for proximate analysis were 19.0% protein, 3.9% ash, 6.9% fat, 2.43% total dietary fiber, and 67.8% carbohydrate (DWB) and

Sweet potato level affected the caloric content of the yogurt. As level of sweet potato was increased, the caloric content was decreased as the level of fat was decreased also. The calculated value for yogurt with 14% sweet potato was 1,726 kjoules energy, and for yogurt with 18% sweet potato, 1,651 kjoules (DWB).

The level of sweet potato affected the level of vitamin C and pro-vitamin A, but not that of riboflavin and niacin. As the level of sweet potato was increased, the vitamin C content was increased to 0.41 mg and vitamin A to 1,252 RE per 100 g sample (DWB).

As the sweet potato level was increased, calcium and zinc contents of the yogurt decreased. The levels of six other minerals were not affected.

The level of sweet potato affected the levels of fructose, glucose, sucrose, and lactose, but not that of maltose.

Sugar and sweet potato levels had a significant effect

on the Hunter L, "a", and "b" color values, while time of incubation had a significant affect only on L and "b" values. Extending the incubation period increased the L and "b" values. The L value decreased and the "a" and "b" values increased as the level of sweet potato was raised. Yogurt was a light yellow-orange color.

The predominant microfloral of the sweet potato puree was the lactic acid organisms with a mean 2.89 log CFU/g count on SMA medium and a mean 3.97 log CFU/g on MRS medium. The inoculated sweet potato mixture had 5.55 log CFU/g count on MRS medium. During fermentation, the cell count increased rapidly and reached 8.22 log CFU/g, an increase of approximately 0.44 log CFU/g each hour. Counts on SMA medium before and after inoculation were a mean 1.57 log CFU/g and 3.45 log CFU/g, respectively. After fermentation, the microbial count on MRS medium was very low or almost absent.

All steps in the processing of the sweet potato yogurt are critical. The blending time of the mixture of sweet potatoes and milk should be held to a minimum to insure the production of yogurt with acceptable attributes.

APPENDIXES

APPENDIX 1

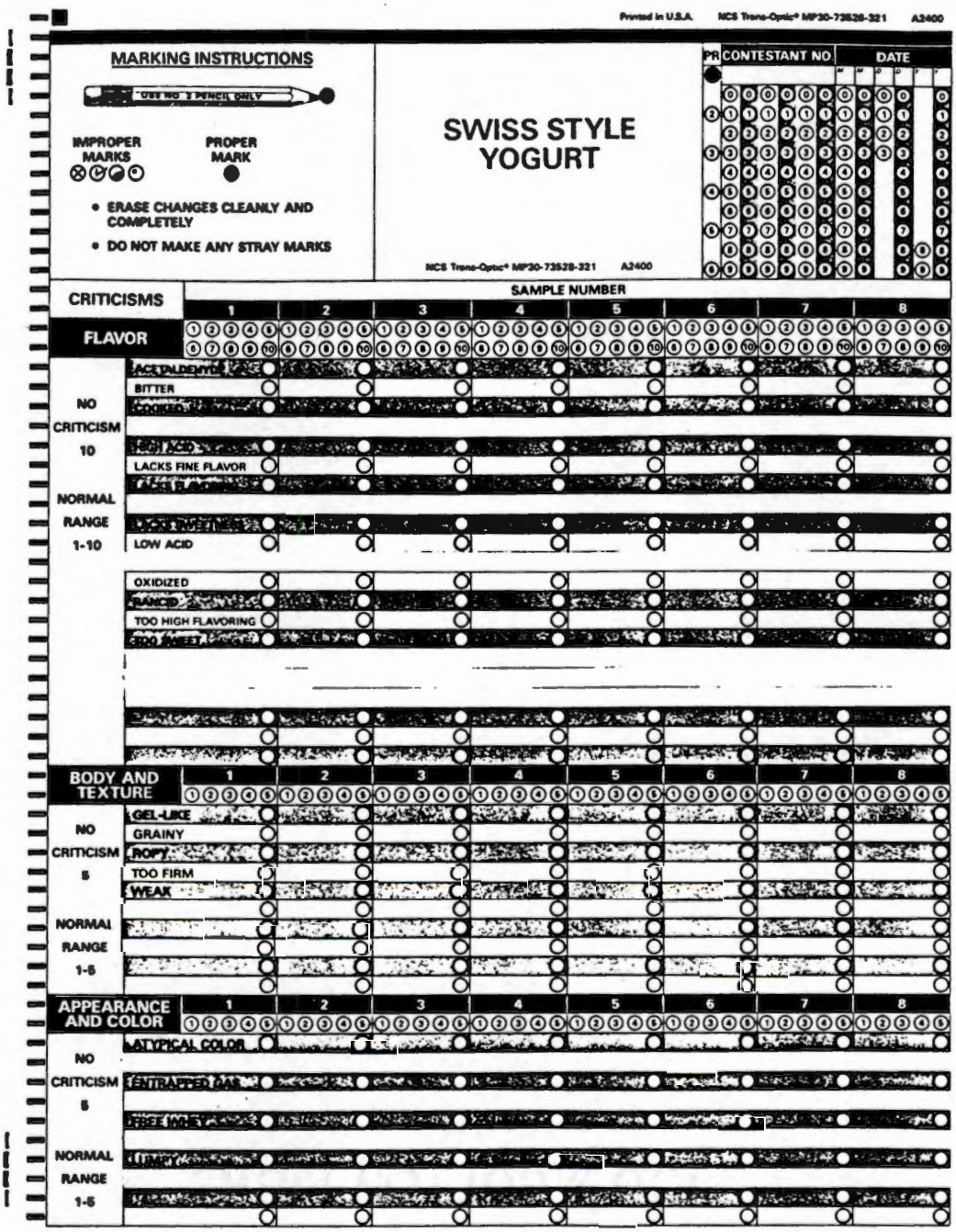
SCHEME TO DETERMINE pH AND PERCENTAGE OF TITRATABLE ACIDITY FOR YOGURT WITH 12% SWEET POTATO+

% Sweet Potato	% Sugar	Time of Incubation	TA	pH
12	4.00	5.00	--	--
12	4.00	5.33	--	--
12	4.00	5.67	--	--
12	4.00	6.00	--	--
12	4.67	5.00	--	--
12	4.67	5.33	--	--
12	4.67	5.67	--	--
12	4.67	6.00	--	--
12	5.33	5.00	--	--
12	5.33	5.33	--	--
12	5.33	5.67	--	--
12	5.33	6.00	--	--
12	6.00	5.00	--	--
12	6.00	5.33	--	--
12	6.00	5.67	--	--
12	6.00	6.00	--	--

+This scheme was followed to prepare yogurt with 14, 16 and 18% sweet potato for measurement of pH and titratable acidity.

APPENDIX 2

EVALUATION SHEET USED BY THE EXPERT PANELS TO SCORE THE YOGURT WITH SWEET POTATO



APPENDIX 3

FORM USED BY HEDONIC PANEL TO EVALUATE YOGURT WITH SWEET POTATO

Please taste the sample of yogurt and describe how well you like the color, flavor, and texture of the sample. Please give us a rating of how well you liked the product overall.

SAMPLE NUMBER _____

Panelist number _____

COLOR

Like extremely	_____
Like very much	_____
Like moderately	_____
Like slightly	_____
Dislike slightly	_____
Dislike moderately	_____
Dislike very much	_____
Dislike extremely	_____

TEXTURE (how the yogurt feels in our mouth)

Like extremely	_____
Like very much	_____
Like moderately	_____
Like slightly	_____
Dislike slightly	_____
Dislike moderately	_____
Dislike very much	_____
Dislike extremely	_____

OVERALL ACCEPTABILITY

Like extremely	_____
Like very much	_____
Like moderately	_____
Like slightly	_____
Dislike slightly	_____
Dislike moderately	_____
Dislike very much	_____
Dislike extremely	_____

FLAVOR

Like extremely	_____
Like very much	_____
Like moderately	_____
Like slightly	_____
Dislike slightly	_____
Dislike moderately	_____
Dislike very much	_____
Dislike extremely	_____

APPENDIX 4

SUMMATION OF QUESTIONNAIRE COMPLETED BY MEMBERS OF THE HEDONIC PANEL WHO EVALUATED YOGURT WITH SWEET POTATO

Panelist number _____

Thank you for tasting the yogurt samples. We would appreciate it if you would complete the following questionnaire.

1> Gender: Male 33 Female 30

2> Age:

0	less than 18-24
19	18-24
30	25-34
10	35-44
1	45-54
3	55 and over

3> Which do you prefer?

plain yogurt	4
flavored yogurt	51
no preference	8

4> Check the frequency with which you eat yogurt

14	Several times a week
25	Several times a month
24	Several times a year

5> Have you purchased flavored yogurts? No 3 Yes 60

If so, what flavors? _____

_____

6> If the product that you tasted today were available in the market, would you buy it? Yes 46 No 14

Maybe 3

THANK YOU FOR PARTICIPATING IN OUR SURVEY.

APPENDIX 5

SCHEME TO MEASURE COLOR OF YOGURT WITH 12% SWEET POTATO +

% Sweet Potato	% Sugar	Time Minutes	L	"a"	"b"
12	4.00	5.00	--	--	--
12	4.00	5.33	--	--	--
12	4.00	5.67	--	--	--
12	4.00	6.00	--	--	--
12	4.67	5.00	--	--	--
12	4.67	5.33	--	--	--
12	4.67	5.67	--	--	--
12	4.67	6.00	--	--	--
12	5.33	5.00	--	--	--
12	5.33	5.33	--	--	--
12	5.33	5.67	--	--	--
12	5.33	6.00	--	--	--
12	6.00	5.00	--	--	--
12	6.00	5.33	--	--	--
12	6.00	5.67	--	--	--
12	6.00	6.00	--	--	--

+This scheme was followed to prepare yogurt with 14, 16, and 18% sweet potato for color measurement.

APPENDIX 6

SWEET POTATO YOGURT AND CONTROL FLOW RATES AS MEASURED BY THE BOSTWICK CONSISTOMETER

Sample	Flow Rate (cm/30 sec)
12% SP + 2.20 g gelatin	6.50
12% NFDM + 2.20 g gelatin	6.65
12% SP + 2.52 g gelatin	5.90
12% NFDM + 2.52 g gelatin	6.30
12% SP + 2.85 g gelatin	5.80
12% NFDM + 2.85 g gelatin	5.15
12% SP + 3.18 g gelatin	4.50
12% NFDM + 3.18 g gelatin	4.90
14% SP + 2.20 g gelatin	6.20
14% NFDA + 2.20 g gelatin	6.75
14% SP + 2.52 g gelatin	3.90
14% NFDM + 2.52 g gelatin	4.50
14% SP + 2.85 g gelatin	4.00
14% NFMD + 2.85 g gelatin	5.90
14% SP + 3.18 g gelatin	3.00
14% NFDM + 3.18 g gelatin	3.70
16% SP + 2.20 g gelatin	5.40
16% NFDM + 2.20 g gelatin	6.50
16% SP + 2.52 g gelatin	4.80
16% NFDM + 2.52 g gelatin	6.50
16% SP + 2.85 g gelatin	6.10
16% NFDM + 2.85 g gelatin	5.10
16% SP + 3.18 g gelatin	4.30
16% NFDM + 3.18 g gelatin	4.65
18% SP + 2.20 g gelatin	6.50
18% NFDM + 2.20 g gelatin	6.90
18% SP + 2.52 g gelatin	5.00
18% NFDM + 2.52 g gelatin	5.60
18% SP + 2.85 g gelatin	5.20
18% NFDM + 2.85 g gelatin	5.90
18% SP + 3.18 g gelatin	3.70
18% NFDM + 3.18 g gelatin	4.20

SP - Sweet Potato NFDM - non-fat dry milk

LIST OF REFERENCES

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Alcott, K. M. and Labuza, T. P 1972. Yogurt: Is it truly Adell's B vitamin factory? Food Prod. Dev. 6(11):50

Alm, L. 1982. Effect of fermentation of milk fat of Swedish fermented milk products. J. Dairy Sci. 65:521.

Alstin, F. 1985. Experience with the fibertec E in relation to the AOAC study on dietary fiber. Intecatur instruction manual for fibertec E.

Anonymous. Undated. Yogurt. Technical Bulletin YG 9725, Microlife Technics, Sarasota, Florida.

Anonymous. 1960. Oxygen Bomb Calorimetry and Combustion Method. Technical Manual 130, Parr Instrument Co., Moline, Illinois.

Anonymous. 1976. Composition and nutritive value of dairy food. Dairy Council Digest 47:25.

Anonymous. 1984. Composition of Foods: vegetables and vegetable products. Agriculture Handbook 8-11. USDA Human Nutrition Information Service, United States Department of Agriculture, Washington, D.C.

AOAC. 1984. "Official Methods of Analysis." 14th ed. Association of Official Analytical Chemists, Washington, D.C.

Augustin, J. 1984. Simulataneous determination of thiamine and riboflavin in foods by liquid chromatography. J.A.O.A.C. 67(5):1012.

Bills, D.D., Yang, C.S., Morgan, M.E. and Bodyfelt, F.W. 1972. Effect of sucrose on the production of acetaldehyde and acids by yogurt culture bacteria. J. Dairy Sci. 55:1570.

Bogdanov, I.G., Velichkov, V.T., and Gurevich, A.I. 1978. Antitumor action of glycopeptides from the cell wall of Lactobacillus bulgaricus. Bull. Exp. Biol. Med. 84:1750.

Bourne, M.C. 1978. Texture profile analysis. Food Technol. 32(7):62.

Bradbury, J.H., Baines, J., Hammer, B., Anders, M. and Millar, J.S. 1984. Analysis of sweet potato (Ipomoea batatas) from The Highlands of Papua New Guinea: Relevance to the incidence of Enteritis necroticans. J. Agric. Food Chem. 32:469.

Breslaw, E.S. and Kleyn, D.H. 1973. In vitro digestibility of protein in yogurt at various stages of processing. J. Food Sci. 38:1016.

Bureau, J.L. and Bushway, R.J. 1986. HPLC determination of carotenoids in fruits and vegetables in the United States. J. Food Sci. 51:128.

Burkitt, D.P. and Trowell, H. 1975. "Refined Carbohydrate Foods and Disease." Academic Press. New York, New York.

Busta, F.F., Patterson, E.H., Adams, D.M. and Johnson, M.G. 1984. Colony count methods. In "Compendium of Methods for the Microbiological Examination of Foods." Ed. Speck, M.L., p. 62. American Public Health Association, Washington, D.C.

Chambers, J.V. 1979. Culture processing techniques important to the manufacture of good quality yogurt. Cultured Dairy Prod. J. 14(2):28.

Chandan, R.C., Argyle, P.J. and Jones, N. 1969. Proteolytic activity of lactic cultures. J. Food Sci. 52:894.

Chichester, D.F. and Tanner, F.W., Jr. 1972. Antimicrobial food additives. In "Handbook of Food Additives." Furia, T.E., Ed. CRC Press, The Chemical Rubber Co., Cleveland, Ohio.

Christensen, V.W. 1970. Yogurt: the bright star among dairy products. Food Prod. Dev. 4:18.

Chung, K.C. and J.M. Geopfert. 1970. Growth of Salmonella at low pH. J. Food Sci. 35:326.

Clemens, R.A. and Brown, R.C. 1986. Nutrition and the elderly: biochemical methods for accessing the vitamin and mineral nutritional status of the elderly. Food Technol. 40:71.

Connolly, E. 1978. Yogurt quality assurance programs. Cultured Dairy Prod. J. 13(1):22.

Cooley, J.S. 1948. Sweet potato world production and food values. Econ. Bot. 2:83.

Cousin, M.A. and Marth, E.H. 1977a. Lactic acid production by Streptococcus thermophilus and Lactobacillus bulgaricus in milk precultured psychrotrophic bacteria. J. Food Prot. 40:475.

Cousin, M.A. and Marth, E.H. 1977b. Cottage cheese and yogurt manufactured from milks precultured with psychrotrophic bacteria. Cultured Dairy Prod. J. 12:15.

Crosby, D.G. 1964. The organic constituents of food. III. Sweet Potato. J. Food Sci. 29:287.

Davis, J.G. and Latto, D. 1957. Yogurt in gasteroentritis of infancy. Lancet 2:275.

Davis, A. 1970. "Let's Eat Right to Keep Fit." The New American Library, Inc. New York, New York.

Deeth, H.C. and Tamime, A.Y. 1981. Yogurt: nutritive and therapeutic aspects. J. Food Prot. 44:78.

Dickey, L.F., Collins, W.W. and Young, C.T. 1984. Root protein quantity and quality in a seedling population of sweet potatoes. Hort Sci. 19(5):689.

Duitschaever, C.L. 1978. Yoghurt from goat milk. Cultured Dairy Products J. 13:20.

Eastwood, M.A. and Passmore, R. 1984. A new look a dietary fiber. Nutr. Today 9:6.

Edmond, J.B. and Ammerman, G.R. 1971. "Sweet Potatoes: Production, Processing, Marketing." AVI publishing Co., Inc., Westport, Connecticut.

Elkins, E.R. 1979. Nutrient content of raw and canned green beans, peaches, and sweet potatoes. Food Technol. 33:66.

Erdman, M.D., Gergen, W.G. and Reddy, C.A. 1977. Amino acid profiles and presumptive nutritional assessment of single-cell protein from certain Lactobacilli. Appl. Environ. Microbiol. 33:901.

FAO/WHO. 1973. Code of principles concerning milk and milk products. CX5/70. Rome, Italy.

FDA. 1985. Eggs and dairy foods: dietary mainstays in decline. FDA Consumer 19(8):10.

Fitzgerald, T.K. 1976. Ipomoea batatas: The sweet potato revisited. Ecol. Food Nutr. 5:107.

Formisano, M., Coppola, S., Percuocco, G., Purcuocco, S., Zoina, A., Germano, S. and Capriglione, J. 1975. Results of five year study on yoghurt. Microbiol. Abstr. 10:19.

Francis, F.J. and Clydesdale, F.M. 1975. "Food Colorimetry: Theory and Applications." Avi Publ. Co., Westport, Connecticut.

Friend, B.A. and Shahani, K.M. 1984. Antitumor properties of Lactobacilli. J. Food Prot. 47:717.

Garvie, E.I. 1978. Lactate dehydrogenases of Streptococcus thermophilus. J. Dairy Res. 45:515.

Goldin, B.R. and Gorbach, S.L. 1976. The relationship between diet and rat fecal bacteria enzymes implicated in colon cancer. J. Natl. Inst. 57:37.

Goldin, B.R. and Gorbach, S.L. 1977. Alternation in fecal microfloral enzymes related to diet, age, Lactobacillus supplements, and dimethylhydrazine. Cancer 40:2421.

Goodbody, S. 1984. Nutritional characteristics of sweet potato collection in the Papua New Guinea highlands. Trop. Agric. 61:20.

Goodenough, E.R. and Kleyn, D.H. 1976. Influence of viable yogurt microflora on digestion of lactose by the rat. J. Dairy Sci. 59(4):601.

Grossowics, N., Kaplan, D. and Sehleerson, S. 1947. Production of an antibiotic substance by Lactobacillus. 4th Report. Proc. Int. Congr. Microbiol.

Hamdan, I.Y. and Mikolajcik, E.M. 1973. Growth, viability, and antimicrobial activity of Lactobacillus acidophilis. J. Dairy Sci. 56:638.

Hargrove, R.E. and Alford, J.A. 1974. Composition of milk products In "Fundamentsla of Dairy Chemistry." 2nd ed., pp. 58-86. Ed. Webb, B.H., Johnson, A.H. and Alford, J.A. Avi. Publ. Co., Westport Connecticut.

Harrison, V.C. and Peat, G. 1975. Serum cholesterol and bowel flora in the newborn. Amer. J. Clin. Nutr. 28:1351.

Hartman, A.M. and Dryden, L.D. 1974. The vitamins in milk and milk products. In "Fundamentals of Dairy Chemistry." 2nd ed., pp. 235-401. Ed. Webb, B.H., Johnson, A.H. and Alford, J.A. Avi Publ. Co., Westport, Connecticut.

Holden, C.D. 1985. Flavor, fatty acid composition, and contents of tocopherols, carotenoids, and phospholipids of beef produced on different feeding regiments. M.S. Thesis. University of Tennessee, Knoxville, Tennessee.

Jones, D.B. and Gersdorff, C.E.F. 1931. Ipomoein, a globulin from sweet potatoes, Ipomoea batatas. J. Biol. Chem. 93:119.

Kamman, J.F., Labuza, T.P. and Warthensen, J.J. 1980. Thiamine and riboflavin analysis by high performance liquid chromatography. J. Food Sci. 45:1497.

Kavasnikov, E.I. and Sodenko, V.I. 1967. Antibiotic properties of Lactobacillus brevis. Dairy Sci. Abstr. 29:3972.

Kelsay, J.L. 1978. A review of research on effects of fiber intake on man. Am. J. Clin. Nutr. 31:142.

Kilara, A. and Shahani, K.M. 1976. Lactase activity of cultured and acidified dairy products. J. Dairy Sci. 59:2031.

Kodama, R. 1952. Studies on lactic acid bacteria. I. Lactolin, a new antibiotic substance produced by acid bacteria. J. Antibiol. 5:75.

Kramer, A. 1973. An analytical and integrative approach to sensory evaluation of food. J. Sci. Food Agric. 24:1407.

Kroger, M. 1973. Controlling the quality of yogurt. Dairy Ice Cream Field 156(1):39.

Kroger, M. 1976. Quality in yogurt. J. Dairy Sci. 59:344.

Kroger, M. and Fram, S.R. 1975. Consumer attitudes towards yogurt. Food Technol. 11:52.

Larmond, E. 1976. The texture profile. In "Rheology and Texture in Food Quality." Ed. de Man, J.M., Voisey, D.W., Rasper, V.F., and Stanley, D.W., p. 546. Avi Publ. Co., Westport, Connecticut.

Little, T.M. and Hills, F.J. 1978. "Agriculture Experimentation; Design and Analysis." John Wiley and Sons, New York, New York.

Luca, C. 1974. Improvement of yogurt quality: lactic acid bacteria and proteolysis of nitrogenous compounds. Dairy Sci. Abstr. 36:663.

Mann, G.V. 1977. A factor in yogurt which lowers cholestermia in man. Atherosclerosis 26:335.

Mann, G.V. and Spoerry, A. 1974. Studies of surfactant and cholestermia in Maasai. Amer. J. Clin. Nutr. 27:464.

Manus, L.J. 1973. Yogurt - how tart? Dairy Ice Cream Field. 156(7):52.

Martin, F.W. 1983. The carotenoid pigment of white-fleshed sweet potatoes. J. Agric. Univ. Puerto Rico 5:494.

Mathia, G.A. 1975. An economic evaluation of consumer characteristics affecting sweet potato consumption. J. Am. Soc. Hort. Sci. 100:529.

Mauro, D.J. and Wetzel, D.L. 1984. Simulataneous determination of thiamin and riboflavin in enriched cereal based products by high performance liquid chromotragraphy using selective detection. J. Chromatography 299:281.

Meiklejohn, P.G. 1978. The phenomenon of seasonal inhibition of yoghurt cultures. Cultured Dairy Products J. 13:8.

Nachev, L. 1969. Lactic acid bacteria in Bulgarian yogurt. III. Proteolytic activity and amino acid pattern in milk culture. Dairy Sci. Abstr. 32:181.

Neilson, V. 1975. Factors which control the body and texture of commercial yoghurts. Am. Dairy Rev. 37(11):36.

Ogai, O.K.; Musaev, Sh. M.; Madrna Khimov, Yu. 1970. Comparative study of the formation of free amino acids by local thermiphilic lactic acid bacteria. Dairy Sci. Abstr. 34:698.

Ottogalli, G., Resmini, P., Randinini, G. and Saracchi, S. 1974. Chemical and microbiological changes in stored yogurt. Dairy Sci. Abstr. 36:314.

Parnell-Clunies, E.M., Kakuda, Y. and Deman, J.M. 1986. Influence of heat treatment of milk on the flow properties of yoghurt. J. Food Sci. 55:1459.

Pelczar, M.J. and Reid, R.D. 1958. "Microbiology." McGraw-Hill Book Co., Inc. New York, New York.

Picha, D.H. 1985a. HPLC determination of sugars in raw and baked sweet potatoes. J. Food Sci. 50:1189.

Picha, D.H. 1985b. Crude protein, minerals, and total caroteinoids in sweet potatoes. J. Food Sci. 50:1768.

Picha, D.H. 1986. Sugar content of baked sweet potatoes from different cultivars and lengths of storage. J. Food Sci. 51:84.

Prosky, L., Asp, N.G., Furda, I., Devries, J.W., Schweizer, T.F. and Harland, B.F. 1985. Determination of total dietary fiber in foods and food products: Colloborative study. J. Assoc. Offic. Anal. Chem. 68(4):677.

Purcell, A.E. and Swaisgood, H.E. 1972. Protein and amino acid content of sweet potato cultivars. J. Am. Soc. Hort. Sci. 97:30.

Purcell, A.E., Walter, W. M., Jr. and Griesbrecht, F. G. 1976. Distribution of protein within sweet potato roots (Ipomoea batatas L.) J. Agric. Food Chem. 24:64.

Rao, D.R., Chawan, C.B. and Pulusani, S.R. 1981. Influence of milk and thermophilus milk on plasma cholesterol levels and heptic cholesterogenesis in rats. J. Food Sci. 46:1339.

Rao, D.R. and Reddy, J.C. 1984. Effects of lactic fermentation of milk on milk lipids. J. Food Sci. 49:748.

Rasic, J. and Panic, B. 1963. A study of the vitamin B_{12} content in milk and milk products. Dairy Ind. 28:35.

Rasic, J.L. and Kurmann, J.A. 1978. "Yoghurt: Scientific Grounds, Technology, Manufacture and Preparations." Technical Dairy Publ. House, Copenhagen, Denmark.

Reddy, G.V. and Shahani, K.M. 1971. Isolation of an antibiotic from Lactobacillus bulgaricus. J. Dairy Sci. 54:748.

Reddy, K. P., Shahani, K.M. and Kulkarni, S.M. 1976. B-complex vitamins in cultured and acidified yogurt. J. Dairy Sci. 59:191.

Reif, G.D., Shahani, K.M., Vakil, J.R. and Crowe, L.K. 1976. Factors affecting the B-complex vitamin content of cottage cheese. J. Dairy Sci. 59:410.

Renner, E. 1983. "Milk and Dairy Products in Human Nutrition." p. 324. W-GmbH, Volkswirtschaftlicher Verlag, Munich, West Germany.

Richardson, G.H. (Ed.). 1985. "Standard Methods for the Examination of Dairy Products." American Public Health Association, Washington, D.C.

Rutgus, R. 1958. Consistency of starch milk puddings. J. Sci. Food Agri. 9:61.

Sandine, W.E. 1979. Roles of Lactobacillus in the intestinal tract. J. Food Prot. 42:239.

SAS. 1985. "SAS User's Guide." 5th ed., SAS Institute, Inc., Cary, North Carolina.

Schneeman, B.O. 1986. Dietary fiber: physical and chemical properties, methods of analysis, and physiological effects. Food Technol. 40:104.

Shahani, K.M., Reddy, G.V. and Joe, A.M. 1974. Nutritional and therapeutic aspects of cultured dairy foods. Proc. XIX Int. Dairy Congr.

Shahani, K.M. and Chandan, R.G. 1979. Nutritional and healthful aspect of cultured and culture - containing dairy foods. J. Dairy Sci. 62:1685.

Speck, M. L. 1976. Interaction among Lactobacilli and man. J. Dairy Sci. 59:338.

Speck, M.L. and Katz, R.S. 1980. Nutritive and health values of cultured dairy foods. Cult. Dairy Prod. J. 15:10.

Tamime, A.Y. 1977. The behavior of different starter cultures during the manufacture of yogurt from hydrolyzed milk. Dairy Ind. Intern. 42:7.

Tamime, A.Y. and Deeth, H.C. 1980. Yogurt: technology and biochemistry. J. Food Prot. 43:939.

Technical Committee S-101. 1980. Sweet potato quality. Southern Cooperative Series Bull. 249.

Thompson, D.P. 1984. Composition of sweet potato cultivars at harvest time. J. Food Sci. Technol. 21:4.

Toma, R.B. and Tabekhai, M.M. 1979. High performance liquid chromatographic analysis of B vitamins in rice and rice products. J. Food Sci. 44:263.

USDA. 1980. The Vegetable Situation, TVS 217. Economic Research Service, United States Department of Agriculture, Washington, D.C.

Vakil, J.R. and Shahani, K.M. 1965. Partial purification of antibiotic from Lactobacillus acidophilus. Bacteriol. Proc., p. 9.

Walter, W.M., Jr. and Catignani, G.L. 1981. Biological quality and composition of sweet otato protein fractions. J. Agric. Food Chem. 29:797.

Watt, B.K. and Merrill, A.L. 1963. Composition of foods. Agriculture Handbook 8, p. 160, United States Department of Agriculture, Washington, D.C.

*WHO. 1973. Energy and protein requirements. Report of a joint FAO/WHO ad hoc expert committee. World Health Organization Technical Report Services 522. Rome, Italy.

Wiesner, H.V., Stahlhut-Klipp, H. and Benner, J. 1975. Occurrence of D(-) lactate in fermented milk, yogurt and kefir. Dairy Sci. Abstr. 37:704.

Zugmunt, L.C. 1982. High pressure liquid chromatographic determination of mono and disaccharides in presweetened cereals: collorborative study. J. Assoc. Offic. Anal. Chem. 65:1982.

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