

201
PREPARATION OF YOGURT-LIKE PRODUCT FROM
FERMENTATION OF EGG WHITE

by

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
LITERATURE REVIEW	3
Composition of Egg White	3
Proximate Composition	3
Egg White Protein Composition	3
Physicochemical Properties of Egg White	7
Viscosity	7
pH	8
Antimicrobial Activity of Egg White	9
Destruction of Pathogens in Egg White	12
Fermentation of Egg White	16
Fermentation of Soybean Milk as New Product Development	19
Fermentation	19
Removal of Beany Flavor	20
MATERIALS AND METHODS	23
Growth Study of Fermentative Bacteria in Egg White ...	23
Liquid Egg White	23
Pasteurization	23
Acidification	23
Culture and Media	24
Inoculation of Egg White	25
Development of a New Fermented Yogurt-like Egg Product	25
Fermentation of Egg White Combined with Skim Milk	26
Fermentation of Egg White Combined with Skim Milk Powder	26
Fermentation of Egg White with Gums Added as Texture Improver	27
Fermentation of Egg White Combined with Soymilk .	28

	Page
A. Soymilk Fermentation	28
B. Fermentation of Combined Soymilk and Egg White	29
Fermentation of Egg White with the Combination of Skim Milk and Soymilk	29
A. Combination of Skim Milk and Soymilk	29
B. Egg White Combined with Alkali Treated Soymilk	30
C. Modification Study	30
Organoleptic Evaluation of New Fermented Yogurt-like Egg Product	31
Composition Analysis	31
Product Evaluation	32
RESULTS AND DISCUSSION	33
Growth Study of Fermentative Bacteria in Egg White ...	33
Development of a New Fermented Yogurt-like Egg Product	43
Fermentation of Egg White Combined with Skim Milk	43
Fermentation of Egg White Combined with Skim Milk Powder	46
Fermentation of Egg White with Gums Added as Texture Improver	48
Fermentation of Egg White Combined with Soymilk ..	48
A. Soymilk Fermentation	48
B. Fermentation of Combined Soymilk and Egg White	48
Fermentation of Egg White Combined with Skim Milk and Soymilk	53
A. Fermentation of Skim Milk and Soymilk ...	53
B. Fermentation of Egg White and Skim Milk Combined with Alkali Treated Soymilk	53
C. Modification Study	57
Organoleptic Evaluation of New Fermented Yogurt-like Egg Product	57
Composition Analysis	60
Product Evaluation	60

	Page
CONCLUSION	62
REFERENCES	63

LIST OF TABLES

Table		Page
1.	Protein in egg albumen	4
2.	The influence of gum on the appearance, color, flavor, and pH of egg white/skim milk : 50/50 fermented at 37 C for 6 hr	49
3.	The pH value and viscosity of the fermentation of egg white (EW) with the combination of skim milk (SM), soymilk (SBM) and 2% glucose at 37 C for 6 hr	55
4.	The pH value and viscosity of egg white (EW) combined with skim milk (SM), soymilk (SBM) and 2% glucose fermented at 37 C for 6 hr	56
5.	The pH value and viscosity of egg white (EW) combined with skim milk (SM), soymilk (SBM), 2% glucose, 0.01% vanilla extract, and 3% sucrose fermented at 37 C for 6 hr	58
6.	Average organoleptic scores of new egg white fermented product	59
7.	Composition of yogurt-like product prepared from fermented egg white (47.4%), alkali treated soymilk (28.4%), skim milk (19.0%), sucrose (2.8%), xanthan gum (0.5%) and vanilla extract (0.01%)	61

LIST OF FIGURES

Figure		Page
1.	Recommended pasteurization temperatures for raw egg white at various pH levels	17
2.	The growth rate and acid production of <u>Lactobacillus bulgaricus</u> NRRL B-548 in pasteurized, neutralized egg white at 37 C	34
3.	The growth rate and acid production of <u>Lactobacillus acidophilus</u> NRRL B-4495 in pasteurized, neutralized egg white at 37 C	35
4.	The growth rate and acid production of <u>Lactobacillus plantarum</u> ATCC 21028 in pasteurized, neutralized egg white at 37 C	36
5.	The growth rate and acid production of <u>Pediococcus cerevisiae</u> NRRL B-1153 in pasteurized, neutralized egg white at 30 C	37
6.	The growth rate and acid production of <u>Lactobacillus plantarum</u> ATCC 21028 with the combination of <u>Pediococcus cerevisiae</u> NRRL B-1153 in pasteurized, neutralized egg white at 30 C	38
7.	The growth rate and acid production of <u>Streptococcus diacetylactis</u> NRRL B-2356 in pasteurized, neutralized egg white at 30 C	40
8.	The growth rate and acid production of <u>Streptococcus thermophilus</u> ATCC 14485 in pasteurized, neutralized egg white at 37 C	41
9.	The growth rate and acid production of <u>Streptococcus lactis</u> NRRL B-633 in pasteurized, neutralized egg white at 30 C	42
10.	The pH value of the combination of egg white (EW) and skim milk (SM) when fermented with 2% <u>Lactobacillus bulgaricus</u> and 2% <u>Streptococcus thermophilus</u> at 37 C	44
11.	The viscosity of the combination of egg white (EW) and skim milk (SM) when fermented with 2% <u>Lactobacillus bulgaricus</u> and 2% <u>Streptococcus thermophilus</u> at 37 C	45
12.	The pH value of the combination of egg white (EW) and skim milk powder (SMP) when fermented with 2% <u>Lactobacillus bulgaricus</u> and 2% <u>Streptococcus thermophilus</u> at 37 C	47

13. The viscosity of egg white/skim milk containing guar, CMC or xanthan gum after fermentation at 37 C for 6 hours 50
14. The pH value and viscosity of soy milk when fermented with 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C for 6 hours 51
15. The pH value of the fermentation of egg white (EW) with the combination of soymilk (SBM) and 2% glucose by 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C 52
16. The viscosity of the fermentation of egg white (EW) with the combination of soymilk (SBM) and 2% glucose by 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C 54

INTRODUCTION

Fermenting egg products for desugaring before drying has long been studied and practiced by the egg industry. However, fermentation of liquid egg whites for developing a new type product has not been extensively researched. Cunningham and Francis (1982) showed that a successful egg-cheddar cheese product was possible through fermentation of whole egg or white and low-fat milk. Those results pointed out the feasibility and suggested further study in the fermentation egg in order to develop new products.

In this study, egg white was rendered suitable for sustaining microbial growth by pasteurization, blending, and acidification. Seven different lactic acid bacteria were inoculated into egg white to determine growth, flavor development, and acid production. Selected cultures were then inoculated into treated egg white and (in combination with glucose, skim milk, soymilk, and other additives) allowed to ferment the blended products.

The basic objectives of this study were: 1) To treat liquid egg whites so that prolific growth of fermentative microorganisms could occur, 2) To monitor growth rate, odor, flavor development, and pH changes of egg white inoculated with different organisms, 3) To test the effects of glucose, skim milk, soymilk, guar gum, CMC, and xanthan gum on the physical and sensory characteristics of new fermented egg products.

Since egg white is recognized as a high protein, low calorie food, the goal of this research was to develop a yogurt-type egg product.

LITERATURE REVIEW

Composition of Egg White

Proximate Composition

Liquid egg white consists of water (87.6%), protein (10.9%), carbohydrate (1.1%), free carbohydrate (0.4%), ash (0.7%) and trace amount of fat (Anonymous, 1969). Carbohydrates in the albumen are in the free form as glucose and in combination with protein as glycoprotein which contains mannose and galactose unit. Protein is the major solid constituent in albumen. The amount of protein in egg white is highly affected by the age of the laying hen and the size of the egg. Marion et al. (1964) studied the relation of egg size and albumen content and found that for each gram of egg weight increment there was a corresponding albumen increased of 0.2%.

Egg White Protein Composition

The egg white proteins are composed of ovalbumin, conalbumin, ovomucoid, lysozyme, globulins, ovomucin, flavoprotein, ovomucoid, avidin, and others.

Ion-exchange techniques using carboxymethylcellulose and diethylaminoethylcellulose have been recently used for fractionation and purification of albumen proteins. Relative amounts, isoelectric points, molecular weights and characteristics for the individual egg protein are given in Table 1.

Ovalbumin is made of 3 components A_1 , A_2 , and A_3 , with

Table 1. Protein in egg albumen (Baker, 1968)

Protein	Relative Amount in Albumen (%)	Isoelectric Point	Molecular Weight	Characteristics
Ovalbumin	54	4.6	45,000	Phosphoglycoprotein
Conalbumin	13	6.6	80,000	Binds metal especially iron
Ovomucoid	11	3.9-4.3	28,000	Inhibits trypsin
Lysozyme (G ₁ globulin)	3.5	10.7	14,600	Lyses some bacteria
G ₂ globulin	4.0?	5.5	30,000-45,000	-
G ₃ globulin	4.0?	5.8	?	-
Ovomucin	1.5	?	?	Sialoprotein
Flavoprotein	0.8	4.1	35,000	Binds riboflavin
Ovoglycoprotein	0.5?	3.9	24,000	Sialoprotein
Ovomacroglobulin	0.5	4.5-4.7	760,000-900,000	?
Ovoinhibitor	0.1	5.2	44,000-	Inhibits several proteases
Avidin	0.05	9.5	53,000	Binds biotin

a relative proportion of 85:12:3, and which differ in phosphorus content, A_1 has 2 phosphates per molecule, A_2 has 1 and A_3 has none.

During storage of eggs, ovalbumin is converted to S-ovalbumin, a more heat stable protein. This conversion was explained by the interchange of its sulfhydryl-disulfide groups (Powrie, 1977). In solution, ovalbumin is readily denatured by shaking but is resistant to thermal denaturation. Lineweaver et al. (1967) studied the heat stability of egg white proteins, and found when heating of albumen to 62 C for 3.5 minutes at pH 9, only 3 to 5% of ovalbumin denatured, whereas negligible amounts of this protein were changed by heating albumen with a pH of 7.

Conalbumin is a glycoprotein which contains about 0.8% hexose and 1.4% hexosamine. By the ion-exchange chromatography, conalbumin separates into 2 fractions with a ratio of 4:1 (Powrie, 1977).

Cunningham and Lineweaver (1965) studied the pH and temperature effect on conalbumin, they found this protein had a minimum heat stability near pH 6, at which value 40% conalbumin was altered during heating to 57°C for 10 minutes, whereas conalbumin was not altered significantly when the solution was heated under the same conditions at pH 9. They also found the addition of Fe^{+3} , Cu^{+2} , Al^{+3} at the level of $10^{-3}M$ have marked stabilization effect at pH 7 to 60 C.

Ovomucoid is a glycoprotein which exists in three forms, all of which have trypsin-inhibiting abilities. Less than

1 molecule of ovomucoid is required to reduce the activity of 1 molecule of trypsin by 50%. Ovomucoid in acidic media is very resistant to heat denaturation, but in alkaline solutions this protein is altered rapidly at 80 C (Powrie, 1977).

Lysozyme is an enzyme which consists of 129 amino acid residues and 4 disulfide bonds, and has a lytic action on some bacterial cell walls. This lytic action is due to the capacity of lysozyme to hydrolyze the $\beta(1-4)$ linkages between N-acetylneuraminic acid and N-acetylglucosamine of bacterial cell wall. Thermal inactivation of lysozyme is dependent on pH and temperature. Generally speaking, lysozyme is more heat-sensitive in albumen than in phosphate buffer by 50 times (Powrie, 1977).

Ovomucin is a glycoprotein which contributes to the gel-like structure of thick albumen and has the ability to inhibit viral hemagglutination. Purified ovomucin in solution is resistant to heat denaturation (Powrie, 1977).

Cunningham and Lineweaver (1965) found that ovomucin solution with pH values between 7.1 and 9.4 did not change in optical density during heating for 2 hours at about 90 C.

Avidin, a biotin-binding protein, is composed of three components, A, B and C. Ovoglobulins G₂ and G₃ have been found to be excellent foaming agent. Ovoinhibitor is capable of inhibiting trypsin and chymotrypsin. Flavo-protein is made up of two types of apoprotein (nonriboflavin-containing protein) which bind riboflavin tightly (Powrie, 1977).

Physicochemical Properties of Egg White

Viscosity

Hundreds of million pounds of egg white are processed annually in the United States. Processing operations include pumping, mixing, heating, cooling, freezing, and spray drying - all influenced by the viscous properties of egg white (Forsythe, 1968). The viscosity of egg albumen is dependent on the age, mixing treatment, temperature, and rate of shear. Longree et al. (1966) reported that most liquid foods are non-Newtonian, that is, the consistency changes as the shearing rate is varied. Kaufman et al. (1968) cited a datum in which viscosity of commercial unfrozen egg products at pasteurization temperatures did not change greatly with changes in shear rate.

However, Tung et al. (1969) found that mixing egg white between 10 and 40 C at shear rates of 220-3140 sec^{-1} , apparently resulted in viscosity decrease with increasing shear rate. Effect of a low unfrozen temperature on egg white's viscosity was studied by Tung et al. (1970). They reported that unmixed albumen is pseudoplastic at 2 C between 8.1-147 sec^{-1} and the shear stress-shear rate relationship is accurately described by power law and Casson models. They also concluded that fresh and aged egg white did not have significant difference in viscosity, but both were higher than those of irradiated samples.

The viscosity of egg albumen also influenced by the pH value. Myers and France (1940) reported that upon the addition of concentrated acetic acid, the viscosity of

albumen increased to a point where a solid gel was formed. According to Cunningham and Cotterill's studies (1962, 1964), the viscosity of egg albumen was increased by the addition of 3N sodium hydroxide or 3N hydrochloric acid. When the pH was above 11.5, the viscosity of alkaline egg white rises rapidly until the sol-gel transformation occurs. Whereas the pH of acidified egg white is below 1.0 gelation occurred very quickly. They also found the viscosity of albumen reached a minimum around pH 4.0.

The viscosity of egg white at different pH level affected by the heat was reported by Seideman et al. (1963). They pointed out that at the pH value above 8.0, the viscosity of the heated egg white was greatly increased. Heating the egg white at pH 7.0 through 8.0 had little effect on the viscosity.

pH

The pH of albumen from a newly-laid egg is about 7.6 to 7.9. During the storage of shell egg, the pH of albumen increases at a temperature dependent rate to a maximum value of about 9.7. The pH rise in the albumen is caused by a loss of carbon dioxide from the egg through the pores in the shell. The pH of albumen is dependent on the equilibrium between the dissolved carbon dioxide, bicarbonate ion, carbonate ion, and protein (Powrie, 1977).

Much research has been done using shell sealing agents to retard carbon dioxide loss, retard the increase in pH, and aid in maintaining egg quality (Stadelman and Wilson,

1957; Cotterill and Gardner, 1957; Schwall et al., 1961; Homler and Stadelman, 1963). Hudspeth et al. (1965) found that the pH value of 27 days old egg was 9.17 and 9.18 when stored at room temperature and refrigeration temperature, whereas the oiled eggs had pH 8.13 and 8.37 individually.

Variations in pH are responsible for major changes in the physical properties of whole egg white and of individual proteins. Cotterill et al. (1959) studied the bicarbonate buffering system in egg white. They found that between pH 7.5 and 8.5, egg white lacked buffering capacity and ease of pH change, and in the regions of pH 6.4 and pH 10.3 egg white was strongly buffered due to a slight decrease in the carbon dioxide concentration of the white. They also found that when the pH of egg white was increased to 10 with 0.1N sodium hydroxide, then back-titrated to pH 4 with 0.1N hydrogen chloride there was no deviation from the original titration curve of egg white. However, if the pH was first lowered to pH 4, then back-titrated to 10, large deviations were observed in the curve. This was due to the loss of carbon dioxide and possible irreversible changes in protein structure.

Antimicrobial Activity of Egg White

Growth of bacteria in egg white is limited due to several inhibitory factors. Lysozyme lyses Gram-positive bacteria (Geoffery and Bailey, 1975). Conalbumin forms a stable complex with iron which renders the medium deficient in available iron and the protein resistant to proteolysis

(Feeney and Nagy, 1952; Azari and Feeney, 1958; Donovan et al., 1976). Avidin, a biotin-binding egg white protein, prevents biotin-dependent bacteria from multiplying (Eakin et al., 1940; Chignell et al., 1975). Ovomucoid, the anti-trypsin factor has been mentioned as affecting growth (Ayres, 1958; Osuga and Feeney, 1974). Ovoflavoprotein which combines with riboflavin also affects growth of some bacteria (Clagett, 1971). Ovoinhibitor, a proteolytic enzyme inhibitor, is capable of inhibiting trypsin and chymotrypsin as well as fungal and bacterial proteases (Osuga and Feeney, 1974). Moreover, the alkaline condition of the albumen (pH 9.0 above) also accounts for its antimicrobial activity (Sharp and Whitaker, 1927; Banwart and Ayres, 1957).

The antimicrobial activity of lysozyme in egg white could be altered by different treatments. Seideman et al. (1963) found that when the egg white at pH 9 or above heated to 60 C for 3 minutes revealed a decrease in lysozyme mobility. Moreover when the sample heated at pH 9.5 showed no detectable mobile lysozyme in electrophoresis patterns.

Cunningham and Lineweaver (1965) reported that when egg white was heated to 62.5 C for 10 minutes at pH 9, lysozyme was inactivated extensively, but that the purified lysozyme dissolved in buffer was unaffected by this time-temperature condition. Cunningham and Lineweaver postulated (1967) that the sulfhydryl groups of ovalbumin were implicated in the inactivation of lysozyme by reduction of one or more disulfide bonds which were under an electrostatic interaction.

In the absence of ovalbumin, lysozyme was more stable to heat.

According to Cunningham and Cotterill (1971) 0.1% yolk contaminated egg white (pH 9) reduced the lysozyme activity between 40 and 45%. They reported that the lytic activity could be reduced to less than 10% when 5% yolk was added in pH 6.2 phosphate buffer.

The lysozyme activity in fertile eggs was also studied by Cunningham (1974). He found that lysozyme decreased in activity rapidly during the first 12 days of incubation (37.8 C) and less than 20% of original activity remained after 17 days.

Those results indicated that there was a difference between lytic activity of fertile and infertile eggs since infertile eggs when incubated at 35 C for 42 days, lost only 20-25% lysozyme activity (Feeney et al., 1952). Cunningham (1974) concluded the decreased activity was due to an interaction of lysozyme with conalbumin, ovomucin, or ovalbumins.

Conalbumin plays a major role in preventing growth of Gram-negative spoilage bacteria in egg white. Garibaldi (1960) reported that this inhibition in egg white was completely reversed by saturating the conalbumin with iron. Garibaldi (1960) also found the high pH in egg white did not inhibit growth of any test bacteria when supplemented with sufficient iron to saturate the conalbumin. The inhibitory action of high pH in unsupplemented egg white was explained by its effect on the dissociation of the iron-conalbumin

coordination compound and thereby iron becomes less available to the microorganisms.

Nath and Baker (1973) studied the antimicrobial activity of egg white by inoculating Pseudomonas fluorescens. They found that P. fluorescens grew rapidly when egg albumen was diluted with water or supplemented with carbohydrate and ovomucoid-rich egg exudate. They explained that the rapid growth was because the diluted egg white make more nutrients available, not because the concentration of conalbumin and lysozyme was lowered by the water.

A more recent study on the mechanism of antimicrobial activity of egg white was made by Yadav and Vadehra (1977). Their results of water treatments, iron, and egg yolk treatments given to egg white agreed with results of other investigators (Garibaldi, 1960; Cunningham and Cotterill, 1971; Nath and Baker, 1973). They also reported that papain and sonic treatment reduced inhibition whereas dehydration enhanced antimicrobial activity.

However, since most of those treatments appeared to reduce inhibitory effect of egg white to bacterial growth, Yadav and Vadehra (1977) concluded that in fresh egg white, the physical structure of its proteins was probably a primary barrier to bacterial growth, besides the other factors such as lysozyme, avidin, ovotransferrin, and lack of free water and nutrients.

Destruction of Pathogens in Egg White

Pasteurization of egg products in the United States

became virtually mandatory on June 1, 1966 (Cunningham, 1970). Regulations governing all USDA inspected plants were passed (Fed. Reg., May 1, 1965; Egg Products Inspector Handbook, Aug 1, 1965); new standards of identify for egg products were adopted by Food and Drug Administration (Fed. Reg., March 19, 1965); and some states enacted laws requiring pasteurization. The purpose of these various measures was to insure the public against the presence of any pathogenic organisms in egg products (Cunningham, 1970).

Although egg albumen possesses antimicrobial activity, large numbers of organisms were recovered from 20 day old albumen stored under commercial conditions (Board, 1977). Many bacterial species were detected in albumen; among them Salmonella, which is commonly found in egg and egg products.

Wilkin and Winter (1947) reported that 1.6-4 minutes pasteurization treatment at 56.7 C reduced total counts by 99% and eliminated coliforms in egg white.

Salmonella can be a contaminant in liquid egg white. After examining 12 samples of raw egg white (from 11 plants) intended for fruther processing, North (1961) found that 10 were either negative or contained less than 0.2 Salmonella per ml (MPN), and the other 2 contained 1.5 and 24 organisms, respectively. Kline et al. (1965) reported that low levels ($<100/\text{ml}$) of Salmonella were found in egg white at processing plants. Those results suggested that Salmonella contamination, when it occurred, was generally at comparatively low levels.

Ayres and Slosberg (1949) used commercial-scale equipment to apply heat pasteurization to fermented (deglucosed) egg whites that had been adjusted back to pH 9.0 with ammonium hydroxide, and reported that flash pasteurization at 59.4 C or above would destroy naturally occurring Salmonella. On the other hand, Bergquist (1961) suggested use of a lower temperature (54.4 C) to minimize protein coagulation. He pasteurized commercially prepared egg white at 54.4 C for 80 seconds and found that Salmonella count (MPN) was reduced from 0.072 per ml to less than 0.03.

The pasteurization of egg white between 51.1 C and 60 C with commercial type heat exchanger and holding tube equipment was studied by Kline et al. (1965). They found that pasteurization for 2 minutes at 56.4 C reduced Salmonella typhimurium from 150 per ml to nondetectable levels. Pasteurization at 60 C caused physical changes in the egg white that interfered with operation of the exchanger. They concluded that treatment at 57.2-57.8 C for 2 minutes was the maximum possible pasteurization temperature for egg white.

Since many investigators reported that high temperature pasteurization caused physical changes of albumen, various modifications and additives have been proposed by some researchers to increase the stability of the egg white protein system to heat denaturation. Seideman et al. (1963) found that egg white had minimum gelation at pH 8.75 and 6.0, when heated for 30 minutes at 58 C or 56 C. Azari and Feeney

(1958) studied the stabilizing effect of iron salts on conalbumin, and found that iron-conalbumin complex was much more heat stable than iron-free conalbumin. Cunningham and Lineweaver (1965) studied the influence of polyvalent cations on the heat stability of conalbumin in egg white at pH 7 and 60 C. Iron, copper, and aluminum ions were effective stabilizers at pH 7 but not at pH 9. When albumen at pH 7 containing 10^{-3} moles of aluminum ion was heated for 13 minutes at 60 C, the volume and texture of cakes prepared from this pasteurized albumen were normal but the whipping time was increased. This increase in whipping time was attributed to heat denaturation of the ovomucin-lysozyme complex (Garibaldi et al., 1968).

According to Kline et al. (1965) pasteurization of egg white at 126-128 F for 2-3 minutes, resulted in a damaged foaming power. However, they found the addition of permissible levels of triacetin and triethyl citrate fully restored foaming power, while adding sodium lauryl sulfate was virtually ineffective.

The addition of sodium hexametaphosphate (SHMP) had been studied by Winter (1952) for stabilization of albumen to produce pasteurized frozen egg products. Chang et al. (1970) reported that 2% SHMP was effective in inhibiting thermal coagulation of conalbumin in egg white at pH levels between 7 and 9, with greatest stabilization occurring at about pH 7. The foam performance of the SHMP-treated albumen heated for 3 minutes at 61.7 C was only slightly damaged.

Osborne et al. (1954) reported that thermal death times at 60 C for selected strains of Salmonella in egg white were approximately 1/3 to 1/4 of those for the same strains in whole egg. This result was similar to an earlier study by Wilkin and Winter (1947) who reported that bacterial contaminants were more easily destroyed in egg white than in egg yolk. Anellis et al. (1954) postulated that the higher pH of egg white resulted in greater ease of thermal destruction of Salmonella compared with egg yolk. Cotterill (1968) studied the effect of different pH levels on the destruction of Salmonella in liquid egg white at low pasteurization temperatures. He found albumen with a high pH levels allowed use of lower temperatures for pasteurization. His result showed that pasteurization at pH 7.0 with aluminum salt at 60 C (Cunningham and Lineweaver, 1965) was equivalent to pH 8.7 at 57.8 C or pH 9.1 at 56.2 C. Cotterill (1968) also suggested that S. oranienburg was more resistant to heat than other Salmonella spp.

To effectively destroy Salmonellae in liquid egg white by pasteurization, pH, time and temperature should be carefully adjusted according to Fig. 1 (Cunningham, 1977).

Fermentation of Egg White

Fermentation of egg white has been practiced for a long time by the egg-drying industry to remove sugar and prevent Maillard browning reaction.

Formerly, sugar was depleted from egg white by a

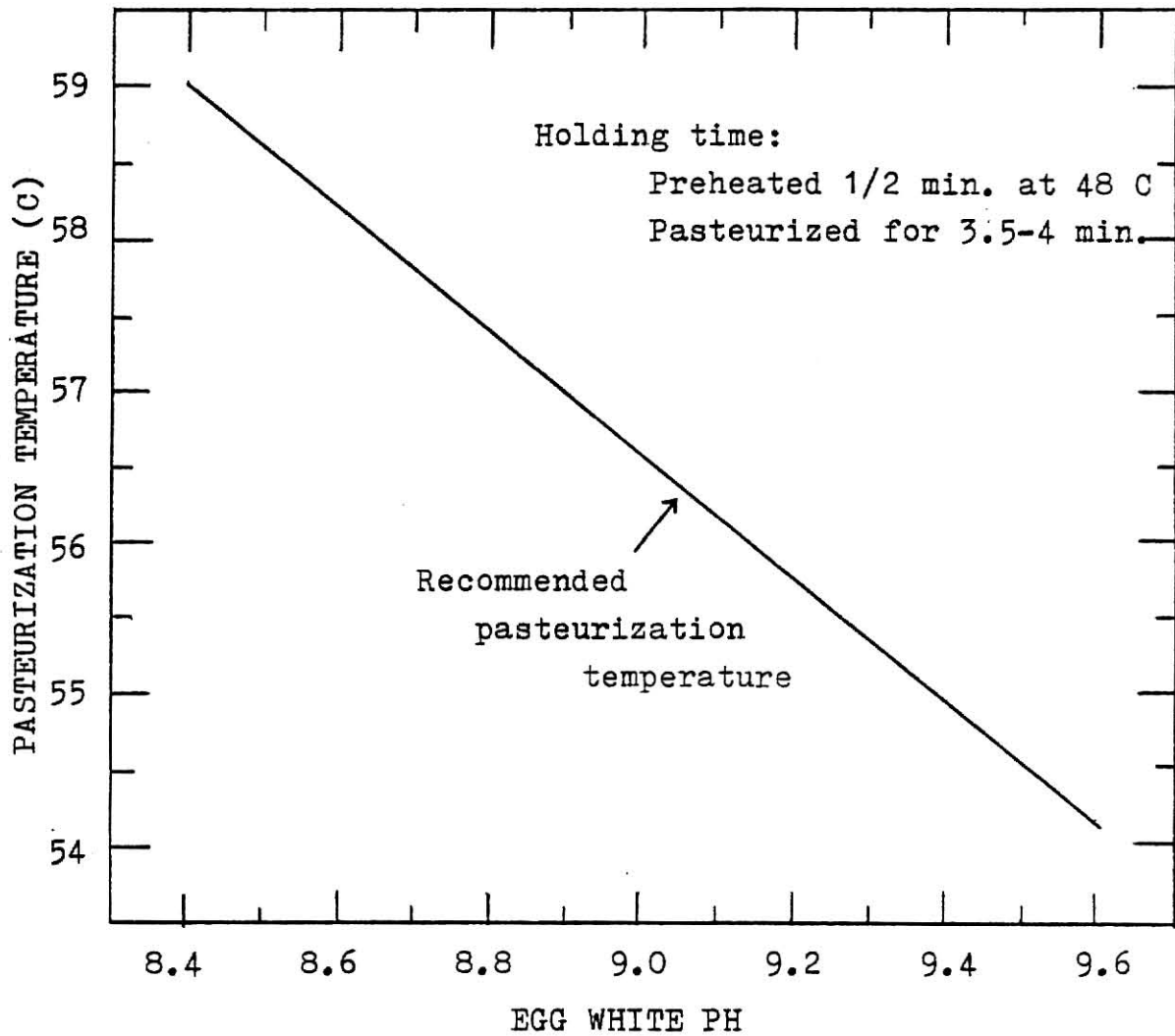


Fig. 1. Recommended pasteurization temperatures for raw egg white at various pH levels (Cunningham, 1977)

spontaneous fermentation. The objectionable odors and proteolysis was obvious in the later stages of fermentation. In addition, organisms of the genus Salmonella thrived in the albumen and presented a health hazard (Hill and Sebring, 1977). Use of pure culture fermentation of egg white would render the practice more controllable.

Stuart and Goresline (1942) reported that pure culture fermentation by coliform organisms yielded albumen of good quality. Stewart et al. (1943) desugared egg white by inoculating a pure culture of Streptococcus, however some flavor changes were noted. Hawthorne and Brooks (1944) indicated that glucose could be removed from egg white by seeding the white with 1% Saccharomyces apiculatis. The final product was considered objectionable because of its marked yeast flavor. Hopkins et al. (1947) reported that Streptococcus lactis, S. diacetylactis and S. thermophilus could rapidly desugar whole egg. Kaplan et al. (1950) reported a satisfactory resting cell fermentation by S. lactis when 1% cell inoculum was introduced into egg white. They also found that Streptococcus could suppress off-odor producing microorganism during fermentation. However, Ayres (1958) found that S. lactis can ferment egg white, but needed yeast extract for better growth. On the other hand, Bean et al. (1963) suggested that egg white pH be lowered to 5 to achieve better fermentation for S. lactis.

Lowering the pH value so that fermentative microorganisms can grow better is also required for whole egg. According

to Galluzzo et al. (1974), inoculation of lactic streptococci into pasteurized whole egg (pH 7.25) resulted in a rapid reduction in numbers of lactic streptococci in the presence or absence of added yeast extract. When the pH was reduced to 6.5 S. diacetylactis grew better. They explained that though yolk does inhibit lysozyme activity, whole egg still retained some lytic activity. Therefore, when whole egg pH was lowered, the remaining lytic activity was then decreased and bacterial growth improved (Galyean et al., 1972).

Fermentation of Soybean Milk as New Product Development

Fermentation

Soybean milk has a long history in the Orient as a popular beverage, but fermented soybean milk has never been a traditional one. In recent years, many attempts have been undertaken to develop fermented soybean milk by the same cultures employed in making fermented cow's milk.

Ariyama (1963) steamed, soaked, and ground soybeans with 0.1N sodium hydroxide then neutralized the soybean milk with hydrochloric or citric acid. The milk was supplemented with 15% cane sugar and inoculated with Lactobacillus bulgaricus at 37-43 C for 4-6 hours. Ariyama showed that soybean yogurt had a protein content of 9.8% compared to 3-3.4% in yogurt made from cow's milk.

Wang et al. (1974) studied the growth rates of 8 Lactobacillus acidophilus strains and 4 L. bulgaricus strains in soybean milk with or without glucose and lactose supplement.

Their results showed 4 L. acidophilus strains grew well in soybean milk alone, the remainder grew better in soybean milk supplemented with glucose or lactose. A taste panel indicated a sweet-sour taste which masked the beany flavor of the soybean milk drink.

Mital et al. (1974) reported that L. acidophilus, S. thermophilus, L. cellobiosus, and L. plantarum were able to utilize sucrose to produce fermented soybean milk products. Mital (1974) also reported that the amino acid content did not significantly change under normal lactic fermentation.

In his study on fermented soymilk, Kraidej (1975) reported that the best results were obtained with NRRL-B1910 mixed with NRRL-B1145 Lactobacillus culture for the yogurt like product with 16-20 hours fermentation at 37 C. Less inoculum and longer fermentation time gave better texture and acidity in the end product. Kraidej also pointed out that although the product had reasonable keeping quality, the texture was not quite stable and the flavor was beany.

Removal of Beany Flavor

The beany flavor formation during soymilk production is produced by the action of the enzyme lipoxygenase on unsaturated fatty acids, principally linoleic and linolenic acids (Wolf, 1975). Wilkens et al. (1967) found that off-flavors of soymilk were not present in the intact dry beans but were formed when raw beans were macerated. Badenhop and Wilkens (1969) found that 1-octen-3-ol was formed in soy beans during soaking. Mattick and Hand (1969) isolated and

identified ethyl vinylketone as a volatile component which developed in soybeans and contributed to the beany flavor. Wilkens and Lin (1970) found that volatile components were very complex. About 80 peaks were evidenced by gas chromatographic analysis of the oxidized milk; 41 compounds were identified and 13 tentatively identified. Among the identified compounds were hexanal, hexanol, 2-hexenal, ethyl vinylketone, 2-pentylfuran, and others. They concluded that the typical beany flavor of soy products was caused by a mixture of many compounds by lipid oxidation.

Heating is the method currently proposed for inactivating heat labile lipoxygenase during processing of soy beans. Wilkens et al. (1967) reported that grinding unsoaked, dehulled soybeans with hot water at 80-100 C and maintaining the temperature for 10 minutes would inactivate lipoxygenase and produce an acceptable bland soybean milk product. Badenhop and Hackler (1970) found that alkaline soaking (0.05N sodium hydroxide) of soybeans for 2 hours at 50 C prior to a high temperature grinding operation produced a significantly better flavor than a water-soak control treatment. Nelson et al. (1976) developed a method by blanching soybeans before grinding and homogenized whole soybean slurry without filtration and result in a bland flavor product.

Recent research concerned with the removal of beany flavor was made by Chiba et al. (1979). They used NAD-dependent aldehyde dehydrogenase which was purified from bovine liver mitochondria for removing the beany flavor from

soybean products. They found after incubation of the enzyme in the presence of NAD^+ with soybean milk, an almost complete disappearance or a great reduction of the off flavor.

MATERIALS AND METHODS

Growth Study of Fermentative Bacteria in Egg White

Liquid Egg White

Eggs were obtained from Kansas State University's poultry Farm. They were cleaned, broken, and separated using a hand separator. After the separation of albumen from yolk, the chalazae cords were removed with a tweezer and discarded (Baker et al., 1959). The pH of the liquid egg white was between 8.9 and 9.3.

Pasteurization

Egg white was heat treated in a sterile Erlenmeyer flask fitted with a rubber stopper and a thermometer. A thermomagnetic stirrer (Fisher Thermix) was equipped with a water bath to hold flask for pasteurization. The egg white was stirred vigorously during heating with a magnetic stirring bar. Temperature was increased within 30 minutes to 60 C and held for 3 minutes to kill pathogens which could naturally exist in the egg white (Cunningham et al., 1965). Following heat treatment, the flask was placed in an ice water bath and cooled to room temperature.

Acidification

Prior to the acidification, pasteurized egg white was blended for 15 seconds in a sterile Waring Blender to get a homogenous composition. Egg white was neutralized by adding

lactic acid (85%, Fisher Scientific Company) drop by drop until a pH of 7.00 ± 0.02 was obtained. A pH meter (Fisher Accumet pH meter, Model 292) was used for the pH measurement.

Culture and Media

Seven different lactic acid producing bacteria were selected for this study. Lactobacillus bulgaricus NRRL B-548, L. acidophilus NRRL B-4495, Streptococcus lactis NRRL B-633, S. diacetylactis NRRL B-2356, and Pediococcus cerevisiae NRRL B-1153 were obtained from the Northern Regional Research Center, Peoria, Illinois. Streptococcus thermophilus ATCC 14485 and L. plantarum ATCC 21028 were purchased from American Type Culture Collection (ATCC), Rockville, Maryland.

The propagating media, selective plate count agar, and incubation temperature used in this study are as follows (Kaplan et al., 1950; Gherna et al., 1978):

<u>Organisms</u>	<u>Propagating Media</u>	<u>Plate Count Agar</u>	<u>Incubation Temperature</u>
<u>L. bulgaricus</u>	MRS Broth	MRS Agar	37 C
<u>L. acidophilus</u>	MRS Broth	MRS Agar	37 C
<u>L. plantarum</u>	MRS Broth	MRS Agar	37 C
<u>P. cerevisiae</u>	MRS Broth	MRS Agar	30 C
<u>S. diacetylactis</u>	Litmus Milk	KF Agar	30 C
<u>S. lactis</u>	Litmus Milk	Tryptic Soy Agar	30 C
<u>S. thermophilus</u>	MRS Broth	Tryptic Soy Agar	37 C

The media and agars were obtained from DIFCO.

Inoculation of Egg White

Aliquots (80 ml) of pasteurized and neutralized egg whites were dispensed into sterile beakers (100 ml) and separated into two groups. One group was mixed with 3.2 ml sterile glucose solution (50% w/v) to obtain a 2% glucose enrichment. The other group, without glucose added, served as controls. Pure cultures (1.6 ml) with 3.5×10^8 to 3.0×10^9 CFU/ml were inoculated into each group and mixed by a magnetic stirring bar. After inoculation, the egg white samples were incubated at 30 C or 37 C depending on the organism studied. For growth rate studies, portions of egg white were periodically removed (4 hours) and plated in selective plating count agar by standard method (Marth, 1978). The pH of the solution was also measured.

Development of a New Fermented Yogurt-like Egg product

The development of a new fermented egg product has been studied by inoculating a mixed starter culture of L. bulgaricus NRRL B-548 and S. thermophilus ATCC 14485 into egg white containing various combinations of skim milk, skim milk powder, gums, and soybean milk. The preparation of liquid egg white and pasteurization were the same as described earlier. Starter cultures used in this study were maintained in sterile 12% reconstituted skim milk by transferring 1% inoculum every other week. The 2% inoculum containing from 1.0×10^9 to 3.0×10^9 CFU/ml was prepared for this study and will be referred to as "starter cultures". All experiments were done in duplicate.

Fermentation of Egg White Combined with Skim Milk

Skim milk powder was obtained from Mid-America Farms, Springfield, Missouri, and reconstituted to 12% total solid skim milk. Skim milk was then pasteurized at 71 C for 15 seconds, cooled to room temperature, and mixed with pasteurized, acidified egg white (pH 6.8). The ratios of egg white to skim milk were as follows:

Group	1	2	3	4	5	6	7
Egg White (ml)	100	80	60	50	40	20	0
Skim Milk (ml)	0	20	40	50	60	80	100

Starter cultures were inoculated into each group and mixed well with a sterile magnetic stirring bar and incubated at 37 C. After 6 to 20 hours of fermentation, pH, viscosity (determined by a Brookfield viscometer "RVF type"), flavor, and appearance of the egg-product were monitored.

Fermentation of Egg White Combined with Skim Milk Powder

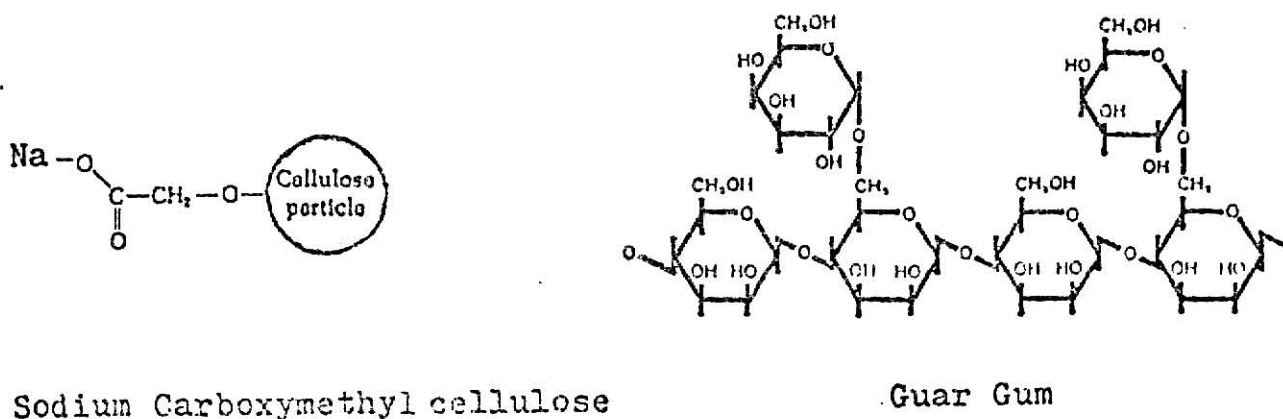
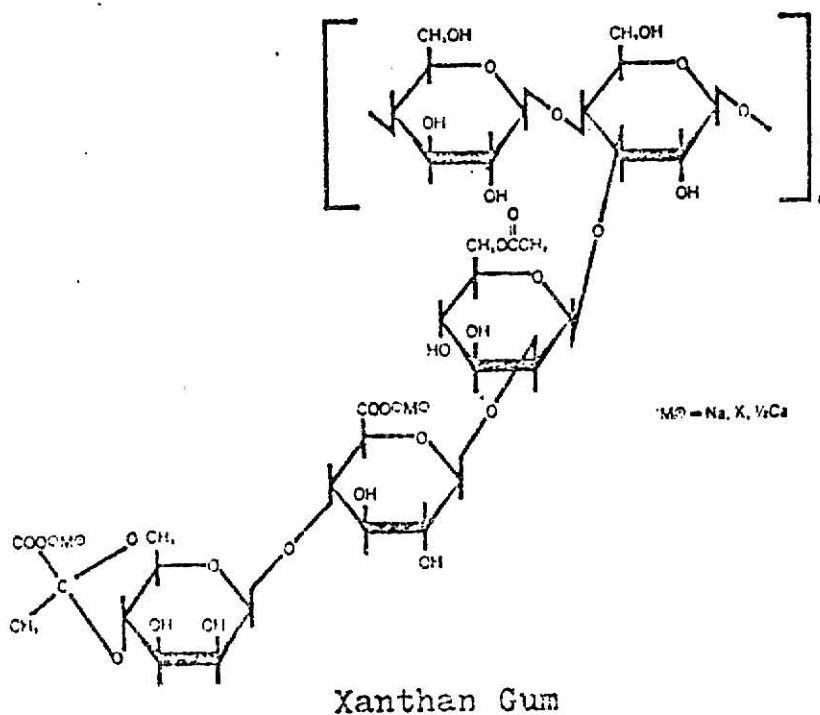
Skim milk powder was dissolved in liquid egg white using a Waring blender. The amount of skim milk powder (SMP) used in this study to mix with egg white (EW) was calculated by the following formula to make a 9% milk-solid-not-fat as 100% reconstitution.

$$\text{SMP(g)} = \text{EW(ml)} \times 87.6\% \times 9\% \times 100\%$$

Four reconstituted SMP groups were prepared: 100%, 80%, 60%, and 40%. The blends were pasteurized at 60 C for 3 minutes and acidified to pH 6.8. Starter cultures were inoculated into each group and mixed well with a sterile magnetic stirring bar and incubated at 37 C. After 6 to 20 hours fermentation, pH, viscosity, flavor, and appearance were determined.

Fermentation of Egg White with Gums Added as Texture Improver

The term "gum" has been applied to many substances used in the food industry to modify viscosity. Three different gums were used in this study to adjust texture. Sodium carboxymethyl cellulose (CMC, E.I. Du Pont Nemons and Co. Grade: p-75-L), Guar gum and xanthan gum (Kelco Co.) were used at 0.1%, 0.5%, and 1.0% level. The structures of these gums are as follows:



Egg white was heat treated, blended, acidified to pH 6.8, and mixed with pasteurized skim milk at a combination ratio of 50:50 (v/v). Gum powder was added and stirred vigorously until dissolved using a magnetic stirring bar.

Starter cultures were inoculated in the mixture. After 6 hours of fermentation at 37 C, samples were refrigerated for 4 hours, before flavor, appearance, pH, and viscosity were determined.

Fermentation of Egg White Combined with Soymilk

A. Soymilk Fermentation

Nitrogen packed one pound bags of soybeans were obtained from Arrowhead Mill Inc., Hereford, Texas. Soymilk was prepared from 100 gram of whole soybeans that were washed with water then soaked in 300 ml water for 4 hours at room temperature. The soaked beans were rinsed, drained, and ground into a slurry with 400 ml water in a Waring blender at the highest speed for 3 min and diluted with water to a total weight of 900 gram. The mixture was filtered through a muslin cloth and the filtrate collected as soymilk. The residue was discarded. The pH of resulting extract was 6.5.

Soymilk was heated at 93 C for 60 min (Hackler et al., 1965). Soymilk samples were divided into two groups; one group had 2% glucose enrichment and the other group had no supplement. The soymilk samples were cooled to 37 C before inoculum was added. After incubation at 37 C for 6 hours, acidity and curd formation was observed.

B. Fermentation of Combined Soymilk and Egg White

Soymilk was mixed with pasteurized, acidified egg white (pH 6.8) in the following proportions:

Group	1	2	3	4	5
Egg White (ml)	80	60	50	40	20
Soymilk (ml)	20	40	50	60	80

Sterile glucose solution (50%:w/v) was added to each group to make a 2% glucose enrichment. Starter cultures were inoculated and samples were determined.

Fermentation of Egg White with the Combination of Skim Milk and Soymilk

A. Combination of Skim Milk and Soymilk

Egg white was pasteurized and acidified by lactic acid to reach pH 6.8. Skim milk (12% total solids) was reconstituted from skim milk powder and pasteurized at 71 C for 15 seconds. Soymilk was heated at 93 C for 60 minutes. The milk samples were cooled to 40 C before mixing with egg white. The combinations were prepared as follows:

<u>Group</u>	<u>Egg White %</u>	<u>Skim Milk %</u>	<u>Soymilk %</u>
1	50	10	40
2	50	20	30
3	50	30	20
4	50	40	10
5	60	10	30
6	60	20	20
7	60	30	10
8	70	10	20
9	70	15	15
10	70	20	10
11	80	10	10

All groups contained 2% glucose enrichment and either with or without 0.5% xanthan gum. Starter cultures were inoculated into each group and samples were incubated at 37 C for 6 hours, before pH, viscosity, and texture were determined.

B. Egg White Combined with Alkali Treated Soymilk

Egg white was pasteurized and acidified with citric acid (32.6%:w/w) to pH 6.8. Skim milk (12% total solids) was reconstituted from skim milk powder and pasteurized at 71 C for 15 sec and cooled to 40 C. Soymilk was prepared by Badenhop and Hackler's method (1970). Soybeans were soaked in 0.05 N sodium hydroxide solution in water bath at 50 C for 2 hours, then drained and rinsed with distilled water. Soybeans were ground using distilled water to achieve a ratio of 1:9 (w/w:dry beans/water). The mixture was filtered through a muslin cloth and the filtrate collected as alkali treated soymilk. Blends were prepared as follows:

<u>Group</u>	<u>Egg White %</u>	<u>Skim Milk %</u>	<u>Soymilk %</u>
1	50	10	40
2	50	20	30
3	50	30	20

All the groups contained 2% glucose enrichment and either with or without addition of 0.5% xanthan gum. Starter cultures were inoculated for each group. Incubation was at 37 C for 6 hours and pH, viscosity, and texture were determined.

C. Modification Study

This part was a modification of part B by adding 0.01% vanilla extract (alcohol 35%; Virginia Dare Extract Co.,

Inc. Brooklyn, N.Y.) and 3% sucrose as a sweetener. The same procedure was used as in part B and after 6 hours incubation, pH, viscosity, mouth feel, and flavor were determined.

Organoleptic Evaluation of New Fermented Yogurt-like Egg Product

Test samples in 3 groups were prepared and fermented with the combination of 47.4% egg white, 28.4% soymilk, 19.0% skim milk, 1.9% glucose, 2.8% sucrose and 0.01% vanilla extract was added to each sample. Group 1 had alkali treated soymilk while group 2 had traditional soymilk, and both groups contained 0.5% xanthan gum. Group 3 was a modification of group 1 with 1.0% xanthan gum.

The taste panel was composed of six persons in the Animal Sciences and Industry Department, KSU. The panelists were asked to rate the samples on a nine point hedonic scale in which "like extremely" was assigned a score of 9 and "dislike extremely" assigned a score of 1. The samples were presented in random order, and coded with random three-digit numbers.

Composition Analysis

The composition of samples prepared from group 1 were analyzed by AOAC methods (1980) to determine moisture, protein, fiber, ash, fat, and the amount of carbohydrate was calculated by subtraction.

Product Evaluation

The samples prepared in group 1 were diluted in sterile distilled water and tested for Salmonella by brilliant green agar (DIFCO). After 7, 14, 21 day's storage at refrigeration temperature (4 C), the flavor, appearance, pH, and mouth feel were examined.

RESULTS AND DISCUSSION

Growth Study of Fermentative Bacteria in Egg White

Growth curves and pH drop for each lactic acid forming bacteria in pasteurized (60°C for 3 min) egg white at pH 7.0 are shown in Figures 2 through 9. Viable cells of L. bulgaricus NRRL B-548 (Fig. 2) increased rapidly during 4 to 16 hr incubation and the pH dropped significantly after 8 hours. The addition of 2% glucose to the pasteurized egg white did improve growth and acid production. The final pH of the fermented egg white with 2% glucose was 4.8.

Growth of L. acidophilus NRRL B-4495 (Fig. 3) was similar to L. bulgaricus NRRL B-548, except that the numbers of viable cells were greater and pH value lower during the first 4 hours fermentation.

Lactobacillus plantarum ATCC 21028 did not grow well in egg whites either with or without added 2% glucose (Fig. 4). Better results on growth were obtained from P. cerevisiae NRRL B-1153 (Fig. 5) and 50:50 (L. plantarum: P. cerevisiae) mixed culture (Fig. 6), however, there were no drop in pH although both of the microorganisms were generally used in the meat industry as starter cultures for fermented sausage. These results were similar to those of Raccach and Bakers' (1979). Raccach and Baker inoculated a meat starter culture into pasteurized liquid whole egg (3°C, pH 7.4) to study the repressive action on Pseudomonas fluorescens. Their results pointed out that P. cerevisiae had better growth and caused a larger repressive action than L. plantarum

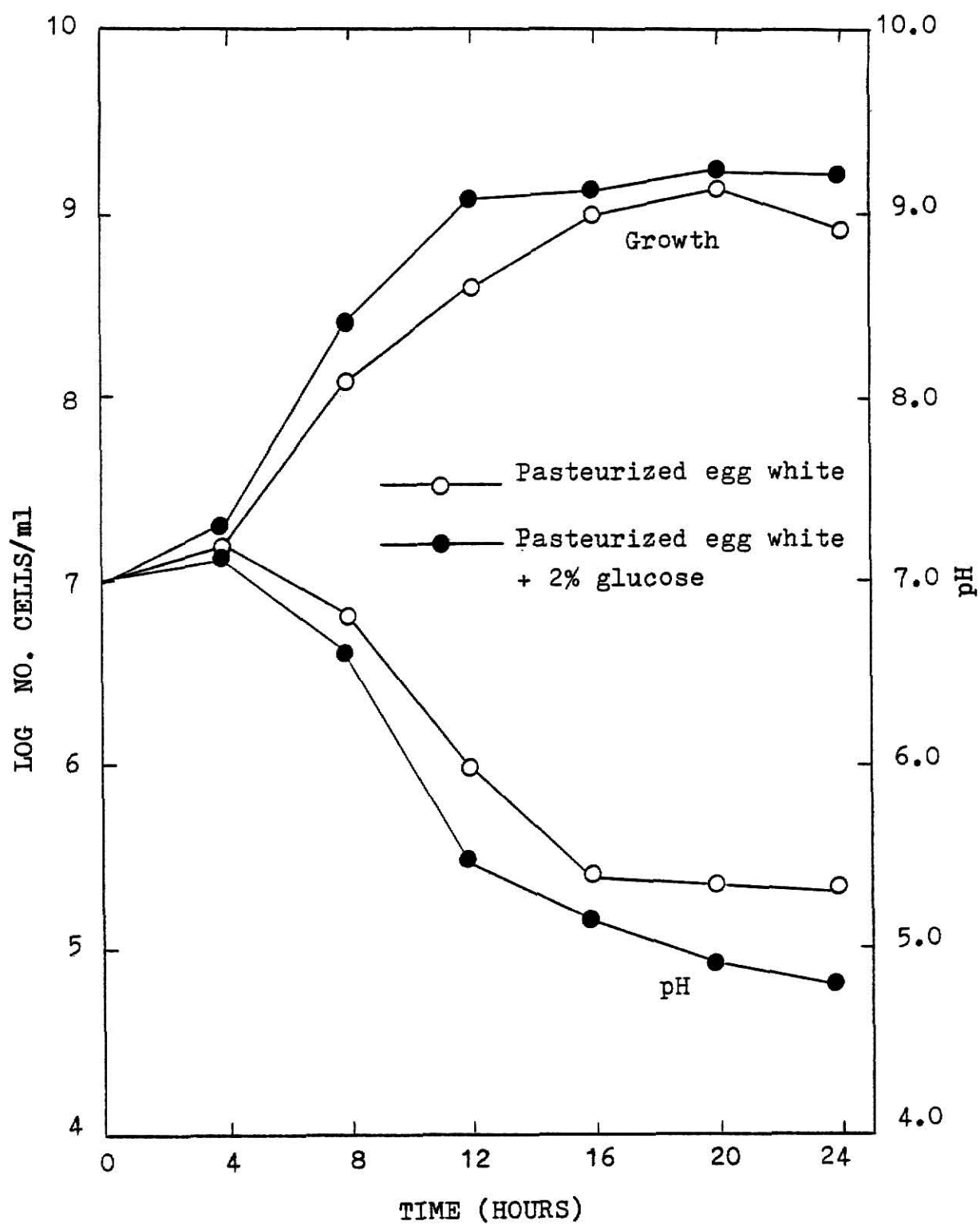


Fig. 2. The growth rate and acid production of Lactobacillus bulgaricus NRRL B-548 in pasteurized, neutralized egg white at 37 C.

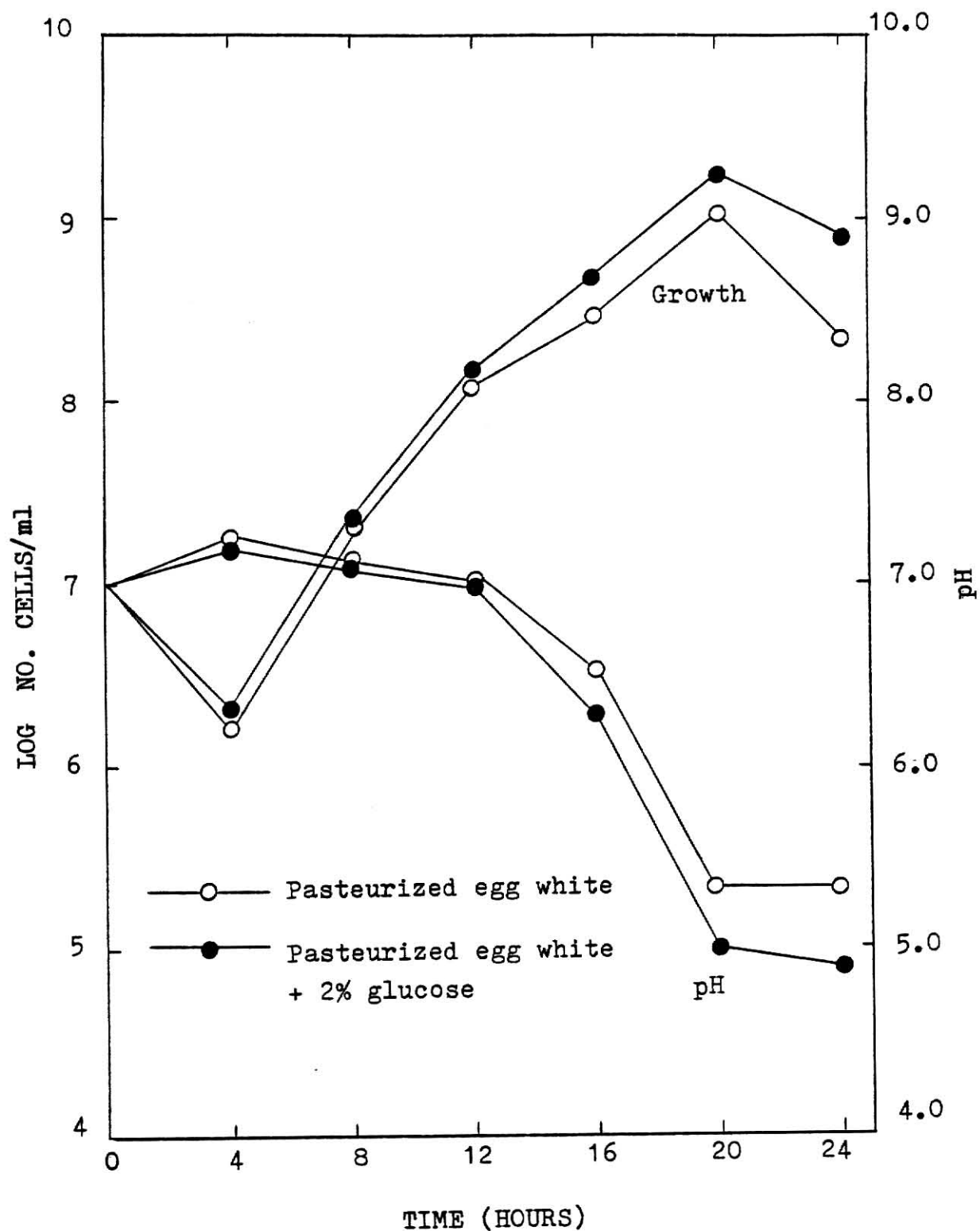


Fig. 3. The growth rate and acid production of Lactobacillus acidophilus NRRL B-4495 in pasteurized, neutralized egg white at 37 C.

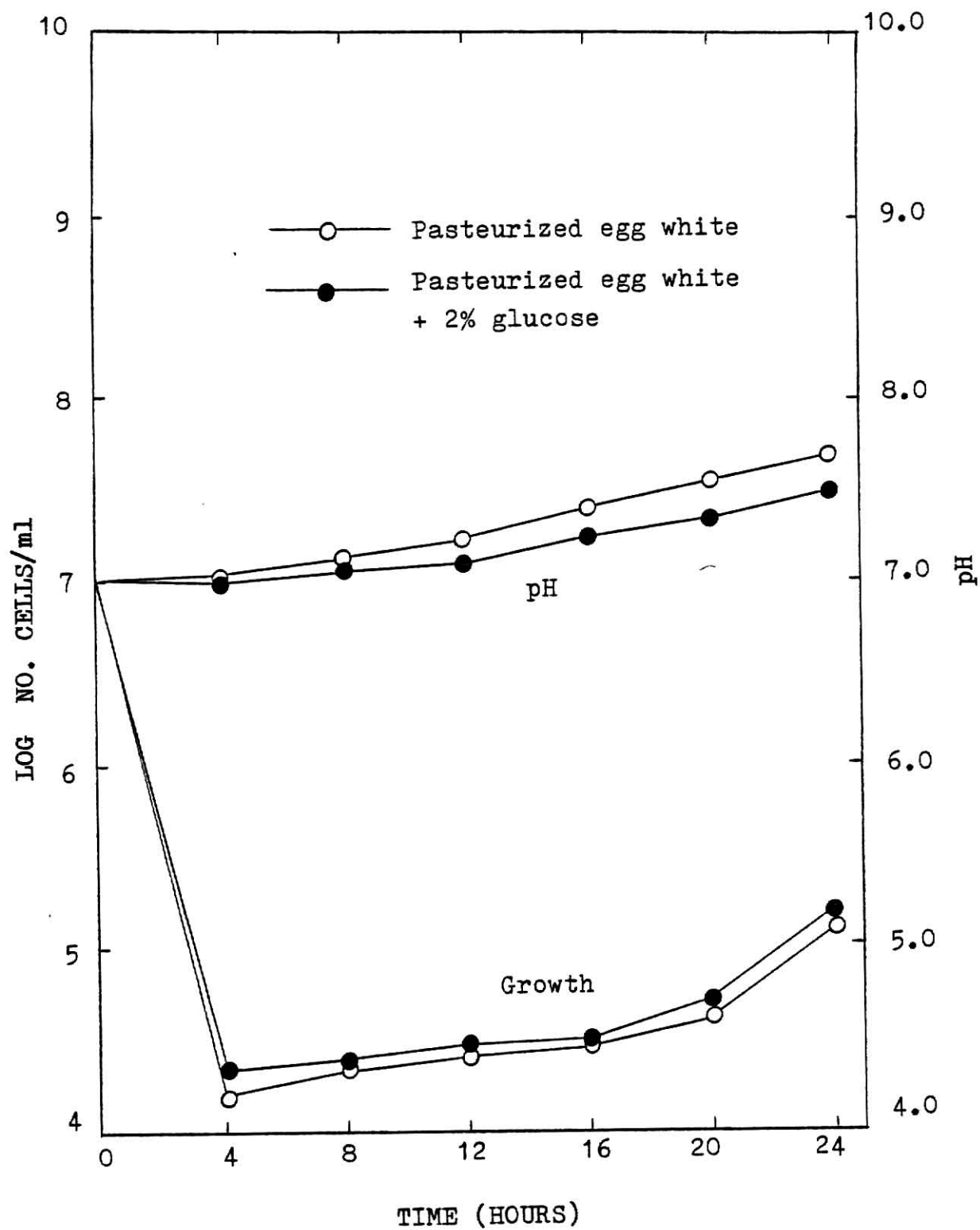


Fig. 4. The growth rate and acid production of Lactobacillus plantarum ATCC 21028 in pasteurized, neutralized egg white at 37 C.

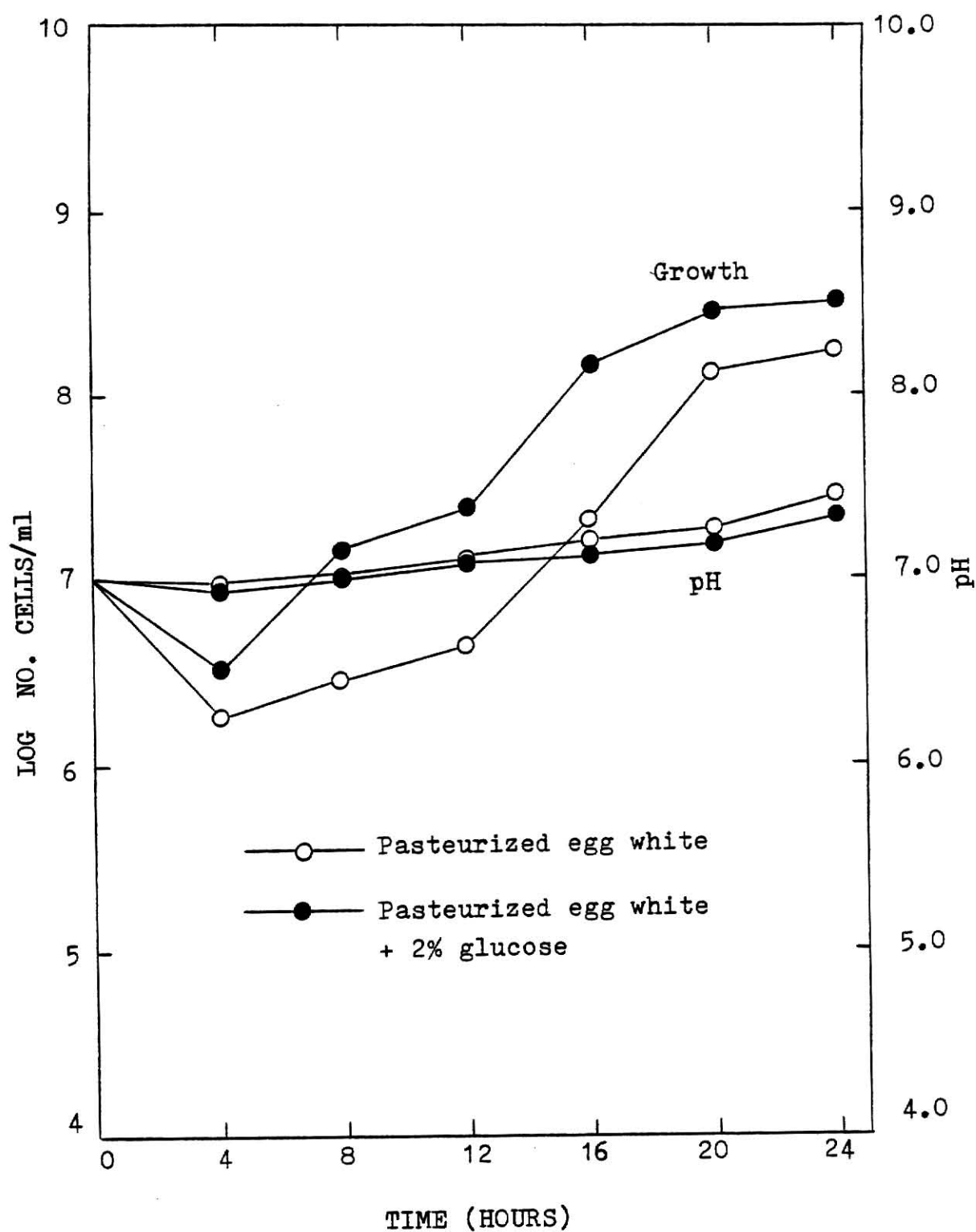


Fig. 5. The growth rate and acid production of Pediococcus cerevisiae NRRL B-1153 in pasteurized, neutralized egg white at 30 C.

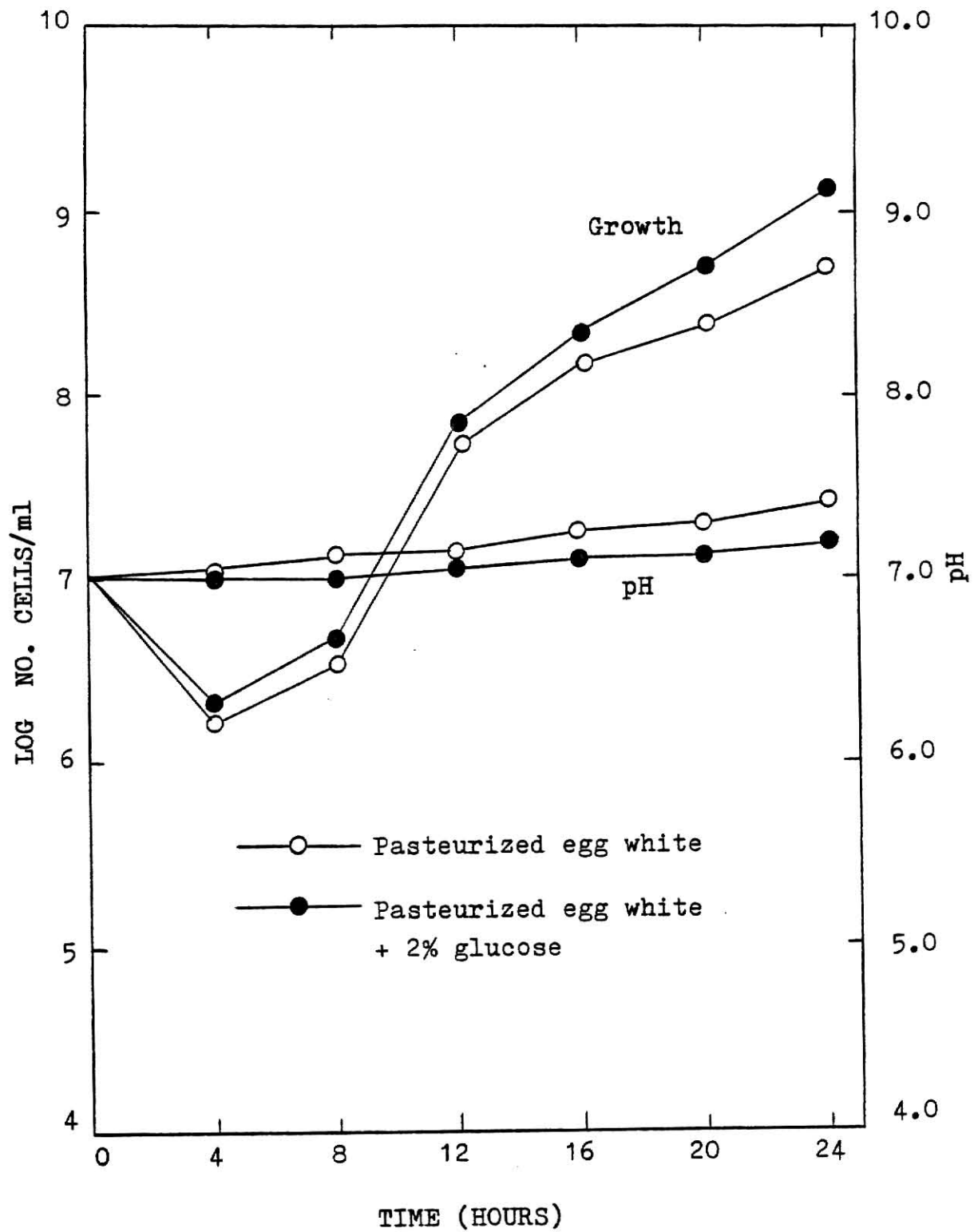


Fig. 6. The growth rate and acid production of *Lactobacillus plantarum* ATCC 21028 with the combination of *Pediococcus cerevisiae* NRRL B-1153 in pasteurized, neutralized egg white at 30 C.

toward P. fluorescens, and the 50:50 mixed culture showed results similar to P. cerevisiae alone. Nevertheless, the meat starter cultures were not suitable inocula, because of their low acid production and slow growth rate, when compared with either L. bulgaricus or L. acidophilus in treated egg white media.

Streptococcus diacetylactis NRRL B-2356 (Fig. 7) showed results similar to L. bulgaricus NRRL B-548 (Fig. 2). The final pH values of the fermented egg white and egg white with 2% glucose were 5.2 and 5.0, respectively. According to Galluzzo et al. (1974), S. diacetylactis grew well in pasteurized whole egg only when the pH was adjusted to 6.5 or below or the whole egg was superheated (65°C for 20 min). However, in this study, results showed a desirable growth curve and rapid pH drop when pasteurized egg white was acidified to pH 7.0.

In Fig. 8, numbers of viable cells of S. thermophilus ATCC 14485 showed a rapid decrease during 24 hours of fermentation at 37 C. Adding 2% glucose to egg white did not improve growth curve or acid production. Though S. thermophilus was used to desugar whole egg (Hopkins et al., 1947), the growth of S. thermophilus in egg whites showed the opposite results. The increased pH can be explained by the loss of carbon dioxide to maintain the equilibrium between bicarbonate ion, carbonate ion, and protein in egg white (Cotterill et al., 1959).

In Fig. 9, S. lactis NRRL B-633 showed a similar growth curve as L. acidophilus NRRL B-4495 (Fig. 2), after 4 hours

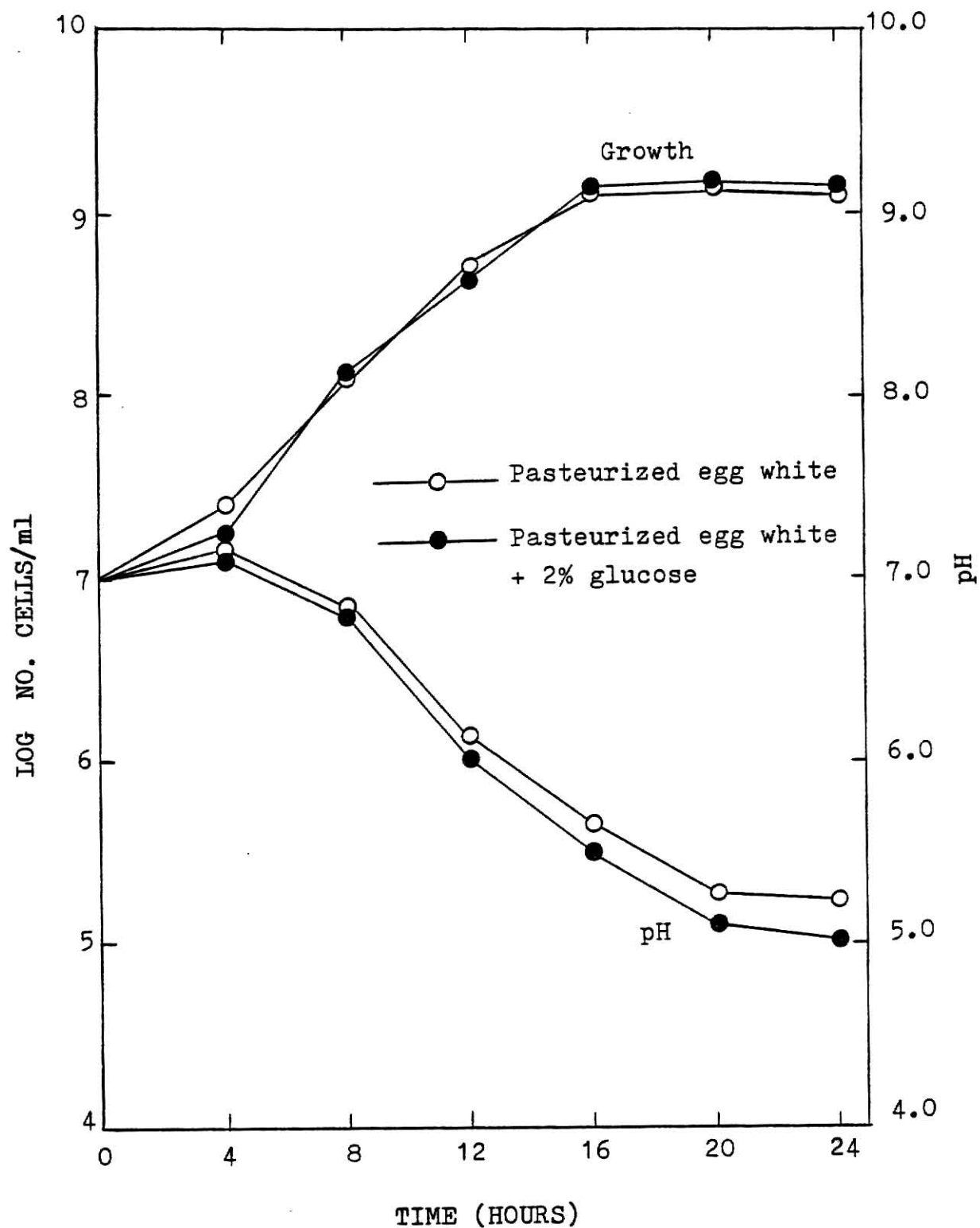


Fig. 7. The growth rate and acid production of *Streptococcus diacetylactis* NRRL B-2356 in pasteurized, neutralized egg white at 30 C.

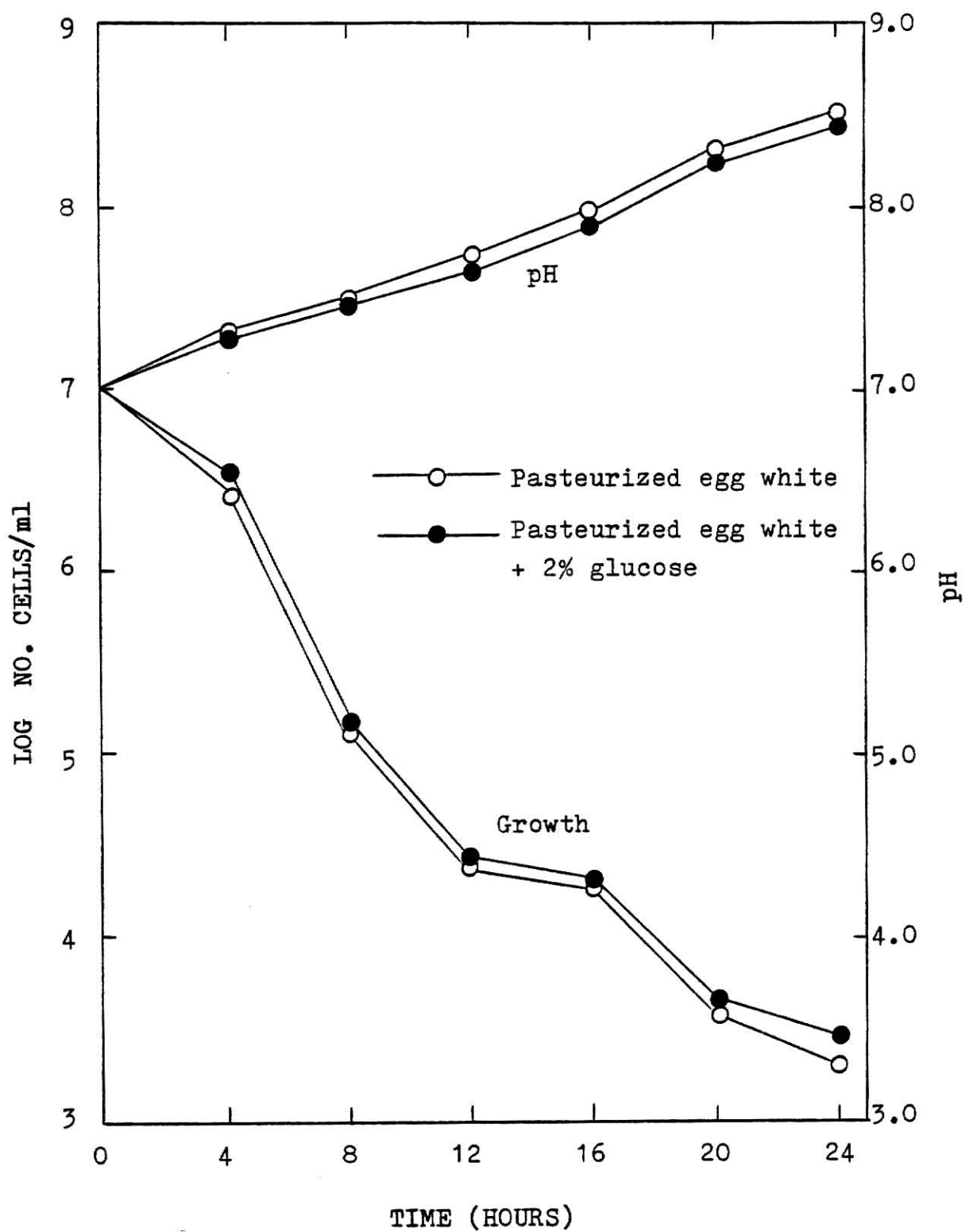


Fig. 8. The growth rate and acid production of Streptococcus thermophilus ATCC 14485 in pasteurized, neutralized egg white at 37 C.

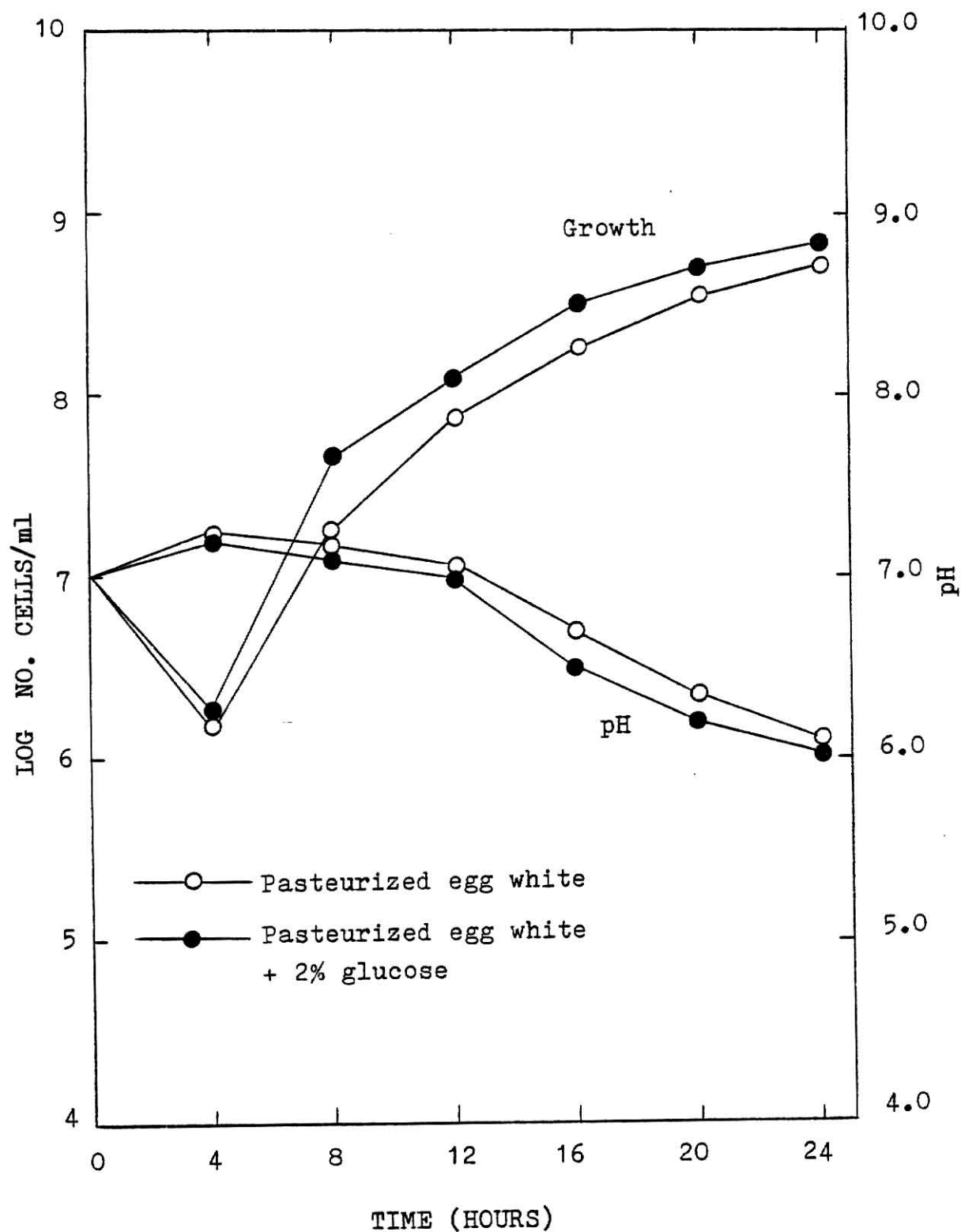


Fig. 9. The growth rate and acid production of Streptococcus lactis NRRL B-633 in pasteurized, neutralized egg white at 30 C.

incubation, the S. lactis appeared to recover and grow. However, the numbers of viable cells were lower and the pH drop was not so rapid as with L. acidophilus after 24 hours fermentation.

Lactobacillus bulgaricus, L. acidophilus, and S. diacetylactis grew better and produced more acid in egg white than the other organisms tested. Several factors could contribute to those results. The egg white chalazae were removed to prevent high lysozyme content (Baker et al., 1959), the egg whites were pasteurized at high pH (8.9-9.3) at 60 C for 3 min to destroy pathogens (Cotterill, 1968; Ayres and Slosberg, 1949) and immobilize lysozyme (Seideman et al., 1963), the whites were blended to alter the physical structure (Yadav and Vadehra, 1977), and acidified to pH 7.0. All those treatments created a better environment in egg white for growth of fermentative bacteria. However, those treatments were not sufficient for all of the test organisms. L. plantarum and P. cerevisiae prefer anaerobic conditions and lower pH values to grow (Buchanan and Gibbon, 1974); therefore, they grow very well in fermented sausage and produce a tangy flavor but not in egg white. For S. thermophilus, added nutrients or lower pH values probably would improve growth rate.

Development of a New Fermented Yogurt-like Egg Product

Fermentation of Egg White Combined with Skim Milk

The results of fermenting "egg white + skim milk" at different ratios are shown in Fig. 10 and Fig. 11. Groups

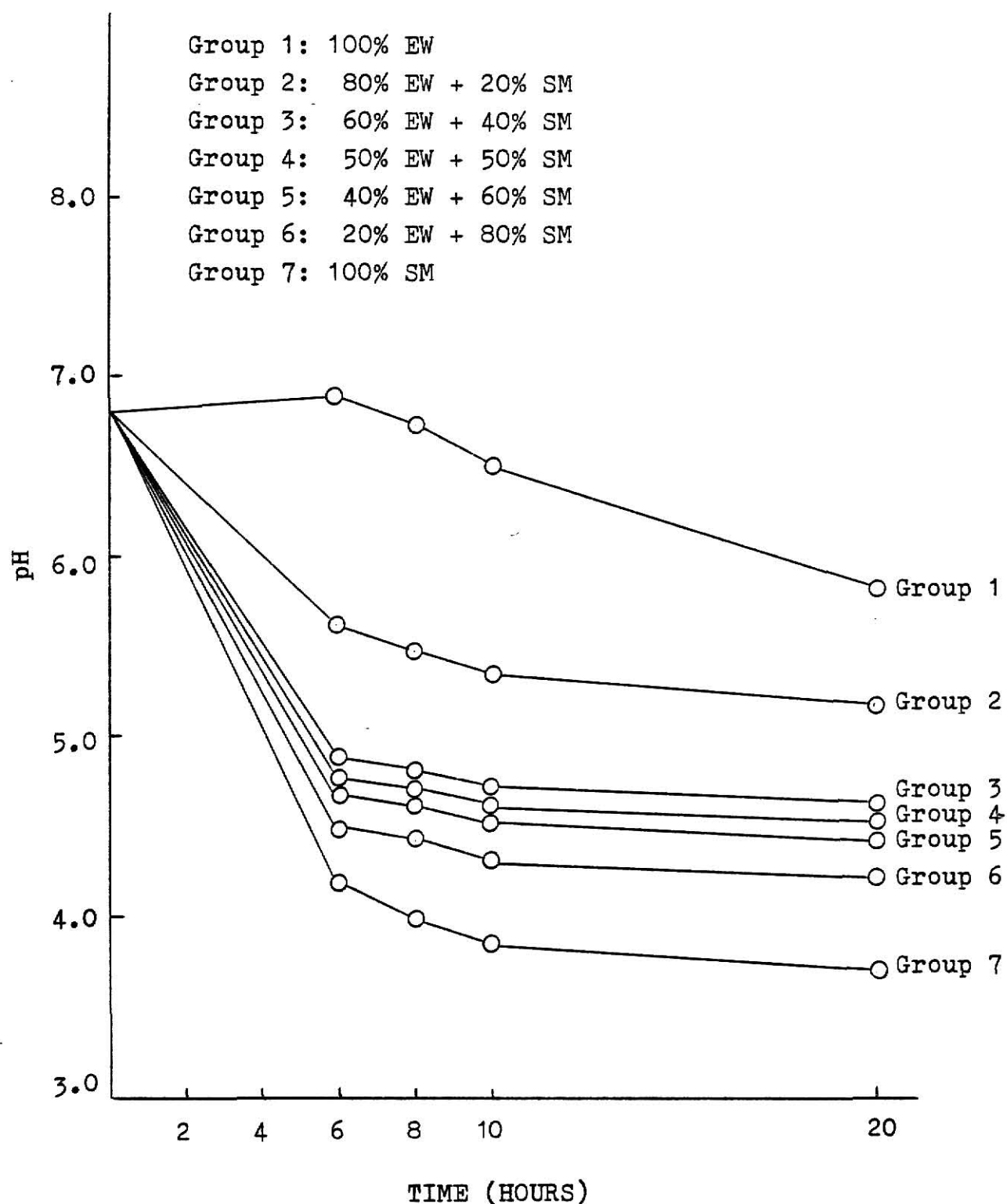


Fig. 10. The pH value of the combination of egg white (EW) and skim milk (SM) when fermented with 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C.

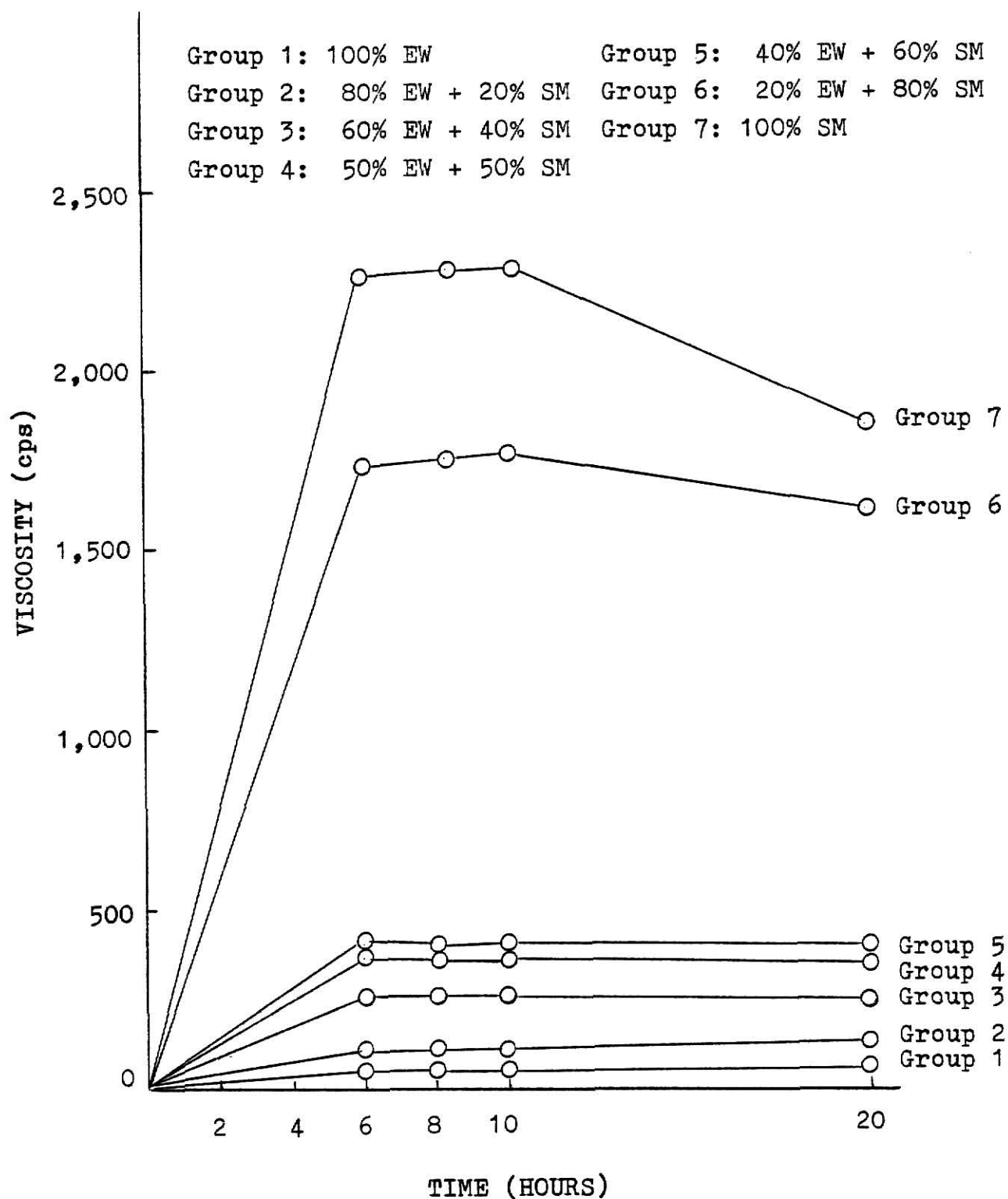


Fig. 11. The viscosity of the combination of egg white (EW) and skim milk (SM) when fermented with 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C.

5 and 6 showed a better curd formation and a yogurt-like flavor was produced in the first 6 hours of fermentation. After 10 hours incubation there was no significant improvement in the appearance, flavor, or viscosity of the test samples; only the pH values dropped slightly (Fig. 10,11). After 10 hours incubation, group 6 and group 7 showed a drop in viscosity (Fig. 11), probably due to the low pH causing whey separation and subsequently lowered consistency.

Since the cultures we used in this study are usually used for making yogurt, it is easier to understand that more skim milk yielded lower pH and higher consistency values. In order to develop a suitable egg product, containing at least 50% egg, some method must be used to increase viscosity and improve texture of the fermented product.

Fermentation of Egg White Combined with Skim Milk Powder

Viscosity of four different samples did not increase after 6, 8, 10 and 20 hours of fermentation. The results were 35 cp (centipoises), 25 cp, 20 cp, and 15 cp, respectively, for the products described in Fig. 12.

The pH dropped slightly during the first 10 hours and after 20 hours fermentation, sample 4 showed the lowest pH 5.5 (Fig. 12). These results indicated that the more milk powder added to the egg white, the less acid produced. That was probably due to the water activity (A_w), at 100% rehydration (sample 1) there was less free water available for the culture to grow, while at 40% rehydration (sample 4) the sample had higher A_w and better growth.

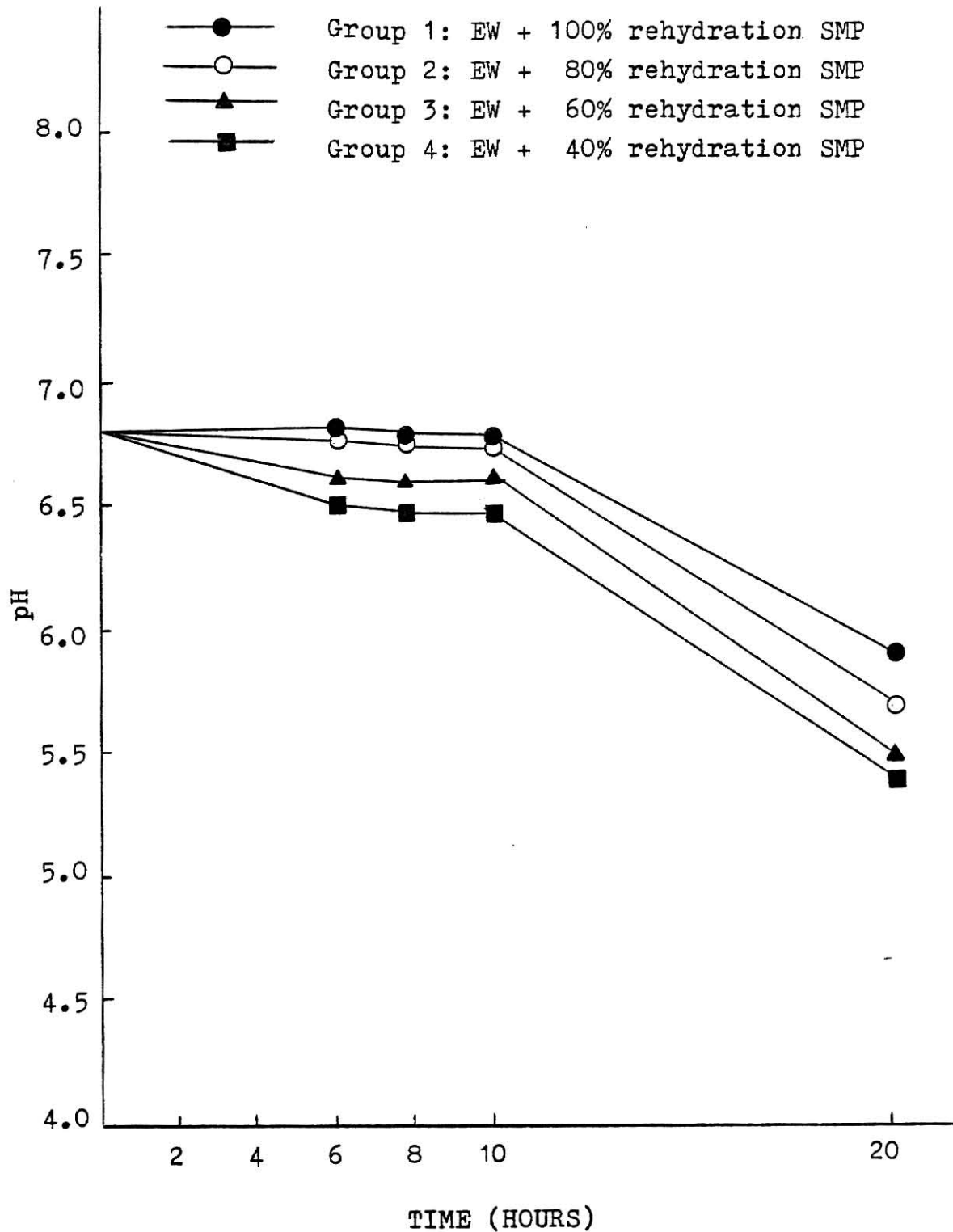


Fig. 12. The pH value of the combination of egg white (EW) and skim milk powder (SMP) when fermented with 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C.

Fermentation of Egg White with Gums Added as Texture Improver

The results of adding gums to fermented egg white/skim milk are shown in Table 2. Adding gums at 1% produced a better and firmer texture, but when the level was reduced to 0.5% only xanthan gum produced a good gel formation. Xanthan gum also produced a more desirable flavor and white color, while CMC and guar gum produced a white to yellowish color. The pH values of the treatments were not significantly different, ranging from 4.7 to 4.9. The viscosities were measured following fermentation (Fig. 13). The 1% addition of guar gum produced a product too viscous, whereas CMC produced a soft texture. Xanthan gum produced a product with more desirable consistency. However, 0.5% addition of xanthan gum was judged as the best.

Fermentation of Egg White Combined with Soymilk

A. Soymilk Fermentation

The pH and viscosity of fermented soymilk are shown in Fig. 14. Adding 2% glucose to the soymilk resulted in lower pH and higher viscosity. Though the flavor was beany, the final fermented soymilk showed a shiny, desirable appearance and high acidity (pH 4.1). Therefore, it was believed that the combination of soymilk and egg white should allow for a better fermentation and a more desirable product.

B. Fermentation of Combined Soymilk and Egg White

The fermentation of combined soymilk and egg white resulted in only a slight pH drop, however, the more soymilk added, the lower the final pH achieved (Fig. 15). In group 5,

Table 2. The influence of gum on the appearance, color, flavor, and pH of egg white/skim milk : 50/50 fermented at 37 C for 6 hr.^a

Gum	Level%	Appearance	Color	Flavor	pH
Guar	0.1	very soft gel	white	plant odor	4.9
Guar	0.5	soft gel	slight yellowish	strong plant odor	4.8
Guar	1.0	gel with particle	yellowish	strong plant odor	4.9
CMC	0.1	soft gel	white	odorless	4.9
CMC	0.5	liquefaction	yellowish	odorless	4.8
CMC	1.0	soft gel	yellowish	odorless	4.9
Xanthan	0.1	soft gel	white	yogurt-like flavor	4.7
Xanthan	0.5	gel	white	yogurt-like flavor	4.7
Xanthan	1.0	firm gel	white	xanthan gum's flavor	4.8

^a The 2% L. bulgaricus and 2% S. thermophilus were inoculated for the fermentation.

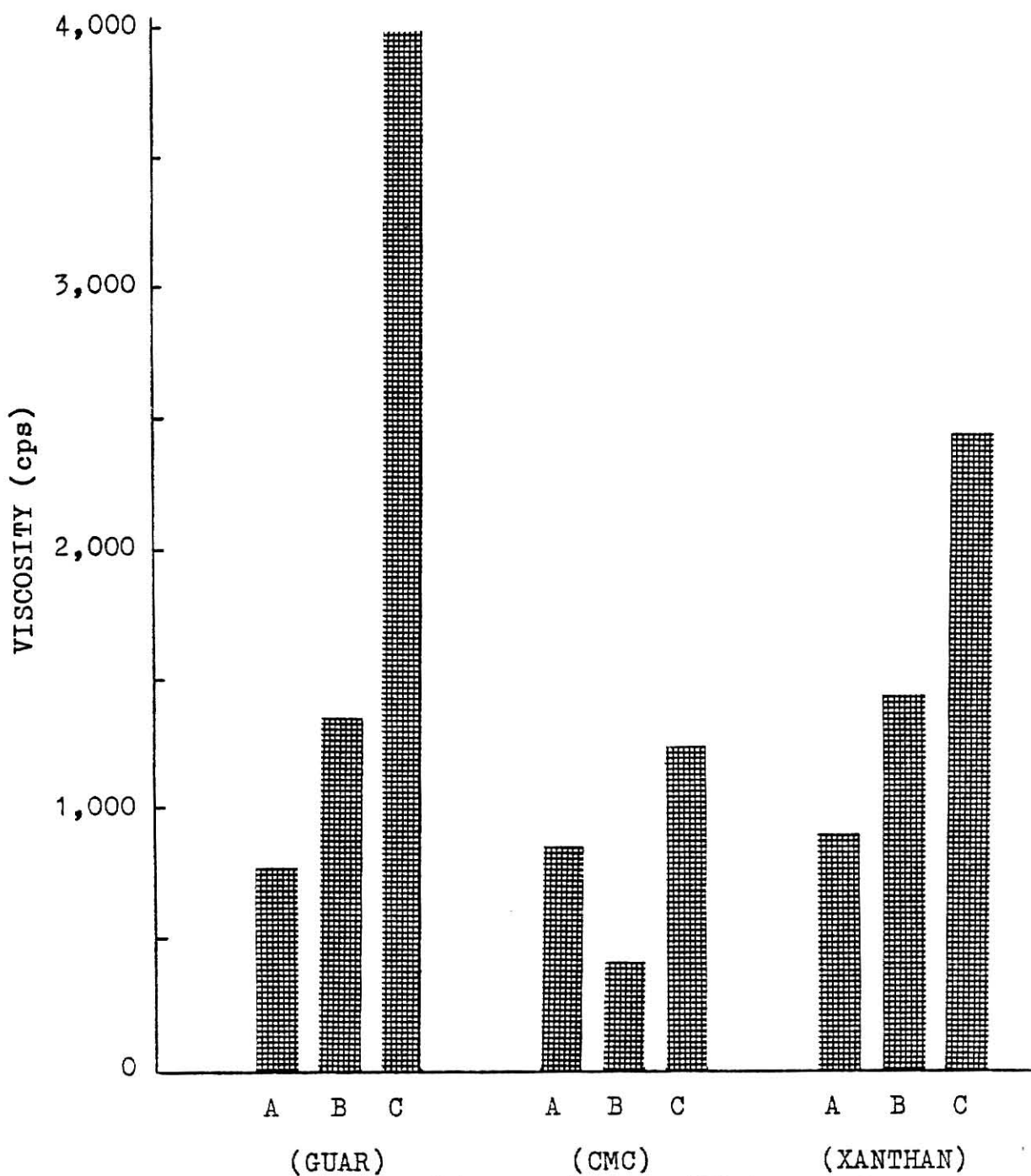


Fig. 13. The viscosity of egg white/skim milk containing guar, CMC or xanthan gum after fermentation at 37 C for 6 hours.

A: 0.1%

B: 0.5%

C: 1.0%

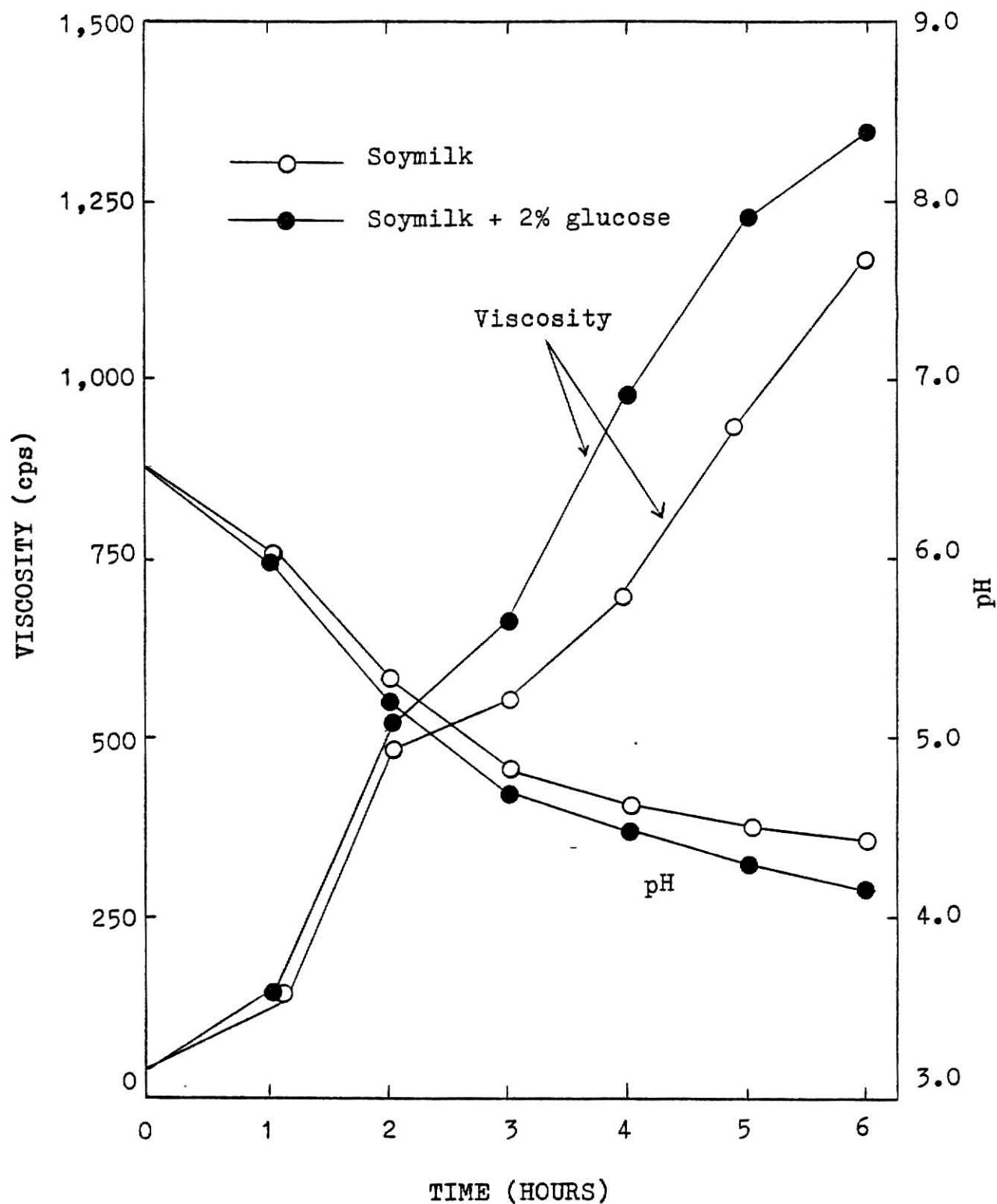


Fig. 14. The pH value and viscosity of soy milk when fermented with 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C for 6 hours.

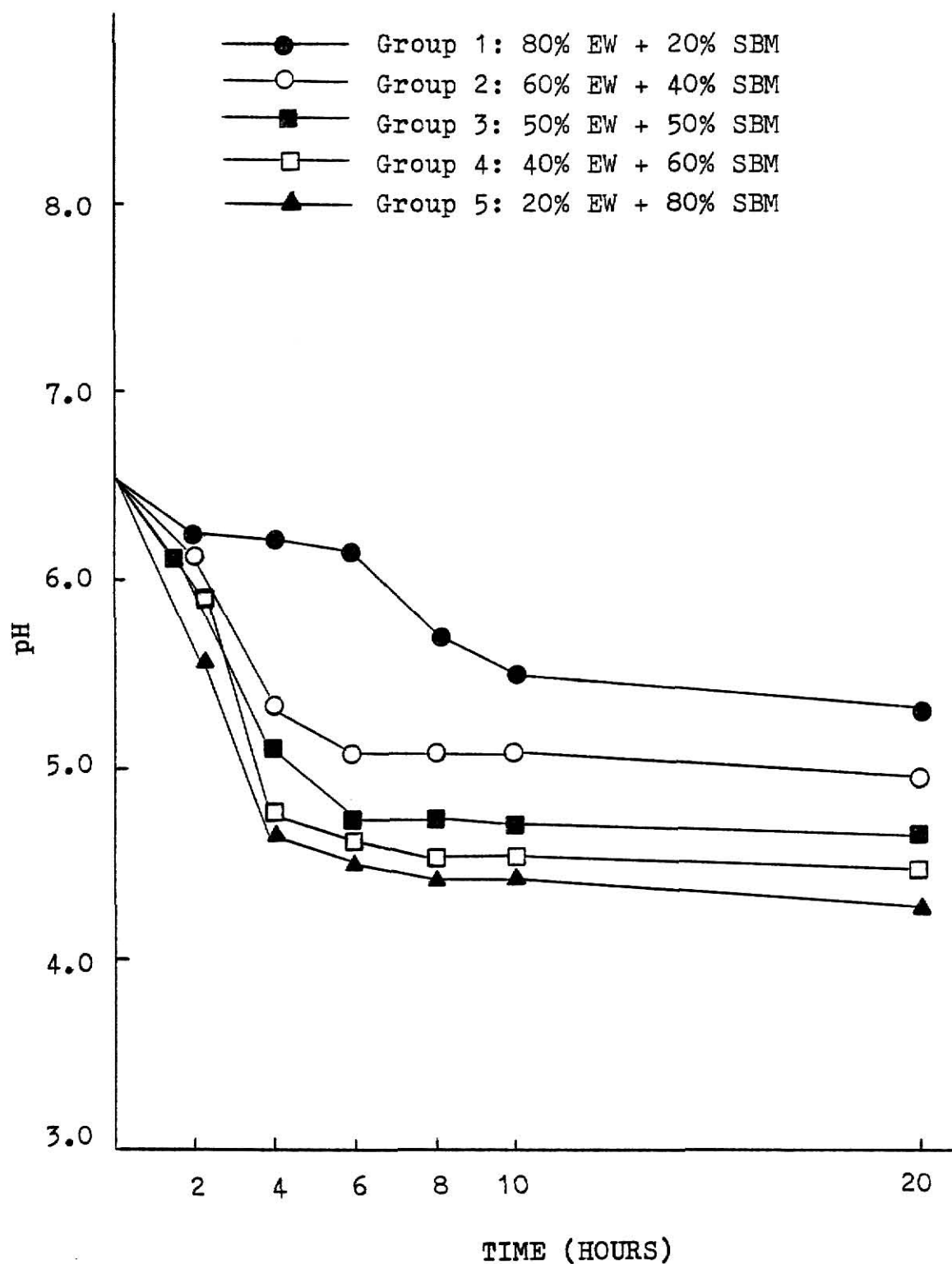


Fig. 15. The pH value of the fermentation of egg white (EW) with the combination of soymilk (SBM) and 2% glucose by 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C.

the final pH was 4.3 which was the lowest value achieved. The high soymilk content also produced a better textured product. In Fig. 16, group 5 showed a very high viscosity. However, when the soymilk content was less than 50%, the products were watery. For improving texture and more acid production, combinations of egg white, soymilk, and skim milk were considered.

Fermentation of Egg White Combined with Skim Milk and Soymilk

A. Fermentation of Skim milk and Soymilk

The pH values and viscosities of the fermented egg white combined with skim milk, soymilk, and 2% glucose after 6 hours at 37 C are shown in Table 3. The egg white content significantly effected the final acidity and texture. Only those samples containing at least 50% egg white achieved low pH and satisfactory consistency. Adding 0.5% xanthan gum did improve the texture and lower the pH. Although the groups 1, 2, 3, and 1A, 2A, 3A, showed better results on pH and texture than other groups, the mouth feel of those products were astringent and beany. For removing the astringency and beany flavor, citric acid was used as an acidifying agent for egg white (Galluzzo et al., 1974) and alkali treatment for soymilk (Badenhop and Hackler, 1970).

B. Fermentation of Egg White and Skim Milk Combined with Alkali Treated Soymilk

The pH values and viscosities of egg white combined with skim milk, alkali treated soymilk, and 2% glucose fermented at 37 C for 6 hours are shown in Table 4.

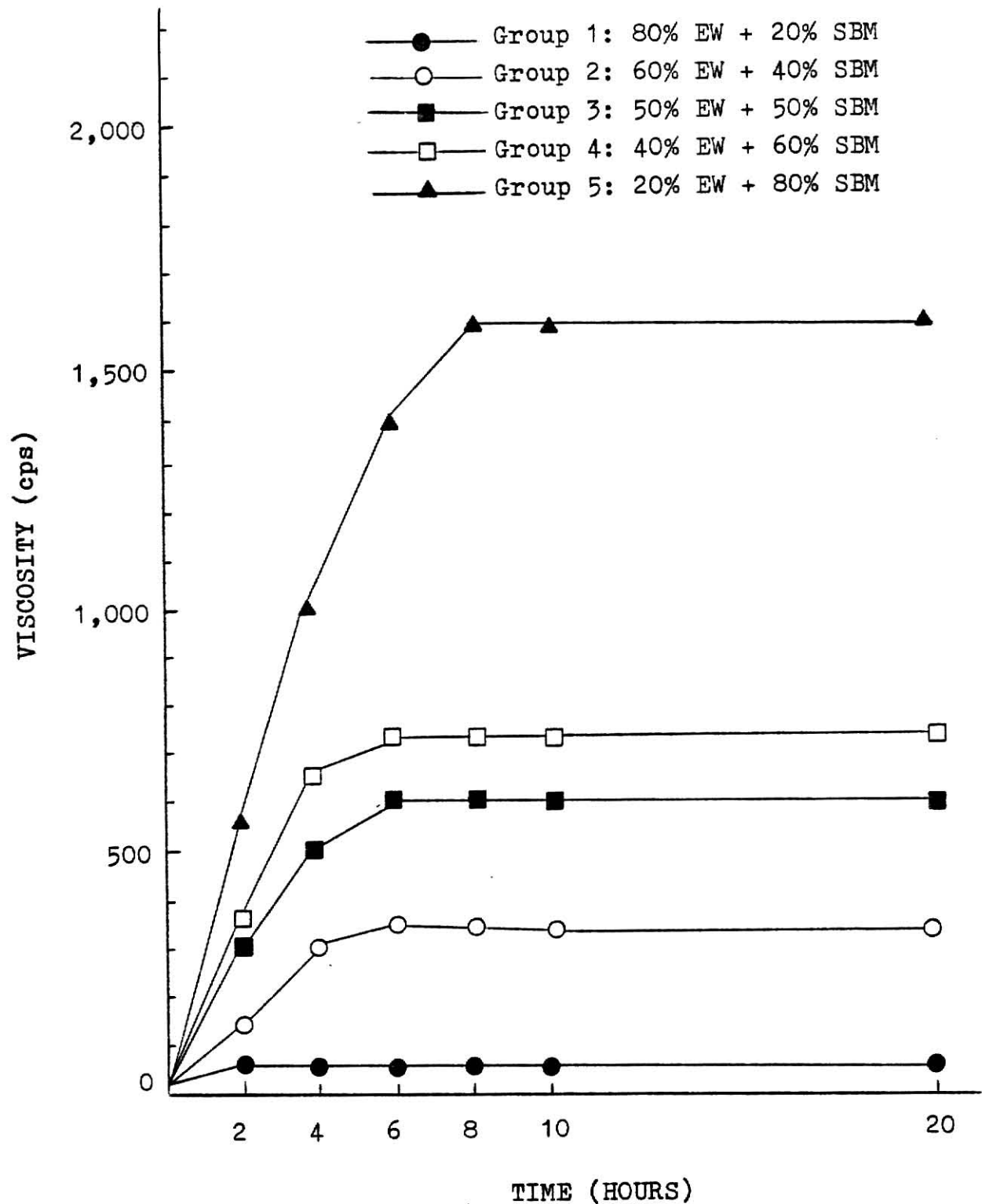


Fig. 16. The viscosity of the fermentation of egg white (EW) with the combination of soymilk (SBM) and 2% glucose by 2% Lactobacillus bulgaricus and 2% Streptococcus thermophilus at 37 C.

Table 3. The pH value and viscosity of the fermentation of egg white (EW) with the combination of skim milk (SM), soymilk (SBM) and 2% glucose at 37 C for 6 hr.^a

Group	Combination			Results	
	EW%	SM%	SBM%	pH	Viscosity (cps)
1	50	10	40	4.9	1,500
2	50	20	30	4.9	1,000
3	50	30	20	4.9	700
4	50	40	10	5.0	450
5	60	10	30	5.2	475
6	60	20	20	5.1	550
7	60	30	10	5.2	375
8	70	10	20	5.4	250
9	70	15	15	5.5	200
10	70	20	10	5.2	300
11	80	10	10	5.9	150
1A ^b	50	10	40	4.7	2,200
2A	50	20	30	4.6	2,150
3A	50	30	20	4.7	1,200
4A	50	40	10	4.8	725
5A	60	10	30	5.0	1,200
6A	60	20	20	4.9	1,150
7A	60	30	10	5.1	525
8A	70	10	20	5.1	425
9A	70	15	15	5.1	425
10A	70	20	10	5.1	425
11A	80	10	10	5.5	400

^a 2% L. bulgaricus and 2% S.thermophilus were inoculated for the fermentation.

^b A series represent the addition of 0.5% xanthan gum.

Table 4. The pH value and viscosity of egg white^a (EW) combined with skim milk (SM), soymilk^b (SBM) and 2% glucose fermented^c at 37 C for 6 hr.

Group	Combination			Results	
	EW%	SM%	SBM%	pH	Viscosity (cps)
1	50	10	40	4.9	1,100
2	50	20	30	5.0	700
3	50	30	20	4.9	750
1A ^d	50	10	40	4.8	1,400
2A	50	20	30	4.7	1,450
3A	50	30	20	4.8	1,000

^a Egg white was acidified by citric acid.

^b Soymilk was treated by Badenhop and Hackler's method (1970).

^c 2% L. bulgaricus and 2% S. thermophilus were inoculated for the fermentation.

^d "A" series represent the addition of 0.5% xanthan gum.

Sodium hydroxide solution treatment resulted in a product free of beany flavor, but kept the pH high. Badenhop and Hackler (1970) showed that most of trypsin inhibitor which exist in the soymilk were destroyed during heat processing. However, the viscosities of the final products were lower than the non-alkali treated group, despite the adding of 0.5% xanthan gum. Nevertheless, group 2A still showed a desirable flavor and appearance.

C. Modification Study

The pH value and viscosity of modification study by adding 0.01% vanilla extract and 3% sucrose, showed similar results as part B (Table 5). The color of the final products were slight brown due to the addition of vanilla extract. The 3% sucrose addition made the product showed sweeter and more palatable.

Organoleptic Evaluation of New Fermented Yogurt-like Egg Product

Organoleptic evaluation scores of 3 group samples of a new egg white fermented product based on a nine point hedonic scale are shown in Table 6. Group 1 prepared with 28.4% alkali treated soymilk was more acceptable. Although group 2 had a firmer and better texture, the beany flavor lowered the panel scores. Group 3 was the same as group 1 except that 1.0% of xanthan gum was added. Group 3 had the lowest score due to the strong gum flavor.

Table 5. The pH value and viscosity of egg white^a (EW) combined with skim milk (SM), soymilk^b (SBM), 2% glucose, 0.01% vanilla extract, and 3% sucrose fermented^c at 37 C for 6 hr.

Group	Combination			Results	
	EW%	SM%	SBM%	pH	Viscosity (cps)
1	50	10	40	5.0	1,050
2	50	20	30	5.0	750
3	50	30	20	4.9	750
1A ^d	50	10	40	4.7	1,350
2A	50	20	30	4.7	1,450
3A	50	30	20	4.8	1,000

^a Egg white was acidified by citric acid.

^b Soymilk was treated by Badenhop and Hackler's method (1970).

^c 2% L. bulgaricus and 2% S. thermophilus were inoculated for the fermentation.

^d "A" series represent the addition of 0.5% xanthan gum.

Table 6. Average organoleptic scores of new egg white fermented product^a.

Group Sample	Panel Score
Group 1 ^b	6.3 ± 1.2 ^e
Group 2 ^c	4.8 ± 1.6
Group 3 ^d	3.7 ± 0.8

^a Score 9 for sample was liked extremely, score 5 was neither liked nor disliked, score 1 was disliked extremely.

^b Prepared with 28.4% alkali treated soymilk.

^c Prepared with 28.4% traditional soymilk.

^d Modifying the group 1 with 1.0% xanthan gum.

^e Standard deviation of mean (n=6).

Composition Analysis

The composition of samples prepared from fermented egg white (47.4%), alkali treated soymilk (28.4%), skim milk (19%), glucose (1.9%), sucrose (2.8%), xanthan gum (0.5%) and vanilla extract (0.01%) is shown in Table 7.

Though the protein content (7.52%) of the new fermented product was lower than egg white (10.9%), it probably showed a better nutritional value due to the combination of albumen, caseinate, and soyprotein. The carbohydrate content (6.74%, mainly the mono and disaccharides, glucose, sucrose, and lactose) is not only a source of energy but enhanced sweetness and improved mouth feel. The low fat content produced low calories in the final product.

Since the new fermented product has high protein, low fat, and low calories, and since the panel score showed acceptability, it is believed that this new product should have high competition potential in future marketing.

Product Evaluation

The Salmonella test of the new fermented product showed negative results. The storage test at refrigeration temperature (4 C) showed no significant difference in flavor, appearance, pH, and mouth feel after 7 and 14 days. A little syneresis was observed after 21 days' storage, a small amount of whey-like liquid floated on top of the product. After these tests, the quality of the product can be assured after three weeks of storage.

Table 7. Composition^a of yogurt-like product prepared from fermented egg white (47.4%), alkali treated soymilk (28.4%), skim milk (19.0%), glucose (1.9%), sucrose (2.8%), xanthan gum (0.5%) and vanilla extract (0.01%).

Moisture	84.14%
Protein	7.52%
Carbohydrate	6.74%
Fat	0.57%
Fiber	0.26%
Ash	0.77%
Calories/100gm ^b	62

^a Values are averages of eight samples.

^b Data obtained from theoretic calculation.

CONCLUSION

Based on the results of this study, the following conclusions are drawn:

1. Egg white can be fermented by L. bulgaricus, L. acidophilus, and S. diacetilactis after pasteurization (60 C, 3 minutes), blending, and neutralization; adding 2% glucose did improve growth and acid production.
2. Addition of skim milk powder to egg white did not improve fermentation, probably due to lowered water activity. However, the addition of skim milk, alkali treated soymilk, and xanthan gum, to egg white improved fermentation and gave a better product.
3. The best formulation for producing a yogurt-like product was obtained by combining egg white (47.4%), alkali treated soymilk (28.4%), skim milk (19.0%), glucose (1.9%), sucrose (2.8%), xanthan gum (0.5%), and vanilla extract (0.01%) with the inoculation of 2% L. bulgaricus and 2% S. thermophilus at 37 C for 6 hours. The finished product had properties similar to yogurt with respect to viscosity, pH value, and sensory acceptability. The product also offered nutritious advantages to the consumer such as low fat, high protein, and low calories.

REFERENCES

- Anellis, A., J. Lubas, and M. R. Rayman. 1954. Heat resistant in liquid egg of some strains of the genus Salmonella. Food Res. 19:377.
- Anonymous. 1969. Egg Pasteurization Manual. USDA ARS 74-78, Mar., Washington, D.C.
- AOAC. 1980. Official methods of Analysis of the Association of Official Analytical Chemist. 13th Edition. Washington, D.C.
- Ariyama, H. 1963. Process for the manufacture of a synthetic yogurt from soybean. U.S. Patent 3,096,177.
- Ayres, J. C. 1958. Methods for depleting glucose from egg albumen before drying. Food Technol. 12:186.
- Ayres, J. C., and H. M. Slosberg. 1949. Destruction of Salmonella in egg albumen. Food Technol. 3:180.
- Azari, P. R., and R. E. Feeney. 1958. Resistance of metal complexes of conalbumin and transferrin to proteolysis and to thermal denaturation. J. Biol. Chem. 232:293.
- Badenhop, A. F., and L. R. Hackler. 1970. Effects of soaking soybeans in sodium hydroxide solution as pretreatment for soy milk production. Cereal Sci. Today. 15:84.
- Badenhop, A. F., and W. F. Wilkens. 1969. The formation of 1-octan-3-ol in soybeans during soaking. J. Am. Oil Chemists Soc. 46:179.
- Baker, C. M. A. 1968. The proteins of egg white. In "Egg Quality - A Study of the Hen's Egg". Edited by Carter, T. C. Oliver and Boyd, Ltd., Edinburg, Scotland.
- Baker, R. C., S. E. Hartsell, and W. J. Stadelman. 1959. Lysozyme studies on chicken egg chalazae. Food Res. 24:529.
- Banwart, G. J., and J. C. Ayres. 1957. The effect of pH on the growth of Salmonella and functional properties of liquid egg white. Food Technol. 11:244.
- Bean, M. L., K. Ijichi, T. F. Sugihara, J. J. Meehan, and L. Kline. 1963. Effects of modified processing techniques on the performance of egg white solids. Cereal Sci. Today. 8:127.
- Berquist, D. H. 1961. Methods of producing egg albumen solids with low bacteria count. U.S. Patent 2,982,663.

- Board, R. G. 1977. The microbiology of eggs. In "Egg Science and Technology". 2nd Ed., Edited by Stadelman, W. J., and O. J. Cotterill. AVI Publ. Co., Inc. Westport, Connecticut. p. 61.
- Buchanan, R. E., and N. E. Gibbon. eds. 1974. Bergey's manual of determinative bacteriology. 8th Ed., The Williams and Wilkins Company, Baltimore.
- Chang, P. K., W. D. Powrie, and O. Fennema. 1970. Disc-gel electrophoresis of protein in native and heat-treated albumen, yolk and centrifuged whole egg. J. Food Sci. 35:774.
- Chiba, H., N. Takahashi, and R. Sasaki. 1979. Enzymatic improvement of food flavor. II. Removal of beany flavor from soybean products by aldehyde dehydrogenase. Agr. and Biol. Chem. 43(9):1883.
- Chignell, C. F., D. K. Starkweather, and B. K. Sinha. 1975. A spin label study of egg white avidin. J. Biol. Chem. 250:5622.
- Clagett, C. O. 1971. Genetic control of the riboflavin carrier protein. Fed. Proc. 30:127.
- Cotterill, O. J. 1968. Equivalent pasteurization temperatures to kill Salmonellae in liquid egg white at various pH levels. Poultry Sci. 47:354.
- Cotterill, O. J., and F. A. Gardner. 1957. Retarding thick white deterioration by holding shell eggs in sealed containers. Poultry Sci. 36:196.
- Cotterill, O. J., F. A. Gardner, F. E. Cunningham, and E. M. Funk. 1959. Titration curves and turbidity of whole egg white. Poultry Sci. 38:836.
- Cunningham, F. E. 1970. The effect of heat on egg white. World's Poultry Sci. J. 26:783.
- Cunningham, F. E. 1974. Changes in egg white during incubation of the fertile egg. Poultry Sci. 53:1561.
- Cunningham, F. E. 1977. Egg product pasteurization. In "Egg Science and Technology". 2nd Ed., Edited by Stadelman, W. J., and O. J. Cotterill. AVI Publ. Co., Inc. Westport, Connecticut. p.167.
- Cunningham, F. E., and O. J. Cotterill. 1962. Factors affecting alkaline coagulation of egg white. Poultry Sci. 41:1453.

- Cunningham, F. E., and O. J. Cotterill. 1964. Factors affecting acid coagulation of the egg white. *Poultry Sci.* 43:53.
- Cunningham, F. E., and O. J. Cotterill. 1971. The influence of yolk on egg white lysozyme. *Poultry Sci.* 50:1013.
- Cunningham, F. E., and C. Francis. 1982. Ferment liquid eggs used in cheddar cheese. *Poultry Tribune.* 88(5):12.
- Cunningham, F. E., J. A. Garibaldi, K. Ijichi, and H. Lineweaver. 1965. Pasteurization of liquid egg white. *World's Poultry Sci. J.* 21:365.
- Cunningham, F. E., and H. Lineweaver. 1965. Stabilization of egg white proteins to pasteurization temperatures above 60 C. *Food Technol.* 19:136.
- Cunningham, F. E., and H. Lineweaver. 1967. Inactivation of lysozyme by native ovalbumin. *Poultry Sci.* 46:1471.
- Donovan, J. W., R. A. Beardslae, and K. D. Ross. 1976. Formation of monoferric ovotransferrin in the presence of chelates. *Biochem. J.* 153:631.
- Eakin, R. E., E. E. Snell, and R. J. Williams. 1940. A constituent of raw egg white capable of inactivating biotin in vitro. *J. Biol. Chem.* 136:801.
- Feeney, R. E., E. D. Ducay, R. B. Dilva, and L. R. MacDonnel. 1952. Chemistry of shell egg deterioration : The egg white proteins. *Poultry Sci.* 31:639.
- Feeney, R. E., and D. A. Nagy. 1952. The antibacterial activity of the egg white protein, conalbumin. *J. Bacteriol.* 64:629.
- Forsythe, R. H. 1968. The science and technology of egg products manufactured in the United States. In "Egg Quality - A Study of the Hen's Egg". Edited by Carter, T. C. Oliver and Boyd, Ltd., Edinburg, Scotland.
- Galluzzo, S. J., O. J. Cotterill, and R. T. Marshall. 1974. Fermentation of whole egg by heterofermentative Streptococci. *Poultry Sci.* 53:1575.
- Galyean, R. D., O. J. Cotterill, and F. E. Cunningham. 1972. Yolk inhibition of lysozyme activity in egg white. *Poultry Sci.* 51:1346.
- Garibaldi, J. A. 1960. Factors in egg white which control growth of bacteria. *Food Res.* 25:337.

- Garibaldi, J. A., J. W. Donovan, J. G. Davis, and S. L. Comino. 1968. Heat denaturation of the ovomucin-lysozyme electrostatic complex - A source of damage to the whipping properties of pasteurized egg white. *J. Food Sci.* 33:514.
- Geoffrey, P., and C. J. Bailey. 1975. The action of hen and goose lysozyme on the cell wall peptidoglycan of Micrococcus lysodeikticus. *Bioch. Soc.* 1:514.
- Ghera, R. L., P. Pienta, A. C. Jong, H. Hsu, and P. M. Daggett. 1978. The American Type Culture Collection Catalogue of Strains I. 13th Ed., Rockville, Maryland.
- Hackler, L. R., J. P. Van Buren, K. H. Steinkraus, I. El Rawi, and D. B. Hand. 1965. Effect of heat treatment on nutritive value of soymilk protein fed to weanling rats. *J. Food Sci.* 30:723.
- Hawthorne, J. R., and J. Brooks. 1944. Dried egg. VIII. Removal of the sugar of egg pulp before drying. A method of improving the storage life of spray-dried whole egg. *J. Soc. Chem. Ind.*, 63:232.
- Hill, M. W., and M. Sebring. 1977. Desugarization. In "Egg Science and Technology". 2nd Ed., Edited by Stadelman, W. J., and O. J. Cotterill. AVI Publ. Co., Inc. Westport, Connecticut. p.189.
- Homler, B. E., and W. J. Stadelman. 1963. The effect of oiling before and after cleaning in maintaining the albumen condition of shell eggs. *Poultry Sci.* 42:190.
- Hopkins, E. W., G. J. Josh, and L. A. Harriman. 1947. Preparing dried egg products. U.S. Patent 2,427,726.
- Hudspeth, J. P., G. W. Newell, D. R. White, J. G. Berry, and R. D. Morrison. 1965. An electrophoretic study of chicken egg albumen. *Poultry Sci.* 44:149.
- Kaplan, A. M., M. Soloway, W. W. Osborne, and H. Tubiash. 1950. Resting cell fermentation of egg white by *Streptococci*. *Food Technol.* 4:474.
- Kaufman, V. F., K. Ijichi, and G. W. Putnam. 1968. Flow characteristics in holding tubes of commercial egg pasteurizers. *J. Milk Food Technol.* 31:269.
- Kline, L., T. F. Sugihara, M. L. Bean, and K. Ijichi. 1965. Heat pasteurization of raw liquid egg white. *Food Technol.* 19:1709.
- Kraidej, L. 1975. Preparation of fermented-milk type products using soymilk. *Food.* 7(4):63.

- Lineweaver, H., H. J. Morris, L. Kline, and R. S. Bean. 1948. Enzymes of fresh hen eggs. *Arch. Biochem.* 16:443.
- Longree, K., S. Beaver, P. Buck, and J. E. Nowrey. 1966. Viscous behavior of custard system. *J. Agr. Food Chem.* 14(6):653.
- Marion, W. W., A. W. Nordskog, H. S. Tolman, and R. H. Forsythe. 1964. Egg composition as influenced by breeding, egg size, age and season. *Poultry Sci.* 43:255.
- Marth, E. H. ed. 1978. *Standard Methods for the Examination of Dairy Products*. 14th Ed., American Public Health Association, Inc. Washington, D.C.
- Mattick, L. R., and D. B. Hand. 1969. Identification of a volatile component in soybeans that contributes to the raw bean flavor. *J. Agr. Food Chem.* 17(1):15.
- Mital, B. K. 1974. Fermentation of soymilk oligosaccharides by lactic acid bacteria. *Dissertation Abstract International*, B. 35(2)880:Order No. 74-17658.
- Mital, B. K., K. H. Strinkhaus, H. B. Naylor. 1974. Growth of lactic acid bacteria in soymilks. *J. Food Sci.* 39:1018.
- Myres, W. G., and W. G. France. 1940. A study of some properties of thixotropic gels containing egg albumen as the disperse phase. *J. Phy. Chem.* 44:1113.
- Nath, K. R., R. C. Baker. 1973. Factors affecting the growth of *Pseudomonas fluorescens* in liquid egg white. *Appl. Microbiol.* 25:442.
- Nelson, A. I., M. P. Steinberg, and L. S. Wei. 1976. Illinois process for preparation of soymilk. *J. Food Sci.* 41:57.
- North, W. R., Jr. 1961. Lactose preenrichment method for isolation of *Salmonella* from dried egg albumen. *Appl. Microbiol.* 9:188.
- Osborne, W. W., R. P. Straka, and H. Lineweaver. 1954. Heat resistance of strains of *Salmonella* in liquid whole egg, egg yolk and egg white. *Food Res.* 19:451.
- Osuga, D. T., and R. E. Feeney. 1974. Avidin egg white proteins. In "Toxic Constituents of Animal Foodstuffs". Edited by Leiner, I. E. Academic Press, New York.
- Powrie, W. D. 1977. Chemistry of eggs and egg products. In "Egg Science and Technology". 2nd Ed., Edited by Stadelman, W. J., and O. J. Cotterill. AVI Publ. Co., Inc. Westport, Connecticut. p.65.

- Raccach, M., and R. C. Baker. 1979. Bacterial repressive action of meat starter culture in pasteurized liquid whole egg. *J. Food Sci.* 44:90.
- Schwall, D. V., F. A. Gardner, and E. D. Parnell. 1961. Effects of oil treating on shell egg quality during short term refrigerated storage. *Poultry Sci.* 40:583.
- Seideman, W. E., O. J. Cotterill, and E. M. Funk. 1963. Factors affecting heat coagulation of egg white. *Poultry Sci.* 42:406.
- Sharp, P. F., and R. Whitaker. 1927. The relation of the hydrogen ion concentration of egg white to its germicidal action. *J. Bacteriol.* 14:17.
- Stadelman, W. J. 1977. Quality identification of shell eggs. In "Egg Science and Technology". 2nd Ed., Edited by Stadelman, W. J., and O. J. Cotterill. AVI Publ.Co., Inc. Westport, Connecticut. p.29.
- Stadelman, W. J., and M. L. Wilson. 1957. Spray oiling of eggs. *Poultry Sci.* 36:1159.
- Stewart, G. F., L. R. Best, and B. Lowe. 1943. A study of some factors affecting the storage changes in spray-dried egg products *Proc. Inst. Food Technol.* p.77.
- Stuart, L. S., and H. E. Goresline. 1942. Studies of bacteria from fermenting egg white and the production of pure culture fermentations. *J. Bacteriol.* 44:65.
- Tung, N. A., E. L. Watson, and J. F. Richards. 1969. Rheology of egg albumen. Paper 69-874. Winter Meeting, Am. Soc. Agr. Eng., Chicago, Ill.
- Tung, M. A., E. L. Watson, and J. F. Richards. 1970. Rheology of fresh, aged and gamma-irradiated egg white. *J. Food Sci.* 35:872.
- Wang, H. L., L. Kraidej, C. W. Hesseltine. 1974. Lactic acid fermentation of soybean milk. *J. Milk Food Technol.* 37:71.
- Wilkins, W. F., and F. M. Lin. 1970. Gas chromatographic and mass spectral analysis of soybean milk volatiles. *J. Agr. Food Chem.* 18(3):333.
- Wilkins, W. F., L. R. Mattick, and D. B. Hand. 1967. Effect of processing method on oxidative off-flavors of soybean milk. *Food Technol.* 21:1630.
- Wilkin, M., and A. R. Winter. 1947. Pasteurization of egg yolk and white. *Poultry Sci.* 26:136.

- Winter, A. R. 1952. Production of pasteurized frozen egg products. Food Technol. 6:414.
- Wolf, W. J. 1975. Lipoxygenase and flavor of soybean protein products. J. Agr. Food Chem. 23(2):136.
- Yadav, N. K., and D. V. Vadehra. 1977. Mechanism of egg white resistance to bacterial growth. J. Food Sci. 42:97.

PREPARATION OF YOGURT-LIKE PRODUCT FROM
FERMENTATION OF EGG WHITE

by

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ABSTRACT

The fermentation of liquid egg white by inoculating lactic acid bacteria to develop a yogurt type new product has been studied. The egg white was rendered by pasteurization, blending and neutralization to minimize antimicrobial activity and more suitable for lactic acid bacteria to grow. Seven different test organisms were inoculated into the treated egg white to study their growth rate and acid production. Lactobacillus bulgaricus NRRL B-548, L. acidophilus NRRL B-4495 and Streptococcus diacetylactis NRRL B-2356 had good growth and acid production, and 2% glucose enrichment showed better results.

To develop a fermented yogurt-like new product, L. bulgaricus NRRL B-548 and S. thermophilus ATCC 14485 have been selected to be the starter culture. Several different trials by combining food additives such as skim milk, skim milk powder, gums (guar gum, CMC, xanthan gum), soymilk and glucose enrichment have been done. The optimum results were obtained when 47.4% treated egg white combined with 28.4% alkali treated soymilk, 19.0% skim milk, 1.9% glucose, 2.8% sucrose, 0.5% xanthan gum and 0.01% vanilla extract.

The composition per 100 gm of the final product showed high in protein (7.52%), low in fat (0.57%) and calories (62 cal). The quality evaluation showed health hazard free and long shelf life at the refrigeration temperature.