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The Louisiana State University and Agricultural and Mechanical Col.

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CHEMICAL AND PHYSICAL CHARACTERISTICS
OF PEPPER MASH AND HOT PEPPER SAUCE

A Dissertation

Submitted to the Graduate Faculty
of the Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Food Science

by

Abdul Rahman Awad
B.S. University of Basra, 1977
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TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	ii
TABLE OF CONTENTS	iii
LIST OF FIGURES	v
LIST OF TABLES	xii
ABSTRACT	xv
INTRODUCTION	1
REVIEW OF LITERATURE	3
History of hot sauce	3
Colloid systems	6
Pectin as a hydrocolloid	9
Factors effecting the stability of hot sauce . .	13
Pectic substances and their enzymes	13
pH enzyme interaction	15
Temperature-enzyme interaction	16
Insoluble solids	19
Homogenization	21
Food additives	22
MATERIALS AND METHODS	24
Experimental set	24
Sampling	25
pH Determination	25
Acidity	25
% Salt	26
Color (dE)	26
Total pectic substances	26
General procedure of making sauce	27
Rapid procedure for making sauce	27
Shaking the sauce	27
Viscosity determination	28
Pectic enzymes	28

TABLE OF CONTENTS (cont'd)

	Page
RESULTS AND DISCUSSION	29
pH	29
Effect of barrel type and depth of mash in	
6% salt treatment	44
8% salt treatment	47
10% salt treatment	49
Effect of salt concentration	52
Acidity	65
Effect of barrel type and depth of mash in	
6% salt treatment	65
8% salt treatment	70
10% salt treatment	73
Effect of salt concentration	75
The salt content	87
Total color differences (dE)	96
Total pectic substances	105
Effect of barrel type and depth of mash in	
6% salt treatment	105
8% salt treatment	106
10% salt treatment	112
Effect of salt concentration	116
Stability of hot sauce	129
Effect of shaking	129
Effect of container size and type of shaking	131
Effect of container position	132
Sauce making	136
Effect of shearing	136
Effect of pectin	148
Effect of pectic enzymes	152
SUMMARY	155
REFERENCES	157
VITA	164

LIST OF FIGURES

Figure		Page
1	Flow diagram of hot sauce manufacturing process	5
2	Relative activity of tomato enzymes at different pH's	17
3	Diagram of fractionation of tomato juice by centrifugation and sieving	20
4	The effect of barrel type (O,P) and depth of mash samples (T,B) on the mean pH value of 6% salt pepper mash (First year samples)	45
5	The effect of barrel type (O,P) and depth of mash samples (T,B) on the mean pH value of 6% salt pepper mash (Second year samples)	46
6	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean pH value of 8% salt pepper mash (First year samples)	50
7	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean pH value of 8% salt pepper mash (Second year samples)	51
8	The effect of barrel type (O,P) and depth of the mash samples (T,B) an the mean pH value of 10% salt pepper mash (First year samples)	53
9	The effect of barrel type (O,P) and depth of the mash samples (T,B) an the mean pH value of 10% salt pepper mash (Second year samples)	54
10	The effect of salt concentration (%) on the mean pH value of the top section of the oak barrel mash sample (First year samples)	55
11	The effect of salt concentration (%) on the mean pH value of the bottom section the oak barrel samples (First year samples) .	56

LIST OF FIGURES (Continued)

Figure		Page
12	The effect of salt concentration (%) on the mean pH value of the top section of the plastic barrel pepper mash samples (First year samples)	57
13	The effect of salt concentration (%) on the mean pH value of the bottom section of the plastic barrel pepper mash sample (First year samples)	58
14	The effect of salt concentration (%) on the mean pH value of the top section of the oak barrel mash sample (Second year sample)	60
15	The effect of salt concentration (%) on the mean pH value of the bottom section the oak barrel samples (Second year sample)	61
16	The effect of salt concentration (%) on the mean pH value of the top section of the plastic barrel pepper mash samples (Second year sample)	62
17	The effect of salt concentration (%) on the mean pH value of the bottom section of the plastic barrel pepper mash sample (Second year sample)	63
18	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean total acidity % (acetic acid) of 6% salt pepper mash (First year samples)	66
19	The effect of barrel type (O,P) and depth of the mash sample (T,B) on the mean total acidity % (acetic acid) of 6% salt pepper mash (Second year sample)	67
20	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean total acidity (% lactic acid) of 8% salt pepper mash (First year samples)	71

LIST OF FIGURES (Continued)

Figure		Page
21	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean total acidity (% lactic acid) of 8% salt pepper mash (Second year samples)	72
22	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean total acidity (% lactic acid) of 10% salt pepper mash (First year samples)	74
23	The effect of barrel type (O,P) and depth of the mash sample (T,B) on the mean total acidity (% lactic acid) of 10% salt pepper mash (Second year samples)	76
24	The effect of salt concentration % on the mean total acidity (% lactic acid) of the top sections of the oak barrel pepper mash (First year samples)	77
25	The effect of salt concentration % on the mean total scidity (% lactic acid) of the bottom sections of the oak barrel pepper mash (First year samples)	78
26	The effect of salt concentration (g%) on the mean total acidity (lactic acid) of the top sections of the plastic barrel pepper mash (First year samples)	79
27	The effect of salt concentration (g%) on the mean total acidity (lactic acid) of the bottom sections of the plastic barrel pepper mash (First year samples)	80
28	The effect of salt concentration % on the mean total acidity (% lactic acid) of the top sections of the oak barrel pepper mash (Second year samples)	81
29	The effect of salt concentration % on the mean total acidity (% lactic acid) of the bottom sections of the oak barrel pepper mash (second year samples)	82
30	The effect of salt concentration (g%) on the mean total acidity (lactic acid) of the top sections of the plastic barrel pepper mash (Second year samples)	83

LIST OF FIGURES (Continued)

Figure		Page
31	The effect of salt concentration (g%) on the mean total acidity (lactic acid) of the bottom sections of the plastic barrel pepper mash (Second year samples)	84
32	The actual amount of salt (g%) in the 6% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (First year samples)	88
33	The actual amount of salt (g%) in the 8% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (First year samples)	89
34	The actual amount of salt (g%) in the 10% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (First year samples)	90
35	The actual amount of salt (g%) in the 6% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (Second year samples)	92
36	The actual amount of salt (g%) in the 8% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (Second year samples)	93
37	The actual amount of salt (g%) in the 10% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (Second year samples)	94
38	The effect of barrel type and depth of the mash samples on the total color differences (dE) of 6% salt pepper mash (First year samples)	97
39	The effect of barrel type and depth of the mash samples on the total color differences (dE) of 8% salt pepper mash (First year samples)	98

LIST OF FIGURES (Continued)

Figure		Page
40	The effect of barrel type and depth of the mash samples on the total color differences (dE) of 10% salt pepper mash (First year samples)	99
41	The effect of barrel type and depth of the mash samples on the total color differences (dE) of 6% salt pepper mash (Second year samples)	101
42	The effect of barrel type and depth of the mash samples on the total color differences (dE) of 8% salt pepper mash (Second year samples)	102
43	The effect of barrel type and depth of the mash samples on the total color differences (dE) of 10% salt pepper mash (Second year samples)	103
44	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 6% salt pepper mash samples (First year samples)	107
45	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 6% salt pepper mash samples (Second year samples)	108
46	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 8% salt pepper mash samples (First year samples)	109
47	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 8% salt pepper mash samples (Second year samples)	111
48	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 10% salt pepper mash samples (First year samples)	114

LIST OF FIGURES (Continued)

Figure		Page
49	The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 10% salt pepper mash samples (Second year samples)	115
50	The effect of salt concentration (g%) on the total pectic content (mg/100g) of the top sections of the oak barrel pepper mash (First year samples)	118
51	The effect of salt concentration (g%) on the total pectic content (mg/100g) of the bottom sections of the oak barrel pepper mash (First year samples)	119
52	The effect of salt concentration (g%) on the total pectic content (mg/100g) of the top sections of the oak barrel pepper mash (Second year samples)	121
53	The effect of salt concentration (g%) on the total pectic content (mg/100g) of the bottom sections of the oak barrel pepper mash (Second year samples)	122
54	The effect of salt concentration (g%) on the total pectin content (mg/100g) of the top sections of the plastic barrel mash (First year samples)	124
55	The effect of salt concentration (g%) on the total pectin content (mg/100g) of the bottom sections of the plastic barrel mash (First year samples)	125
56	The effect of salt concentration (g%) on the total pectin content (mg/100g) of the top sections of the plastic barrel mash (Second year samples)	127
57	The effect of salt concentration (g%) on the total pectin content (mg/100g) of the bottom sections of the plastic barrel mash (Second year samples)	128
58	The effect of shaking on the stability hot pepper sauce shaken vertically and horizontally	135

LIST OF FIGURES (Continued)

Figure		Page
59	The effect of shaking on the stability of homogenized and nonhomogenized hot pepper sauce	141
60	The effect of shaking on the stability of two different commercial hot sauces before and after homogenization	143
61	Light micrographs of commercial, rapid method sauces before and after homogenization	147

LIST OF TABLES

Table		Page
1	Effect of barrel type, depth of mash and salt content on the mean pH, salinity(%), total acid (%), total pectin (mg/100g mash) and change in color (d E) of aged mash. Sample 1 October 12, 1982.	30
2	Sample 2, October 25, 1982	31
3	Sample 3, November 29, 1982	32
4	Sample 4, January 7, 1983	33
5	Sample 5, February 9, 1983	34
6	Sample 6, May 17, 1983	35
7	Sample 7, September 4, 1983	36
8	Sample 8, October 22, 1983	37
9	Sample 9, October 17, 1984	38
10	Sample 10, October 22, 1984	39
11	Sample 11, April 19, 1984	40
12	Sample 12, June 30, 1984	41
13	Sample 13, September 24, 1984	42
14	Sample 14, October 17, 1984	43
15	The effect of barrel type and sampling location on the mean pH values of pepper mash samples containing 6% salt during the first and second year of aging	48
16	The effect of salt treatment, Barrel type and location of mash sample on the initial and average pH of first and second year mash samples	64
17	The initial and mean acidity of first and second year mash samples	86

LIST OF TABLES (Cont'd)

Tables	Page
18 The initial and mean salt concentration (g salt/100g sample) of first and second year pepper mash samples	95
19 The effect of salt treatment and location of mash on the average pH of the oak barrel mash samples during first and second year of the aging process	113
20 The effect of salt treatment and location of mash on the average pH of the plastic barrel mash samples during the first and second year of the aging process	117
21 The effect of shaking on the stability of commercial hot sauce (2 oz bottle) after shaking for 6 hour	130
22 The effect of type of shaking and container size on the stability of three different types of sauces	130
23 Effect of shaking method on the stability of hot sauce (2 oz bottle) after 1 and 3 hour of shaking	133
24 Effect of bottles position on hot sauce stability during straight line shaking	133
25 Effect of hot sauce manufacturing procedure on the viscosity and stability of hot sauce	137
26 Effect of shearing on the stability of hot sauce	137
27 Effect of shaking on the stability of non-homogenized (NH) and homogenized (H) hot sauce prepared by the rapid method	137
28 Effect of shearing on the viscosity of two types of hot sauce after shaking for 1, 3, and 6 hours.	144

LIST OF TABLES (Cont'd)

Tables	Page
29 Total solids content (%) of two different types of hot sauce	145
30 The viscosity and stability of hot sauce made by new rapid method after mixing the mash with the vinegar for 3 days	145
31 Effect of location of pepper mash in oak and plastic barrels on the viscosity and stability of hot sauce before and after homogenization. Mashers from sample 11 . . .	149
32 Effect of location of pepper mash on oak and plastic barrels on the viscosity and stability of hot sauce before and after homogenization. Mashers from sample 12 . . .	150
33 Effect of location of pepper mash on oak and plastic barrels on the viscosity and stability of hot sauce before and after homogenization. Mashers from sample 13 . . .	151
34 Effect of the liquid mash total pectin on improving the viscosity and stability of hot sauce	153
35 Effect of pectinase enzyme treatment on the viscosity and stability of hot sauce . .	153

ABSTRACT

Three different treatments of salt 6, 8 and 10% were used in the process of aging hot pepper mash in oak and plastic barrels over a period of two years.

The chemical characteristics of the changes during the aging process of these mashes were determined. These characteristics included pH, titratable acidity, salt content, color changes and total pectic substances.

The pectic substances were degraded by the hot pepper pectic enzymes very rapidly after only a few days of aging. This degradation could be retarded by increasing the salt content of the mash or by aging in oak barrels.

However, the degradation of pectic substances depended greatly on the pH of the hot pepper mash. The optimum pH for this degradation was found to be in the range of ≤ 4.20 or ≥ 4.60 . Therefore, the degradation of pectic substances declined sharply during the second year of aging, especially in the oak barrels due to the unfavorable pH for the activity of pectic enzymes.

The oak barrel hot pepper mash that was treated with 8% salt was found to contain a higher amount of pectic substances than any other of the treatments and with less color changes as compared with the standard sample. This mash also produced a more stable hot pepper sauce after two years of aging.

A new procedure for preparing hot pepper sauce was developed which required only 20 min as compared to the current 30 days required by the traditional method. The stability of the new hot pepper sauce during shaking was found to be dependent on the amount of pectic substances and the size of the suspended particles in the sauce. The size and position of the hot pepper sauce containers as well as the type of shaking were also important in determining the stability of the hot pepper sauce.

CHAPTER I

INTRODUCTION

Hot pepper sauce is made from hot red peppers and used quite extensively for the seasoning of many foods due to its pungent flavor.

One noticeable problem associated with this product is its tendency to separate into top liquid phase and a sedimentary bottom portion.

Several hydrocolloidal materials have been added to the sauce in order to increase its viscosity and prevent the sedimentation; but none of these materials could prevent this separation (Schlottman, 1977).

McColloch et al. (1950), Steir (1955) and Kertesz (1966) showed that the natural pectic substance is a very important factor and partially responsible for the stability of sauces. A decrease in pectic constituents contributed to liquification of sauces and juices. During processing and storage, pectic substances in these products were hydrolyzed unless pectic enzymes were inactivated by proper treatment (Baker and Gilligan 1947a; Kertesz, 1938).

A complete discussion of the pectinesterase enzyme (PE) was presented by Patel and Phaff (1960). The polygalacturonase enzymes (PG) were discussed in detail by Deuel and Stutz, 1958 and its actions always depended on the actions of PE enzymes to form the substrate. Decreases in

viscosity of tomato juice with ripened fruit were shown by Luh et al. (1980).

The variety of tomato also affect tomato paste and sauce consistency. Luh et al. (1954) investigated the quality and quantity of pectic substances in Person and San Marzaro tomatoes and found the Person to have a lower pectic content.

Whittenberger and Nutting (1957) showed that the consistency of juices depends largely on the quantity, shape and character of the cell wall present.

Robinson et al., (1956) indicated that the degree of settling of tomato juices was determined by the amount of insoluble solids in suspension. They also showed that rupture of the intact cells by homogenization reduces the degree of settling. However, their study indicated that the amount of pectin in tomato juice does not have a major effect on the degree of settling.

The purpose of this study was to determine the chemical characteristics and changes during the aging process of pepper mash and to develop a new procedure for producing a stable hot pepper sauce based on the study of the physical characteristics that are related to separation of solid particles in the hot pepper sauce.

CHAPTER II

Review of Literature

History of Hot Sauce

The hot sauce industry is one of the largest food industries in Louisiana. Hot sauce is manufactured by several plants under different brand names utilizing slightly different processes. Most of these hot sauce processors use red peppers which belong to several species and varieties. The most popular species are Capsicum frutescens L. and Capsicum annum L.

These species of peppers originated in Mexico. Following the war with the United States in the 1840's, many of the returning soldiers brought back seeds of these peppers (Schweid, 1980).

In the early 1920's large pepper dehydrators were built at New Iberia, LA. About this time, the pepper industry in the New Iberia area and Southern Mississippi also started operation. However, today the hot sauce industry is centered in the New Iberia-St. Martinville-Lafayette area. This area is now producing two types of hot sauce: the low consistency brand with a high moisture content (95.5%) and the high consistency brand with low moisture (84.5%) (Noorbakhsh, 1976).

Although the products may differ somewhat from processor to processor, the sauce is basically manufactured by grinding the peppers of the Capsicum annum or Capsicum frutescens varieties into a pepper mash. The mash is mixed with 8 to 20 percent salt and aged. This aging process could be several weeks to three years in duration. The aged mash is then blended with vinegar. This mixture may or may not be ground again, but is strained through screening machines to remove large particles of skin and seed. The finished product is then bottled, labeled and marketed. This process is outlined in Figure 1.

Figure 1 contains the general outline for the hot sauce process, however, the exact procedure may vary somewhat and is considered to be a guarded trade secret. The main differences among the brands are: 1) the amount of salt added; 2) the time the mash is allowed to age; 3) the degree of grinding and straining of the insoluble material and 4) the amount of vinegar added to the final product. The composition of different brands of hot sauce ranged from 81 to 95% moisture, 3 to 8.5% acetic acid, pH 2.0 to 3.0 and a salt content of 2.0 to 15.0% (Noorbakhsh, 1976).

One noticeable problem associated with the hot sauce is its tendency to separate into a top liquid phase (serum) and a sedimentary bottom portion. This may be considered a defect in the quality of the sauce, however it is believed

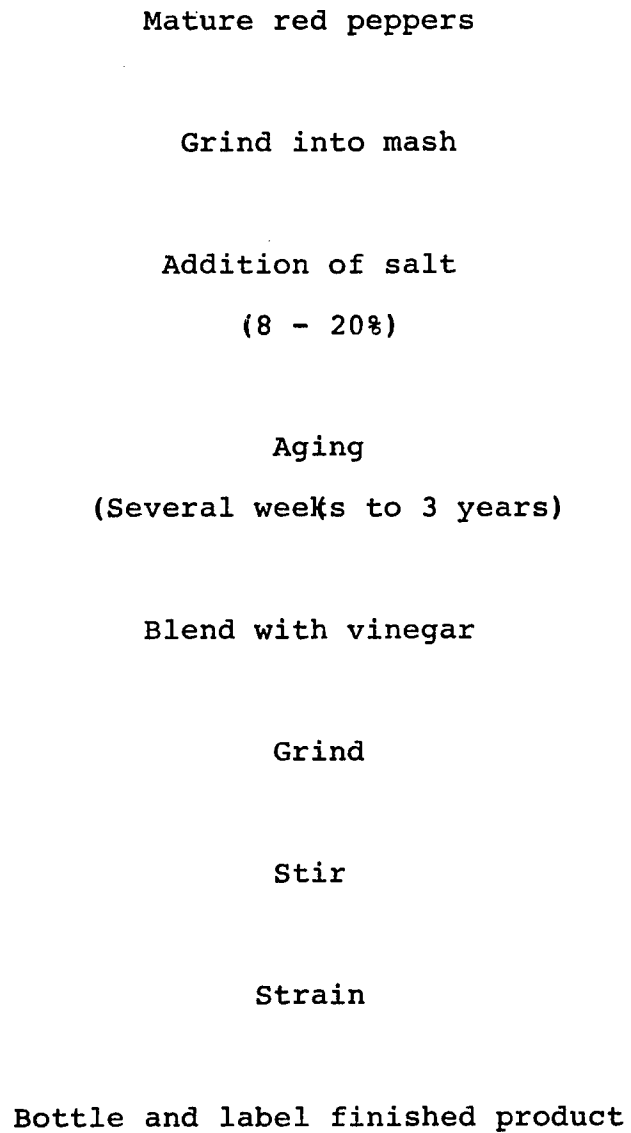


Figure 1-Flow diagram of hot sauce manufacturing process

to have very little influence on consumer acceptance. Some processors presently add hydrocolloids such as xanthan gum to thicken the sauce, but the separation can not be prevented completely (Schlottmann, 1977).

Colloid Systems

The basic principle of the behavior of hot sauce has been known for many years. It behaves as a colloidal system in which the solid particles are suspended in the liquid phase. Therefore, it is very important to explain the behavior of this colloidal system and the role of pectin, a natural hydrocolloid which normally prevents the solid particles from separating.

Most foods are considered to be a dispersion system in which one or more dispersed phases are suspended in a continuous phase. A dispersion can be as simple as sugar and protein solutions or as complex as whipped cream which contains a wide variety of dispersed molecules and particles (Graham, 1977).

The type of dispersed particles in food dispersions include crystals, amorphous solid matter, cell fragments, cells, liquid droplets and gas bubbles. In most cases, the continuous phase is either water or an edible oil. Dispersions can be classified on the basis of the size or physical state of particles. Coarse dispersions have particles with dimensions greater than 0.5 μm and colloidal dispersion systems contain particles ranging in size from

0.5 μm to 1 μm (Farkas and Glicksman, 1967; Graham, 1977; Glicksman, 1982).

The particles in the colloidal system are large enough to impart properties different from those usually found in true solutions, but small enough to prevent the particles from settling out (Glicksman, 1982).

In colloidal particles, the total surface area of these particles is very large in proportion to the mass and the properties of these surfaces are very important in governing the behavior of colloidal systems (Samuel, 1960).

The dispersed state of colloidal particles is maintained by either or both of the following factors:

1. The charge on the surface of the particles and/or
2. A layer of oriented water molecules around the particles.

In any given system, like charges on the surface of the colloidal particles would all be the same, and since like charges repel each other, this tends to keep particles from aggregating and precipitating. The charged surface is regarded as the stabilizing agent in hydrophobic colloidal systems (Samuel, 1960; Graham, 1977; Glicksman, 1982).

In hydrophillic colloidal systems, a shell of oriented water molecules around each particle prevents the particles from aggregating. This is in addition to the potential barrier to flocculation imparted by the charged surface of the particles. In this system, the water tends to form a

surface layer or shell around the particles preventing coalescence and flocculation. Part of the water is bound by hydrogen bonding, part by capillary attraction and part by the interaction between the surface charges of the particles and dipole moment of the water molecules (Glicksman, 1982).

A secondary contributor to stability of colloidal dispersions is the Brownian movement of the dispersed particles. This tends to keep the particles dispersed throughout the system and helps prevent sedimentation (Farkas and Glicksman, 1967).

A substance in the colloidal state that prevents the aggregation of particles is called a hydrocolloid (protective colloids). These protective colloids are characterized by a high degree of hydration and require a large quantity of an electrolyte to produce a viscous solution (Graham, 1977). Most of these materials are usually high molecular weight polymers and are generally polysaccharide in nature.

The importance of hydrocolloids in food applications is due to their unique functional properties; the more important are the following:

1. The water holding capacity
2. The regulation of rheological properties
3. The suspension of insoluble particles
4. Stabilization

A wide variety of natural hydrocolloids are present in foods. The best recognized of these are gum arabic, locust bean gum, pectin, gum tragacanth and starch (Paul, 1972; Glicksman, 1982).

Liquid foods can usually be thickened most economically through the use of gums and other natural or synthetic hydrocolloids. Carageenan, tragacanth and carboxymethyl cellulose (CMC) have been used widely in the stabilization of salad dressings, mayonnaise, sauces, relishes and chocolate milk (Graham, 1977).

Pectin as a Hydrocolloid

Many studies have shown that pectin is responsible for the stability of many products that are made from fruits and vegetables (Baker and Gilligan, 1947a; Baker and Bruemmer, 1971; Becker et al., 1968; Belli-Donini and Stromaikola, 1969; Biggs and Kain, 1962; Deuel and Stutz, 1958; Foda and McCullum, 1970; Kertesz and Loconti, 1944; Lapmi et al., 1958; McCulloch et al., 1950; McCready and McComb, 1954; Rouse and Knorr, 1969; Robinson et al., 1956; Swingle, 1966; Wagner et al. 1975; Wildman, 1930).

Pectin is present as a heterogenous mixture with various degrees of polymerization and methylation. There is also a great deal of cross-linking and interlinkage through the available cations (Deuel and Stutz, 1958; DeMan, 1980).

Pectic substances are high molecular weight acid polysaccharides which are widespread in the plant kingdom (Kertesz, 1951). They are used in the food industry as gelling agents (Gerdes, 1983). The size, charge density, charge distribution and degree of substitution of pectin macromolecules can be changed easily by enzymes or other reagents (Kertesz, 1951; Deuel and Stutz, 1958). Slight modifications of the chemical constituents of the macromolecules can bring about marked changes in their properties due to alterations in the shape of the macromolecules or in the interaction between them.

D-galacturonic acid and methanol are the main constituents of the pectin molecule. These pectin molecules are formed by the glycosidic linkages between pyranose rings of D-galacturonic acid units at the 1 & 4 positions (Kertesz, 1951).

The carboxyl groups of pectin are partially esterified with methanol and in some cases the hydroxyl groups are partially acetylated. Complete esterification of the pectin macromolecule would result in a 16% methoxyl content but these do not occur in nature. The usual range is 9-12% Methoxyl content (Kertesz, 1951). Thus, due to a considerable variation in the degree of polymerization and in amount and distribution of substituents, no two macromolecules of pectin are identical (Deuel and Stutz, 1958).

Pectin probably occurs in all higher plants, mainly as protopectin in the middle lamella and the primary cell membrane as well as inside the cell. The intracellular pectin exists as pectinic and pectic acids (McCready and McComb, 1954). The pectinic acid substances are colloidal polygalacturonic acids containing more than a negligible proportion of methyl ester groups. They are capable, under suitable conditions, of forming gels with sugar and acid or if low in methoxyl content combining with certain metallic ions (Gerdes, 1983). On the other hand, the pectic acid substances are mostly composed of colloidal polygalacturonic acids and essentially free from methyl ester groups (Kertesz, 1951; Glicksman, 1982). These pectic substances tend to stabilize suspensions of insoluble material. Thus, the hydrolysis of these substances can break a suspension resulting in precipitation of insoluble material and clear serum (Kertesz, 1939; McCulloch et al., 1950; Han et al., 1955; Deuel and Stutz, 1958; Luh and Daoud, 1971; Frazier and Westhoff, 1977).

These pectic substances are easily attacked by low molecular weight acids and bases at various temperature levels. The methyl and acetyl groups of pectic substances are easily saponified by dilute alkali. At room temperature the alkaline deesterification is accompanied by a degradation of the macromolecules (Kertesz, 1951; McCulloch et al., 1950). This degradation may be a simple hydrolysis

or a hydrolysis involving β -elimination. On the other hand, the acid degradation is initiated by an attack on the glycosidic oxygen or the pyranose ring oxygen by hydrogen ions. In the latter case a half-chair transition state with a double bond would be formed. The large carboxyl group at C5 hinders the rotation required for this transition and may increase the stability of the glycosidic linkages (Deuel and Stutz, 1958).

In addition to the alkali and acid hydrolysis, the pectic substances can also be attacked by pectic enzymes under various conditions with the production of numerous end-products.

Belli-Donini (1969) reported that the insoluble protopectins of fruit are hydrolyzed to soluble pectins by protopectinase. Then the pectins are demethylated by the pectinesterase and hydrolyzed by polygalacturonase to smaller acid residues. This change in pectic substances always occurs during ripening and storage of many fruits and vegetables as reported by McCready and McComb (1954). This study showed that extractable pectin increased from 39% in unripe pears to 60% in the ripe fruit. The degree of esterification decreased from 89% to 43% in the same fruit. This result was due to a transformation of insoluble pectic substances into soluble ones.

Factors Affecting the Stability of Hot Sauces

The stability of hot sauce will be compared with the stability of tomato products due to their many similarities. Numerous studies have been conducted on tomato product stability over the past four decades, while no formal studies have been reported on hot sauce stability.

Tomato sauces and juices are diphasic systems in which colloidal, highly hydrated solid particles are suspended in the serum which contains various crystalloids and some dispersed colloids (Smith, 1931; Kertesz and Leconti, 1944; Underwood, 1950; Robinson et al., 1956; Becker et al., 1968; Foda and McCullum, 1970; Miers et al., 1971).

Consistency and viscosity were major factors influencing the quality and marketability of these products. However, there are many factors which effected the consistency and viscosity of these products and consequently could affect their overall quality. These factors include: pectic substances and their enzymes, insoluble solids, additives and homogenization.

Pectic Substances and Their Enzymes

The importance of pectic substances in determining the consistency of tomato products has been demonstrated by Kertesz (1951) and McColloch et al. (1950). They showed that a desirable consistency, along with freedom from settling, is closely related to the pectin content of the

finished products. When the settling occurred, the volume of suspended solids contracted leaving a pale yellow serum in the upper portion of the juice. This settling resulted in reduced customer appeal and was a recognized defect in the U.S.D.A. standard grade for quality (Robinson et al., 1956).

Many studies (Deuel and Stutz, 1958; Fonesca and Luh, 1977; Hand et al., 1955; Kertesz, 1938; Kertesz, 1939; Luh and Daoud, 1971; Luh et al., 1954; Miers et al., 1970; Stier et al., 1956; Wagner et al., 1975; Van Buren, 1962) have shown that when tomatoes are mascerated at ambient temperature, pectinesterase (PE) and polygalacturonase (PG) are released from the tomato cells and quickly degraded the pectin which results in a large loss in consistency of the final product. These enzymes have different degradation pathways. The PE catalyzes the cleavage of methoxyl groups from pectin resulting in the formation of low methoxyl pectins and pectic acid (Kertesz, 1958; Pithwala et al., 1948; Pressey and Avants, 1982; Rouse and Atkins, 1955; Termote et al., 1977; Van Buren, 1962; Versteeg, 1979; Wagner and Miers 1967; Wagner et al., 1968). The PG catalyzes the hydrolysis of the α -1-4 glycosidic linkage of pectic substances causing a sharp drop in the viscosity (Kertesz, 1938; Wagner and Miers, 1967). However, the action of PG on hydrolysis of pectin is always dependent on the action of PE to form its substrate (pectinic or pectic acid) from pectin (Deuel and Stutz, 1958; Kertesz, 1938).

Thus efficient inactivation of PE inhibits the action of PG in tomato processing and prevents losses of pectic substances and subsequently prevents loss of viscosity (Dougherty and Nelson, 1974; Wagner et al., 1975).

The action of these enzymes and the amount of pectic substances affect the consistency. These two factors are influenced by a number of factors to be discussed in the following sections.

pH - Enzyme Interaction

Miers et al. (1967) studied the effect of pH during extraction on product consistency. This study showed that the consistency of sauces at the normal extraction pH of 4.4 was relatively lower than that extracted at a lower pH (1-2.5) or a higher pH (5-9). The high consistencies of juices extracted at the lower pH level could be due to extraction of more and/or larger molecular weight amounts of the highly esterified pectin. High consistencies of sauces at the upper pH level were probably due to the extraction and formation of more or larger molecular weights of slightly esterified pectin (Wagner et al., 1969).

The pH dependent effect on the consistency also appeared to involve changes in the activity of the PE and PG enzymes as reported by Patel and Phaff (1960) and McCulloch and Kertesz (1949).

Patel and Phaff (1960) showed that a purified tomato polygalacturonase has two peaks of activity; one at pH 2.5

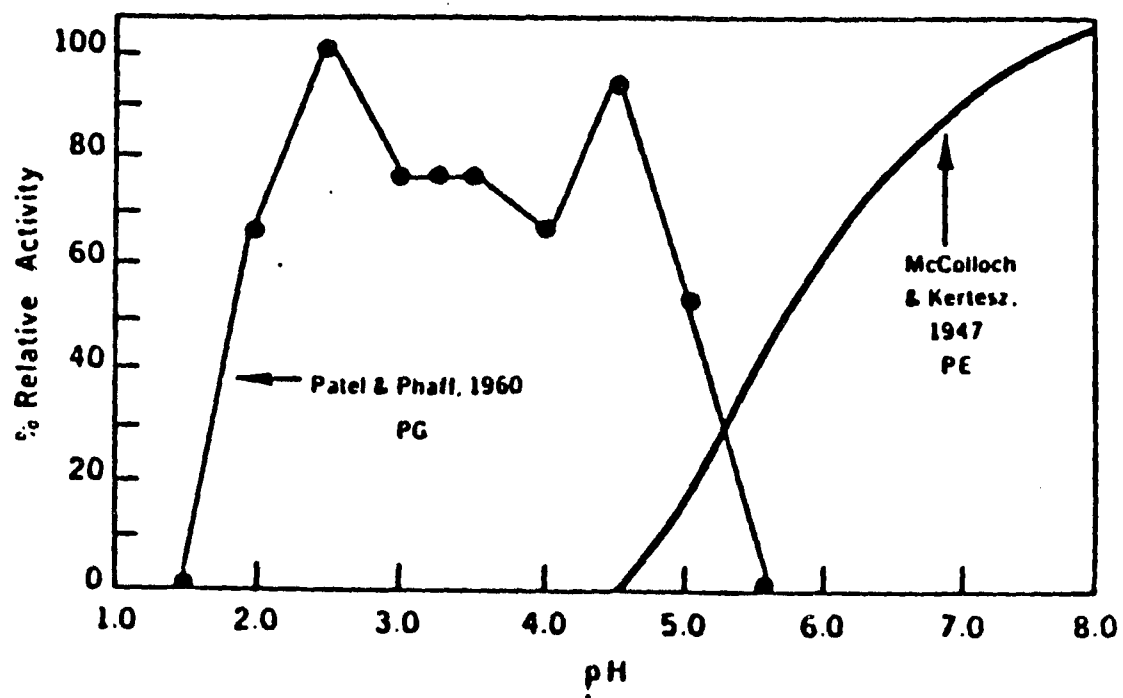
and the other at pH 4.5 and it was completely inactive below pH 1.5 and above pH 5.5 (Fig. 2). On the other hand, McCulloch and Kertesz (1949) showed that the other well known tomato pectin enzyme, pectinesterase (PE), has only slight activity below pH 4.5 and increasing activity through pH 8.0. Therefore, the effects obtained at low pH levels appeared to be related to rapid inhibition of both PE and PG enzymes. Thus, at such acidities more native pectin should be retained than at normal pH levels. However, the effect at high pH levels appeared to be related to PG inhibition, but the PE activity would increase as the pH increased from pH 5.5 to 8.0. This would increase demethylation and minimize depolymerization.

The acid-break technique has been suggested for incorporation into a field processing system where in tomatoes are treated with acid at pH 2.75 to facilitate more complete extraction of tomato product with reported subsequent increases in product consistency (Wagner et al., 1975).

Temperature Enzyme Interaction

One of the most common methods commercially used to prevent these PE and PG enzymatic actions on pectin was heating the product as quickly as possible to 190°F or higher before, during or immediately after mincing (Kertesz, 1939; Luh and Daoud, 1971; Wagner et al., 1975).

Figure 2-Relative activity of tomato enzymes at different pH's.



Kertesz and Loconti (1944) found that a product of pleasing consistency and one that does not settle out can be produced by hot breaking of tomatoes for juice manufacture. They found that the increase in acceptability of tomato juice was due to the increase in the total pectic substances.

Smith (1931) reported that in addition to preventing loss of pectic substances by hot break, a large amount of gum-like soluble substances could be extracted from tomato seed by this method. The gum-like substances were found to be related strongly to the viscosity of catsups.

Wagner et al. (1969) showed that larger amounts of pectin and a larger proportion of highly esterified pectin was found in tomato juices prepared by acidification to pH 2.5 or below during breaking with the rapid heating method than juice prepared at the normal pH and by the slow heating method.

In citrus juice technology, the cloud loss in citrus juices was usually ascribed to deesterification of juice pectin by citrus PE and subsequent precipitation of the low methoxyl pectin as calcium pectinate or pectate (Joslyn and Sedky, 1940; Rouse and Knorr, 1969; Mizrahi and Berk, 1970; Baker and Bruemmer, 1971; Baker, 1976). In this product the PE enzyme was inactivated either by pasteurization or inhibited by frozen storage of juice concentrates at -20°C or below (Rouse, 1962; Termote et al., 1977). This treatment

was very important during the summer season since the activity of citrus PE is always higher during that season when compared to the colder seasons (Rouse, 1962).

Insoluble Solids

Several factors influenced the quantity of insoluble solids in a juice or sauce. Among these were maturity of fruits, type of preheat treatment of fresh fruit and manner of extraction. In tomato juice about 87% of the total solids are soluble in the serum and the remaining 13% of the solids are insoluble. These consist principally of small carotenoid, or proteinaceous granules and cellulose cell walls as shown in Fig. 3 (Whittenberger and Nutting, 1958).

It can be expected then that the increase or decrease of the amount of solids suspended in any juice or sauce will show a relationship to the gross viscosity and consistency in the tomato juice or sauce. This relationship between total solids content and consistency was indicated by many studies (Pressey and Avants, 1982; Pressey et al., 1971; Robinson et al., 1956; Swingle, 1966; Whittenberger and Nutting, 1957).

Whittenberger and Nutting (1958) demonstrated that the washed cell walls which comprised only 6% of the total solids and less than half of the insoluble solids, formed a suspension whose viscosity was twice that of the original

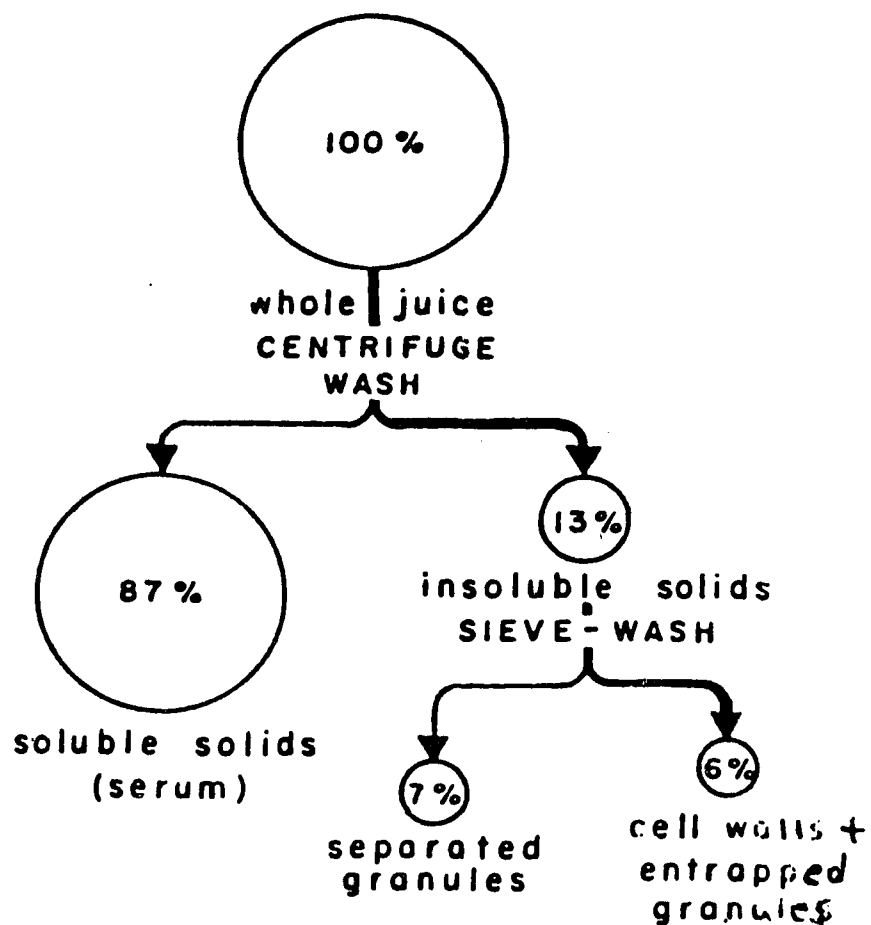


Figure 3 : Diagram of fractionation of tomato juice by centrifugation and sieving

whole juice. In the absence of cell walls the other juice fractions showed no significant viscosity.

The effect of total solids content on the viscosity and consistency were due to the following: 1) the outer boundary of the cell walls consisted of interwoven cellulose fibrils impregnated with pectic compounds and 2) the surface of the cell walls possessed an electrical charge which helps maintain the walls in suspension thereby contributing to the viscosity. In the absence of soluble electrolytes, the charge exhibited a maximum effect. The walls swell, bind quantities of water and promote high viscosity. However, although two juices contain identical quantities of cell walls, they may differ in consistency because of differences in configuration or structural arrangement of the cell wall and the type of associated constituents (Pressey and Avants, 1982; Whittenberger and Nutting, 1957).

Homogenization

One other way to increase the viscosity of juices and sauces and reduce the settling of insoluble solids was by changing the structure of the insoluble constituents. This was accomplished by treating the juices and sauces in a Waring blender or other homogenization device (Wagner et al., 1975).

Increases in the viscosity of homogenized sauces and juices are associated with the conversion of spherical particles to elongated particles (Wagner et al., 1975) and

with a reduction in particle size and an increase in the surface area (Whittenberger and Nutting, 1958).

The homogenization process was used by Wagner et al. (1975) to prepare a high consistency tomato juice by delaying the increase in consistency until a later stage in the total process. This was accomplished by avoiding or minimizing mechanical damage to the fruit cells during the early stages of the processing and then subjecting the fruit material to homogenizing by applying vigorous and repeated shearing action. By such treatment, the fruit cells suspended in the juice are deliberately damaged, ruptured, shredded and sheared with the end result that this material now possesses increased consistency.

The advantage of such a procedure was that it provided products which not only exhibited high consistency but which were smoother and less subject to syneresis than those prepared by the usual procedures.

Food Additives

In recent years, due to the increased importance placed on the retention of natural pectic materials, the use of polyphosphate during fruit extraction has been considered (Baker, 1970). Peters et al. (1954) reported that by using polyphosphate during the extraction of pectins from fruit it could extract 80% more pectin than those which are extracted without the aid of polyphosphate, and therefore, more stable products were produced.

On the other hand, the addition of hydrocolloids to hot sauce has been attempted in order to increase the sauce viscosity and prevent sedimentation (Buescher and Hobdon ., 1982; Schweid, 1980). But these hydrocolloids did not prevent the separation of the hot sauce components. This same result was found in Schlottman's (1977) study in which chitosan was used as the stabilizing agent.

CHAPTER III

Materials and Methods

This study was conducted as a series of experiments over a period of 2 years. Certain basic procedures were used in each experiment and are outlined below. Those that differ will be discussed under specific procedures for each experiment.

The study was divided into two parts. In the first part two sets of 6, 8 and 10% salt of hot pepper mash in oak and plastic barrels were set. Samples from each set were taken for the following measurements: pH, acidity, salt concentration, change in color (dE), total pectic substances, sampling location within the barrels and effect of barrel type. In the second part a hot sauce was prepared from aged mash by two different methods. The effect of shaking on these samples was measured.

Experimental Set

Capsicum frutescens pepper mash was packed with 6, 8 and 10% salt in 55-gallon oak and plastic barrels. Two sets of 3 treatments of both oak and plastic barrels were used. The first set was used for the first year of sampling while the second set was used for the second years samples. These barrels were sealed and topped with a layer of salt. Small bung holes were drilled through the barrels for sampling

purposes. These barrels were stored in a large warehouse at ambient temperature.

Sampling

Samples were collected from the top and bottom portions of the barrels at 1-month intervals. The second set of barrels remained untouched throughout the first year.

A sampler was used to collect the samples from the barrels. The samples were placed in screw top glass jars and transported to the Department of Food Science at LSU-Baton Rouge. Upon arrival in Baton Rouge the jars were stored at 4°C until analyzed, generally within 72 hours.

pH Determination

The pH of each sample was measured using a Corning Model 135 pH/Ion Meter.

Acidity

Five grams of the sample mash was mixed with 100.0 ml distilled water. This was then titrated with 0.1 N NaOH. The titratable acidity was calculated using the following formula and expressed as percent lactic acid:

$$\% \text{ Lactic acid} = \frac{\text{ml of NaOH} \times N \times 90 \times 100}{W \times 1000}$$

N = normality of NaOH

W = wt of the sample in grams

% Salt

The salt content was measured using a Dichromate Salt Analyzer Model 1-1100.

Ten-gram samples of pepper mash was added to 100.0 ml distilled water and then filtered through cheese cloth. The filtrate was placed in the systems reservoir and the percent salt read directly from the digital readout.

Color (dE)

The color (dE) of each mash was measured using a Hunter Color Difference Meter Model D25.

Total Pectic Substances

Total pectic substances were determined using the procedure of Dekker and Richards (1972) and a modification of the carbazole reaction developed by Bitter and Muir (1962).

A 0.5 g sample of pepper mash was extracted with 10.0 ml of 0.25% ammonium oxalate and 0.25% ammonium oxalic acid solution at 100°C for one hour. The filtrate solution was diluted to 200 ml with distilled water. One ml of the diluted solution was reacted with a 0.25 M sodium tetraborate in concentrated sulfuric acid and then with carbazole reagent at 80°C for 15 min. The solution was cooled and the percentage absorption read spectrophotometrically at 530 nm. A standard solution of 10, 20, 30, and 40 ug/ml of pure polygalacturonic acid was

prepared and treated exactly as the filtrate. A standard curve was then prepared and the total polygalacturonic acid in the pepper mash was calculated directly from the standard curve.

General Procedure of Making Sauce

The following general procedure was used in preparing a hot sauce. Two parts of aged mash was mixed with one part of 100 grain vinegar and stirred continuously for 28 days. This solution was then filtered and the resultant sauce placed in standard 2-oz glass bottles.

Rapid Procedure for Making Sauce

A new, rapid procedure for making hot sauce was developed. In this procedure, two parts aged mash were mixed with one part 100 grain vinegar. This solution was mixed for 15 min using an Fherbech mechanical stirring device. The solution was then filtered through a #20 mesh screen. This screened solution was then sheared at very high speed (45,000 rpm) for 5 min using a Virtis homogenizer. The homogenized hot sauce was then packed in standard 2-oz glass jars.

Shaking the Sauce

Three different sizes of containers of hot pepper sauce were shaken from 3 to 6 hrs, two different methods of shaking were used: straight line shaking using a Dubnoff

metabolic shaking incubator and circular shaking using a Junior orbit shaker.

Viscosity Determination

A Brookfield Model LVT synchroelectric viscometer with number 1 spindle rotating at 12 rpm was used to measure the viscosity of the hot sauces.

Pectic Enzymes

A pectinase (Nova Enzyme Corp.) enzyme was added to hot pepper mash and allowed to react for 4 weeks at room temperature. A hot sauce was then made from this mash using the rapid procedure and then compared to the sauce of the same mash which was prepared without the enzyme.

CHAPTER IV

RESULTS AND DISCUSSION

The pepper mash was packed in six plastic (P) and six oak (O) barrels. The mash was prepared and contained 6, 8 and 10 percent salt, respectively. Samples from these barrels were collected during the first (samples 1-9) and second (samples 10-14) years of the study. Two samples were collected from each barrel at the same time. One sample was collected from the top (T) and the other from the bottom (B) area. The pH, acidity, salt content, color differences (dE) and total pectic substances were measured for each sample. The results of these measurements are presented in Tables 1-14. The descriptive phase column in these tables indicates whether the mash sample was solid (S), liquid (L) or approximately half solid and half liquid (SL). The effect of barrel types, depth of the mash, salt concentration and aging time on each variable was studied.

pH:

The pH of the pepper mash was measured prior to the measurement of the total pectin substances or any other evaluation. The pH of the first and second year mash samples are presented in Tables 1-14.

Table 1. Effect of barrel type, depth of mash, and salt content on the mean pH value salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mash.

Sample 1 - October 12, 1982

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	4.77	3.80	0.56	1070.50	
O-6-B	S	4.77	3.80	0.56	1070.50	0.00
P-6-T	S	4.84	3.70	0.56	958.40	0.00
P-6-B	S	4.84	3.70	0.56	958.40	0.00
O-8-T	S	4.77	5.70	0.52	1056.60	0.00
O-8-B	S	4.77	5.70	0.52	1056.60	0.00
P-8-T	S	4.86	4.90	0.49	1247.10	0.00
P-8-B	S	4.86	4.90	0.49	1247.10	0.00
O-10-T	S	4.73	7.60	0.54	1072.10	0.00
O-10-B	S	4.73	7.60	0.54	1072.10	0.00
P-10-T	S	4.78	8.80	0.58	995.50	0.00
P-10-B	S	4.78	8.80	0.58	995.50	0.00

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 2. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mash.

Sample 2 - October 25, 1982

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	4.32	4.30	0.41	897.50	12.72
O-6-B	L	4.25	4.40	1.17	865.60	8.85
P-6-T	S	4.37	5.80	0.58	812.60	8.34
P-6-B	S	4.80	3.90	0.50	788.50	6.61
O-8-T	S	4.83	5.00	0.70	913.20	17.22
O-8-B	SL	4.49	4.30	0.76	846.50	16.38
P-8-T	S	4.86	7.20	0.54	998.90	20.67
P-8-B	S	4.81	5.90	0.58	915.40	15.53
O-10-T	S	4.79	4.60	0.56	883.40	15.38
O-10-B	S	4.79	6.00	0.56	953.40	13.76
P-10-T	S	4.78	6.80	0.58	880.90	13.74
P-10-B	S	4.74	7.60	0.59	909.80	7.29

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 3. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 3 - November 29, 1982

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	3.95	3.70	1.24	620.00	10.42
O-6-B	L	3.92	4.60	2.46	624.90	2.52
P-6-T	S	4.13	4.50	0.58	625.50	7.34
P-6-B	L	3.98	6.00	1.26	661.20	8.16
O-8-T	S	4.29	5.60	0.74	920.10	11.43
O-8-B	L	4.33	7.60	0.90	874.50	15.40
P-8-T	S	4.65	7.00	0.58	489.50	15.40
P-8-B	S	4.54	6.70	0.61	501.00	12.24
O-10-T	S	4.50	8.30	0.63	828.10	5.77
O-10-B	S	4.48	8.30	0.65	803.00	2.77
P-10-T	S	4.48	7.70	0.63	842.90	5.85
P-10-B	S	4.51	8.30	0.65	870.60	8.12

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 4. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 4 - January 7, 1983

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	3.75	4.70	1.28	608.90	2.70
O-6-B	L	3.52	5.50	1.03	560.50	5.74
P-6-B	L	4.08	4.80	0.85	587.20	6.30
O-8-T	S	4.30	4.80	0.49	768.70	6.11
O-8-B	L	4.26	4.30	0.58	755.60	2.10
P-8-T	S	5.36	4.70	0.74	424.30	8.91
P-8-B	S	4.95	4.90	0.65	382.40	5.34
O-10-T	S	4.38	5.30	0.61	678.50	0.42
O-10-B	L	4.40	7.60	0.63	688.50	2.06
P-10-T	S	4.48	7.40	0.65	702.60	1.14
P-10-B	S	4.41	6.60	0.61	644.70	1.86

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 5. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 5 - February 9, 1983

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	4.04	4.10	0.74	640.50	5.04
O-6-B	L	3.92	6.80	2.40	522.50	9.91
P-6-T	S	4.06	4.40	0.77	488.70	2.99
P-6-B	L	3.96	7.40	1.31	478.10	2.52
O-8-T	S	4.26	5.30	0.50	687.10	4.92
O-8-B	SL	4.30	6.50	1.28	632.30	5.65
P-8-T	S	4.69	5.30	0.38	378.50	4.25
P-8-B	S	4.64	6.50	0.50	402.50	4.40
O-10-T	S	4.47	7.10	0.51	459.90	1.74
O-10-B	L	4.50	10.30	0.81	693.30	8.84
P-10-T	S	4.50	8.40	0.76	517.90	5.87
P-10-B	L	4.51	11.00	0.67	637.70	7.43

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 6. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 6 - May 17, 1983

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	4.71	4.40	1.30	614.70	2.00
O-6-B	SL	4.25	5.00	1.44	579.00	1.79
P-6-T	S	4.74	4.80	1.19	522.80	0.79
P-6-B	SL	4.40	5.40	1.22	518.40	2.47
O-8-T	S	4.63	4.80	0.99	594.40	8.81
O-8-B	L	4.93	10.00	1.08	595.30	18.30
P-8-T	S	4.86	5.70	0.74	412.90	9.66
P-8-B		0.00	0.00	0.00	0.00	0.00
O-10-T	SL	4.79	8.00	0.70	457.60	1.56
O-10-B	SL	4.81	8.00	1.33	575.40	5.42
P-10-T	S	4.92	5.40	0.65	521.50	5.18
P-10-B	L	4.88	11.50	0.97	588.80	11.21

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 7. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 7 - September 4, 1983

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	4.44	4.20	1.26	616.20	4.70
O-6-B	SL	4.16	5.10	1.58	531.10	4.67
P-6-T	S	4.22	4.50	1.26	492.30	9.08
P-6-B	L	4.08	7.30	1.42	475.30	0.75
O-8-T	S	4.42	5.00	0.90	635.70	8.95
O-8-B	L	4.15	9.20	1.10	564.50	18.07
P-8-T	S	4.64	5.20	0.83	479.90	11.42
P-8-B	L	4.25	9.10	0.99	517.50	12.93
O-10-T	SL	4.39	6.60	0.85	450.70	4.23
O-10-B	L	4.30	10.00	0.97	618.70	13.41
P-10-T	S	4.66	6.70	0.76	533.40	4.87
P-10-B	L	4.43	11.30	0.92	537.70	13.77

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 8. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 8 - October 22, 1983

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA I
O-6-T	S	4.16	5.30	1.66	495.00	4.29
O-6-B	SL	4.04	5.70	1.82	663.75	4.44
P-6-T	S	4.61	4.80	0.97	562.50	4.00
P-6-B	SL	4.07	5.50	1.44	585.00	2.73
O-8-T	S	4.43	6.20	1.08	614.25	12.41
O-8-B	SL	4.17	8.00	1.17	612.00	8.41
P-8-T	S	4.76	3.50	0.79	417.50	18.91
P-8-B	L	4.22	9.90	1.06	634.50	9.53
O-10-T	S	4.62	7.70	0.63	483.75	9.78
O-10-B	SL	4.44	9.50	0.81	663.75	8.85
P-10-T	S	4.77	8.00	0.67	520.00	11.25
P-10-B	L	4.30	10.90	0.76	625.50	5.74

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 9. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 9 - October 17, 1984

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	SL	4.57	6.30	1.46	600.00	3.08
O-6-B	SL	4.11	6.70	2.00	816.00	2.11
P-6-T	S	4.86	5.50	1.40	502.00	4.93
P-6-B	L	4.13	6.80	1.64	570.00	7.36
O-8-T	S	4.37	7.00	1.39	837.00	10.64
O-8-B	SL	4.22	9.30	1.35	852.00	7.74
P-8-T	S	5.85	7.20	0.68	556.00	11.04
P-8-B	L	4.54	9.50	1.06	666.00	12.08
O-10-T	S	4.40	5.90	1.24	640.00	2.83
O-10-B	L	4.25	13.50	1.26	850.00	7.34
P-10-T	S	5.23	10.30	0.92	440.00	6.94
P-10-B	L	4.39	15.00	1.19	782.00	9.67

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 10. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 10 - October 22, 1983

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	4.50	4.30	1.22	540.00	2.61
O-6-B	SL	4.07	4.60	1.69	652.50	3.05
P-6-T	S	4.29	4.20	1.21	618.75	3.32
P-6-B	SL	4.14	7.00	1.37	596.25	6.98
O-8-T	S	4.31	6.00	0.95	641.25	10.60
O-8-B	SL	4.31	8.00	0.94	663.75	8.43
P-8-T	S	5.57	4.10	0.50	596.25	15.27
P-8-B	L	4.38	9.10	0.81	686.25	7.26
O-10-T	S	4.74	6.40	0.72	572.25	9.37
O-10-B	SL	4.51	9.80	0.81	697.50	7.17
P-10-T	S	4.50	6.70	0.79	585.00	5.37
P-10-B	L	4.49	11.10	0.79	652.50	4.86

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 11. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 11 - April 19, 1984

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	3.98	5.00	1.30	640.50	1.53
O-6-B	S	3.94	4.80	1.58	686.20	1.84
P-6-T	S	4.02	5.40	1.19	567.30	4.30
P-6-B	L	3.94	6.60	1.55	640.50	8.44
O-8-T	S	4.13	6.80	1.08	741.15	8.66
O-8-B	S	4.13	8.70	0.97	713.70	6.33
P-8-T	S	4.19	6.00	0.95	570.95	9.40
P-8-B	L	4.22	8.40	1.39	704.50	5.40
O-10-T	S	4.77	9.00	0.81	567.30	10.96
O-10-B	SL	4.33	9.60	0.94	667.95	4.23
P-10-T	SL	4.50	9.00	0.90	594.65	4.23
P-10-B	L	4.20	11.10	0.88	739.32	2.31

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 12. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 12 - June 30, 1984

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	5.07	5.50	1.03	653.30	5.20
O-6-B	SL	4.30	4.80	1.82	709.70	1.73
P-6-T	S	6.14	4.90	0.43	530.70	9.63
P-6-B	L	4.30	6.70	1.53	878.40	6.36
O-8-T	S	4.49	5.60	0.85	712.70	8.66
O-8-B	S	4.30	8.40	0.99	717.36	7.67
P-8-T	S	5.88	4.40	0.38	649.65	15.31
P-8-B	L	4.40	9.30	1.01	774.09	5.53
O-10-T	S	5.38	7.20	0.72	558.15	9.41
O-10-B	L	4.62	11.70	0.99	640.50	7.98
P-10-T	S	5.76	7.80	0.38	562.00	11.56
P-10-B	L	4.58	11.40	0.86	755.79	7.34

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 13. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 13 - September 24, 1984

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	4.87	4.90	1.58	620.00	5.37
O-6-B	SL	4.51	4.80	1.87	750.00	1.86
P-6-T	S	5.11	4.50	1.44	505.00	1.13
P-6-B	L	4.25	7.20	1.67	970.00	8.07
O-8-T	S	4.38	7.30	1.26	694.00	5.25
O-8-B	S	4.35	8.40	1.17	810.00	8.64
P-8-T	S	4.58	3.90	0.97	711.00	7.51
P-8-B	L	4.40	8.70	1.08	820.00	8.67
O-10-T	S	4.64	8.20	1.21	624.00	6.81
O-10-B	L	4.48	11.60	1.22	700.00	7.59
P-10-T	S	5.13	8.00	0.68	554.00	7.26
P-10-B	L	4.64	11.10	0.83	780.00	7.50

Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section
6, 8, 10 = % salt
S = Solid sample
L = Liquid sample
SL = Half solid, half liquid sample

Table 14. Effect of barrel type, depth of mash, and salt content on the mean pH value, salinity (%), total acid (%), total pectin (mg/100 g mash) and change in color (dE) of aged mesh.

Sample 14 - October 17, 1984

TREATMENT	PHASE	pH	SALINITY	TOTAL ACID	PECTIN	DELTA E
O-6-T	S	4.84	4.80	1.39	666.00	5.33
O-6-B	SL	4.09	4.90	2.14	800.00	3.22
P-6-T	S	5.15	3.00	1.08	430.00	2.26
P-6-B	L	4.29	7.40	1.57	750.00	6.89
O-8-T	SL	4.45	7.70	1.44	730.00	10.41
O-8-B	SL	4.17	9.30	1.46	940.00	8.27
P-8-T	S	5.47	6.80	0.56	530.00	15.92
P-8-B	L	4.30	8.60	1.17	780.00	12.10
O-10-T	S	5.30	7.80	1.10	640.00	9.92
O-10-B	L	4.37	12.10	1.17	872.00	12.35
P-10-T	S	5.03	7.60	0.81	577.50	8.52
P-10-B	L	4.61	11.60	0.90	899.10	9.36

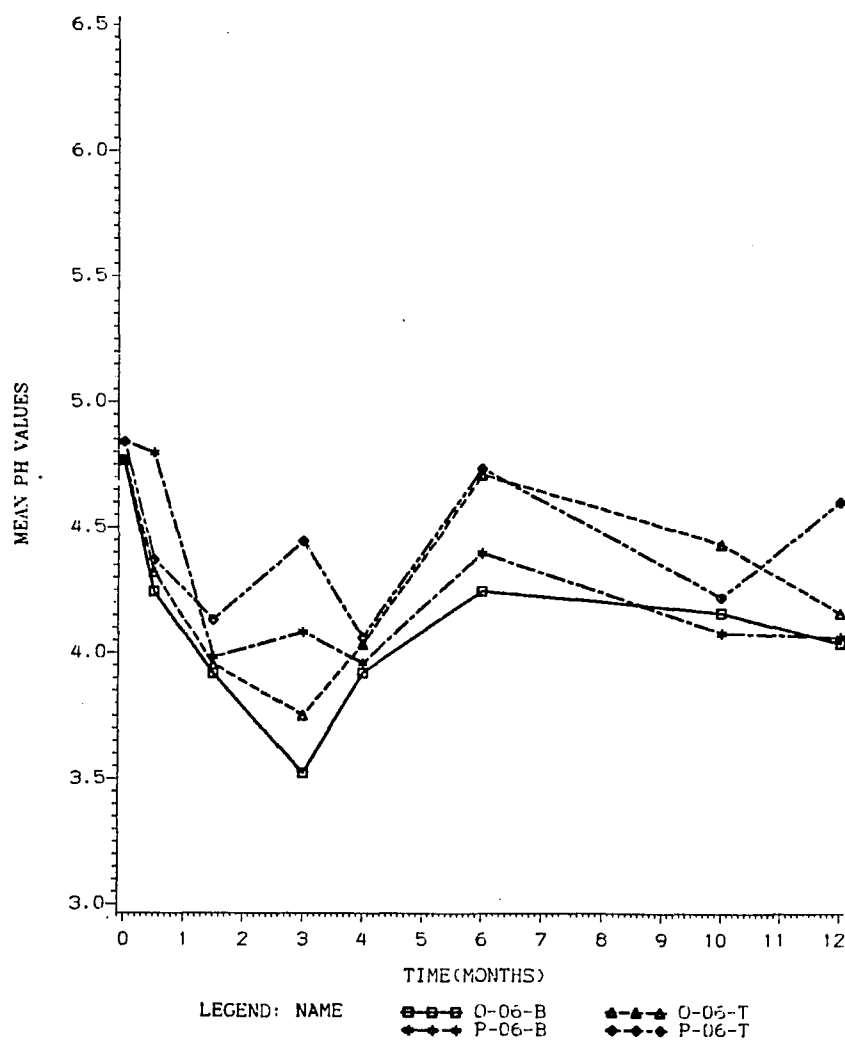
These results indicated that the pH of pepper mash was greatly affected by the barrel type and location of the mash in each barrel. The aging time also had an effect on the pH value of the mash. However, these factors had different patterns of effects on each salt treatment even within the same type of barrel and location of the mash. Therefore, each salt treatment will be discussed separately from the other variables.

6% salt mash. The mean pH values of the 6% salt mash are shown in Figs. 4 & 5. The samples were collected from top and bottom sections of the oak and plastic barrels during the first and second years of this study.

There was a very rapid reduction in the pH values of the mashes immediately after the process of aging began. This reduction in pH was higher in the oak barrel mash than in the plastic barrel mash. These results indicated that most of the organic degradation in the pepper mash components occurred during the first few months of aging. This degradation seemed to occur faster in the oak mash than in the plastic mash. This indicates that the activities of the microorganisms and enzymes present in the mash were higher in the oak barrels than in the plastic barrels.

The pH values then increased sharply in all 6% salt samples after the first six months of aging. The pH then decreased slightly until the last 6 months of aging in which the pH values increased sharply again in all samples.

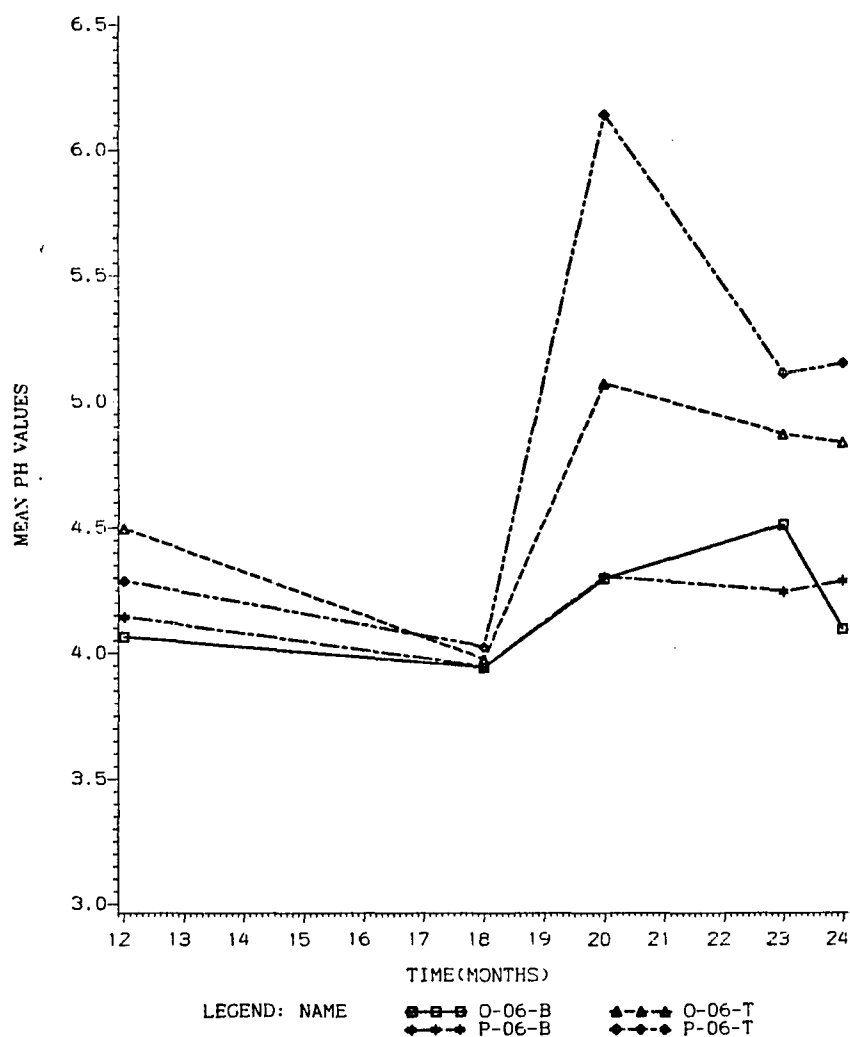
Figure 4--The effect of barrel type (O,P) and depth of mash samples (T,B) on the mean pH value of 6% salt pepper mash (First year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

Figure 5--The effect of barrel type (O,P) and depth of mash samples (T,B) on the mean pH value of 6% salt pepper mash (Second year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

The first and second increase in the pH values were found to occur in samples collected during the warm seasons of first (Table 6) and second (Table 12) year of study. The high temperature of these summer months might have increased the degradation rate of the pepper mash protein with the production of large amounts of buffer components which were responsible for increasing the pH value of these samples (Paulson and Stevens, 1974).

The results seen in Figs. 4 & 5 also indicated that the bottom section of the mash samples always had lower pH values when compared to the top section regardless of barrel type. This was expected since most of the mash samples in the bottom sections was in a very liquid state. Therefore, most of the hydrogen ions would be expected to be leached out and found in the liquid phase section, thus decreasing the pH.

In general, the pH value of the 6% mash samples was not greatly affected by the type of barrel. This can be seen from the similar pH values occurring at the same depth in both types of barrels during the first and second years of the study (Table 15).

8% Salt. The pH values of 8% mash samples exhibited a different characteristic than the 6% salt treatment. In the 8% salt treatment only a slight change in the pH was detected primarily in the first year of study (Figs. 6 & 7).

Table 15. The effect of barrel type and sampling location on the mean pH values of pepper mash samples containing 6% salt during the first and second year of aging.

Barrel Type	Sampling Location	First Year Mean pH	Second Year Mean pH
O	T	4.19	4.65
O	B	4.00	4.28
P	T	4.36	4.94
P	B	4.19	4.30

O = Oak barrel

P = Plastic barrel

T = Top section

B = Bottom section

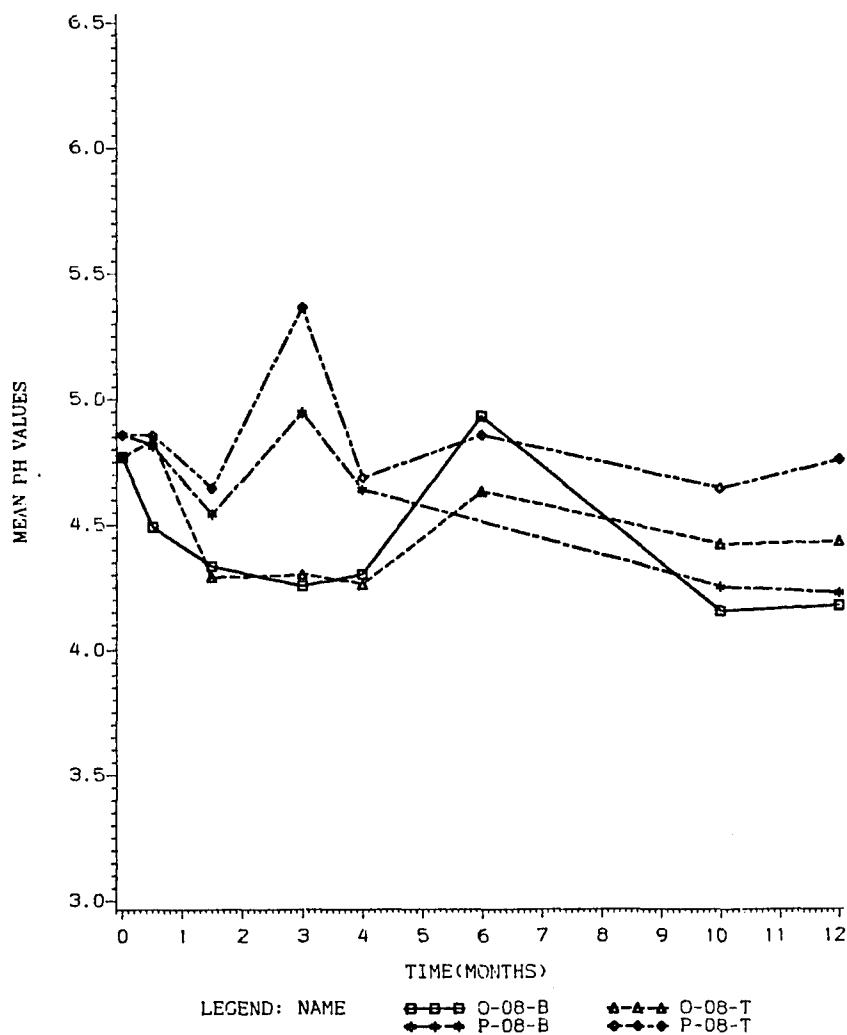
The oak mash samples had lower pH values than the plastic mash samples especially during the first four months of aging. These results suggested that degradation occurred more rapidly in the oak mash components than the plastic mash components.

The pH values obtained were also affected by the sampling depth. The top samples had higher pH values than the bottom samples. This was also found in the 6% barrels. However, the difference in the pH values between the top and bottom sections of the 8% salt mash samples was only significant in the plastic barrels mainly during the second year of aging. The top mash samples of the plastic barrels was somewhat drier than the mash from the bottom section. No such difference was found between the two different locations in the oak barrels. Thus the pH values of the bottom mash samples were lower than the pH values of the top mash samples of the plastic barrel.

10% Salt Mash. The pH values of the 10% mash samples apparently had a delay period before any changes (Figs. 8 & 9). With high levels of salt, this period of time may be considered as a lag phase during which the microorganisms adapted to the high level of salt (Pederson, 1971).

The high temperatures in June (Table 6) also caused an unusual sharp increase in the pH value of all samples, but was higher in the plastic barrel mash samples.

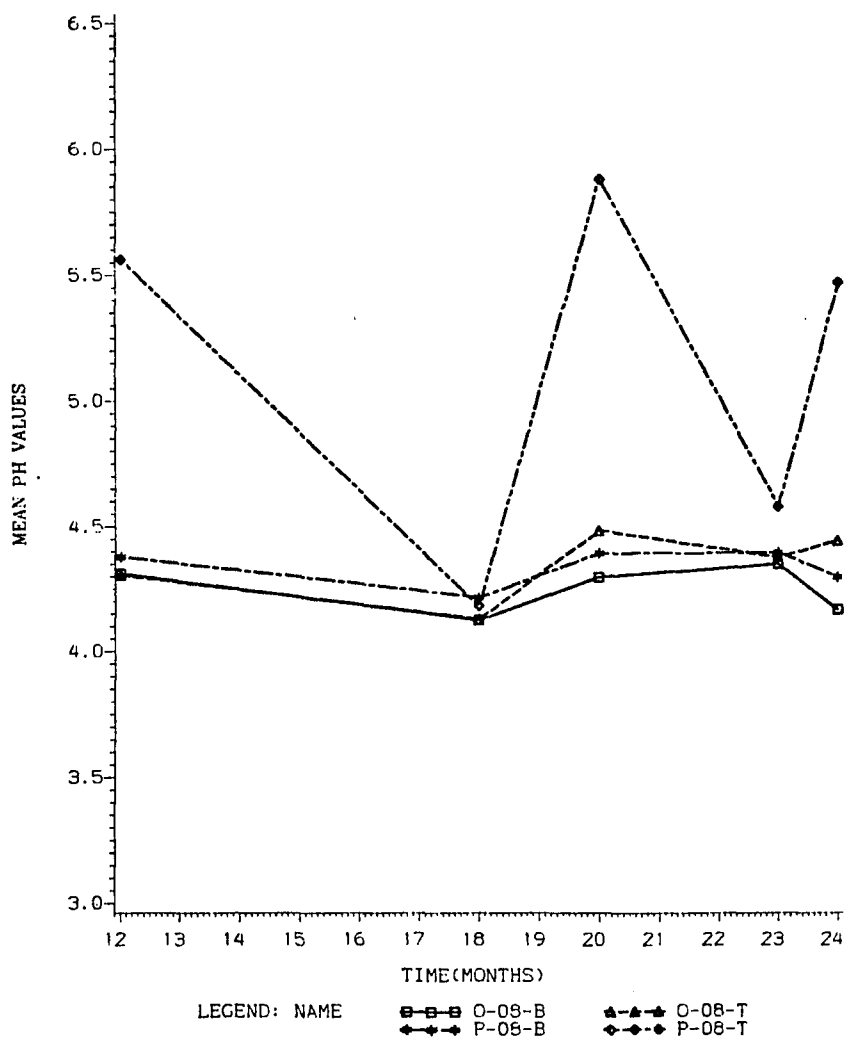
Figure 6--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean pH value of 8% salt pepper mash (First year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

Figures 7--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean pH value of 8% salt pepper mash (Second year samples).



Legend:

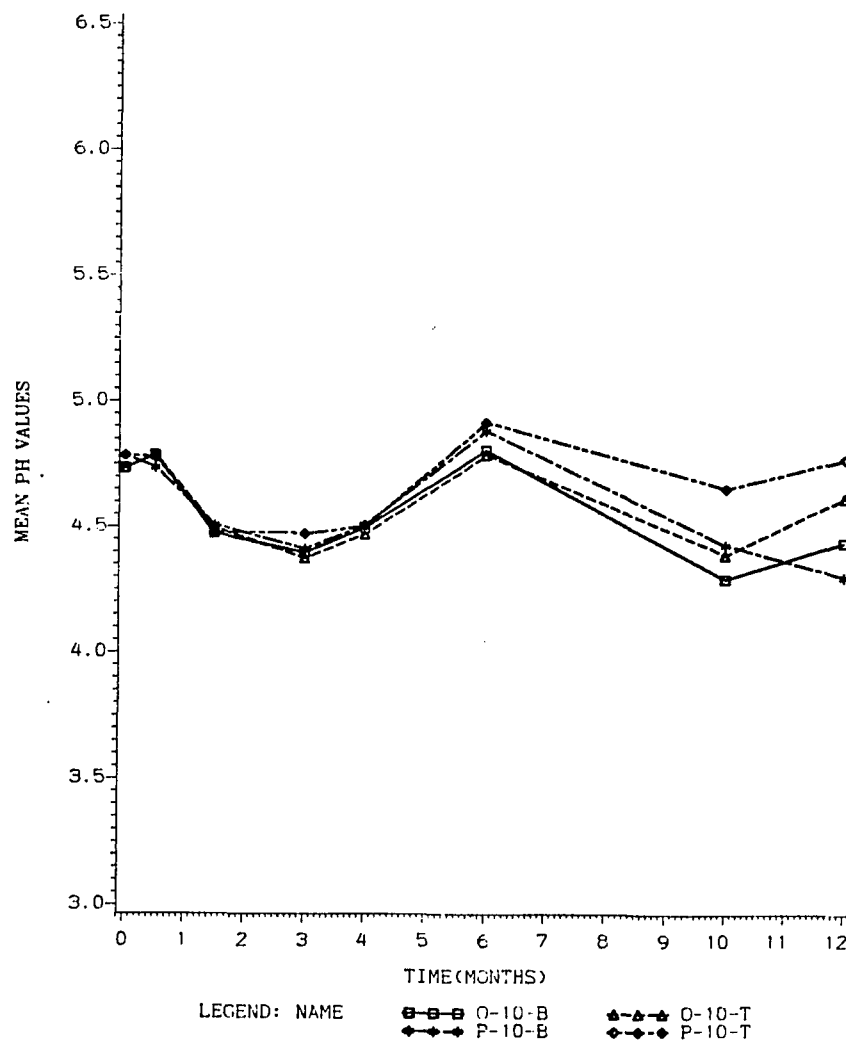
O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

The barrel type also had an effect on the pH values of the mash samples in both years. The oak barrel mash samples were found to have lower pH values than the plastic barrel mash samples in the first year and most of the second year samples. All of the bottom mash samples had lower pH values than the top samples. Both the top and bottom sections of the mash samples showed similar pH values during the entire first year of sampling. In contrast, the second year samples showed noticeable differences between the top and bottom section pH values of both barrel types. This can be attributed to the gradual shifting from the normal mash to a very dry mash found in the top sections of both barrels, especially at the end of the second year.

The higher storage temperatures during the summer months of the second year might also have caused differences in the pH values of the top and bottom mash samples (Table 12).

Effect of Salt Concentration. The pH of the pepper mash was greatly affected by the initial salt treatment. The level of 6% salt was found to cause a rapid decrease in the pH value at all locations of oak and plastic barrel mash samples (Figs. 10-13). However, longer time periods were required to produce small changes in the pH values in the 8 and 10% levels of salt. This was not unexpected since high levels of salt retard the activity of most microorganisms and enzymes in food substrates (Frazier and Westhoff, 1977;

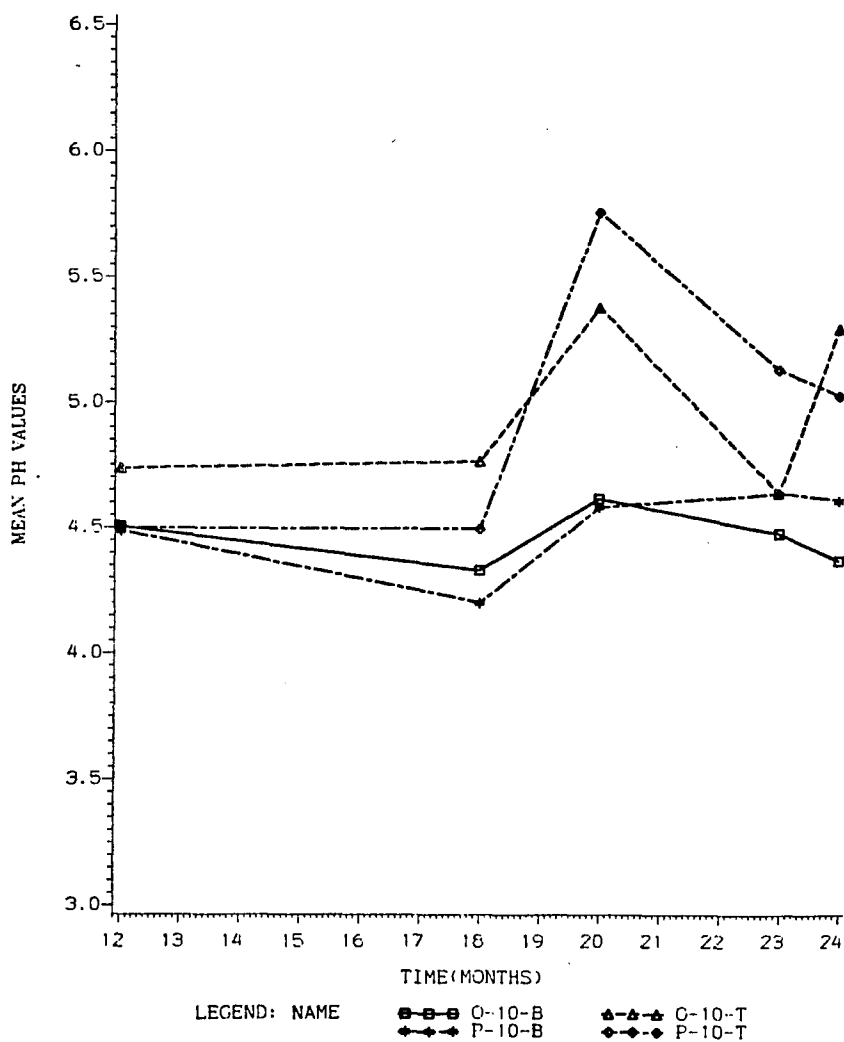
Figure 8--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean pH value of 10% salt pepper mash (First year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

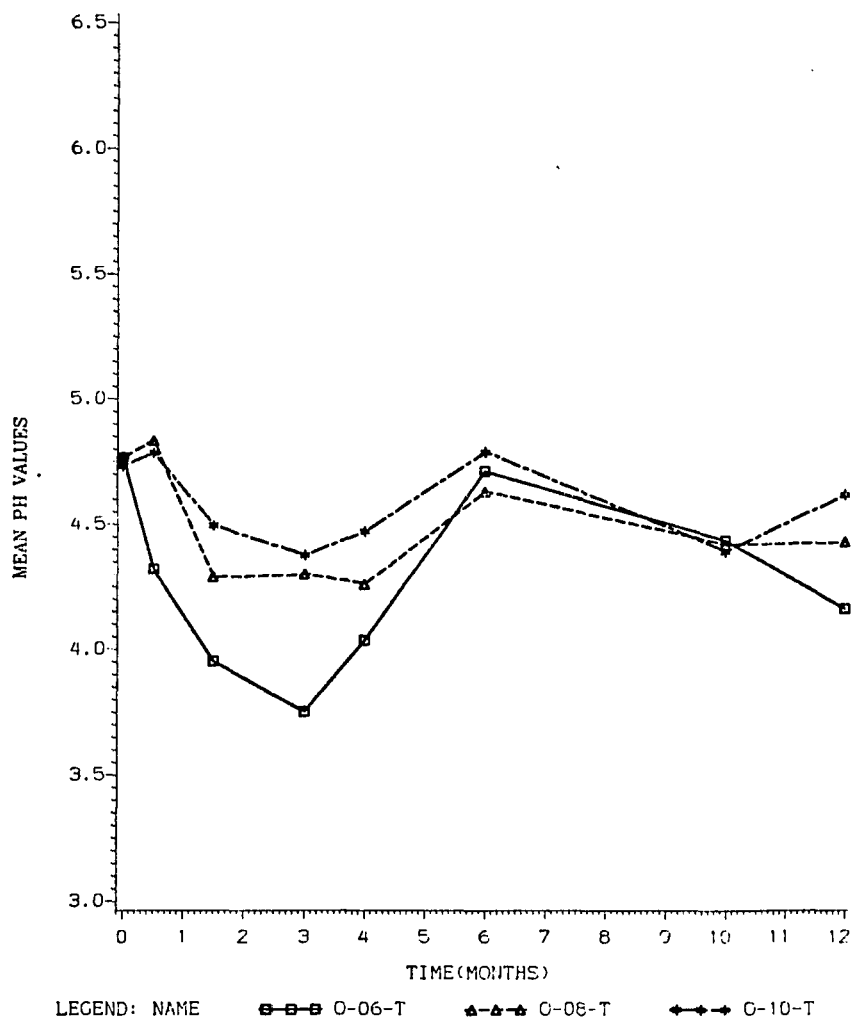
Figure 9--The effect of barrel type (O,P) and depth of the mash samples (T,B) an the mean pH value of 10% salt pepper mash (Second year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

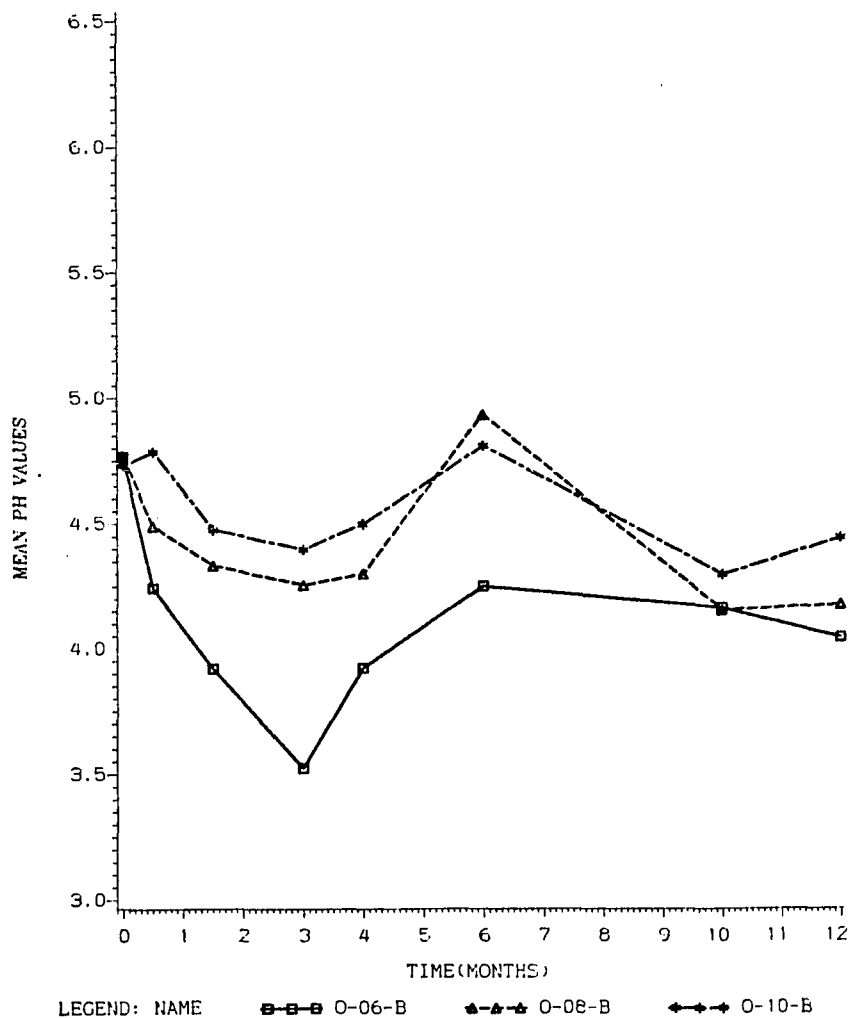
Figure 10--The effect of salt concentration (%) on the mean pH value of the top section of the oak barrel mash sample (First year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

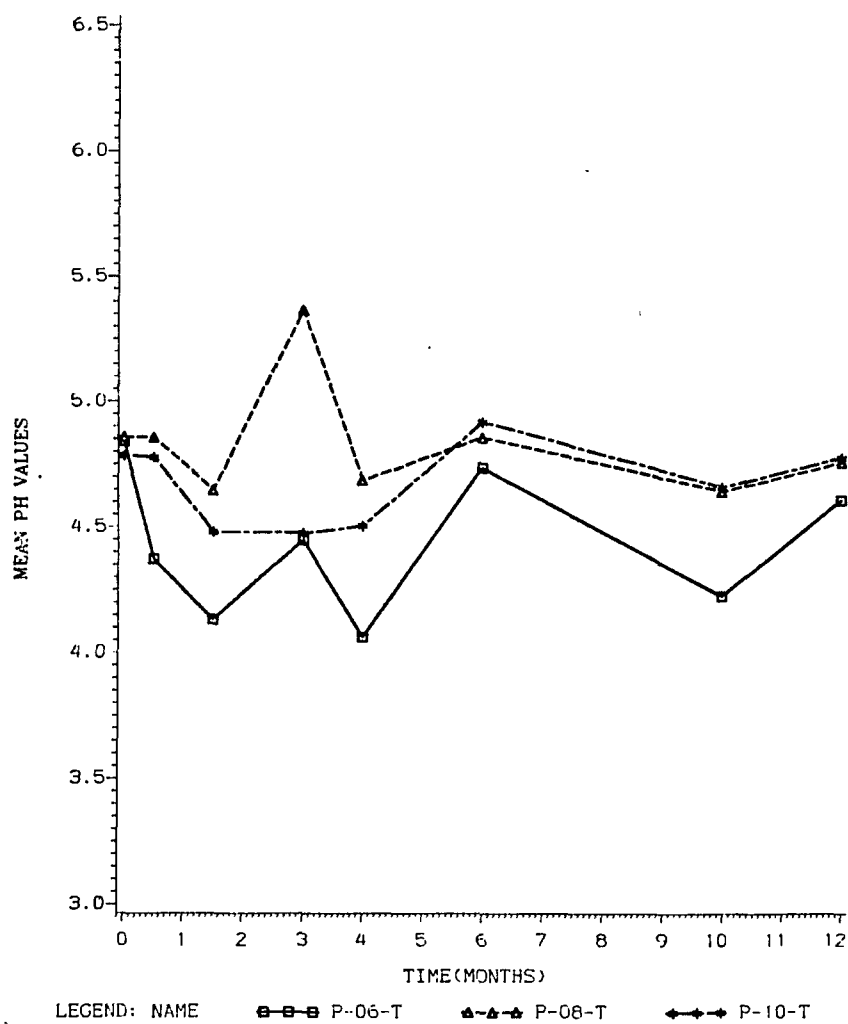
Figure 11--The effect of salt concentration (%) on the mean pH value of the bottom section the oak barrel samples (First year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

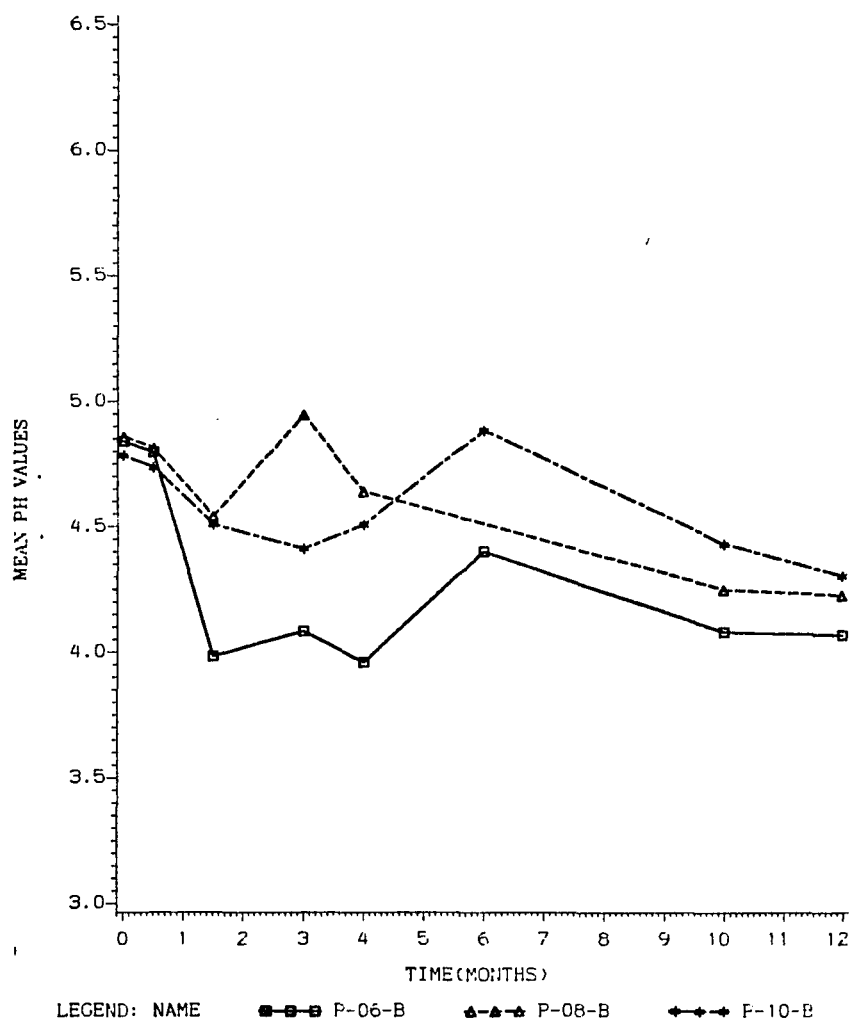
Figure 12--The effect of salt concentration (%) on the mean pH value of the top section of the plastic barrel pepper mash samples (First year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

Figure 13--The effect of salt concentration (%) on the mean pH value of the bottom section of the plastic barrel pepper mash sample (First year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

Luh, 1977; Con Sece, 1977). The 8% salt had an intermediate affect on the pH values during the first year of aging of the oak barrel samples, while the 10% salt resulted in a similar action in the plastic barrel samples.

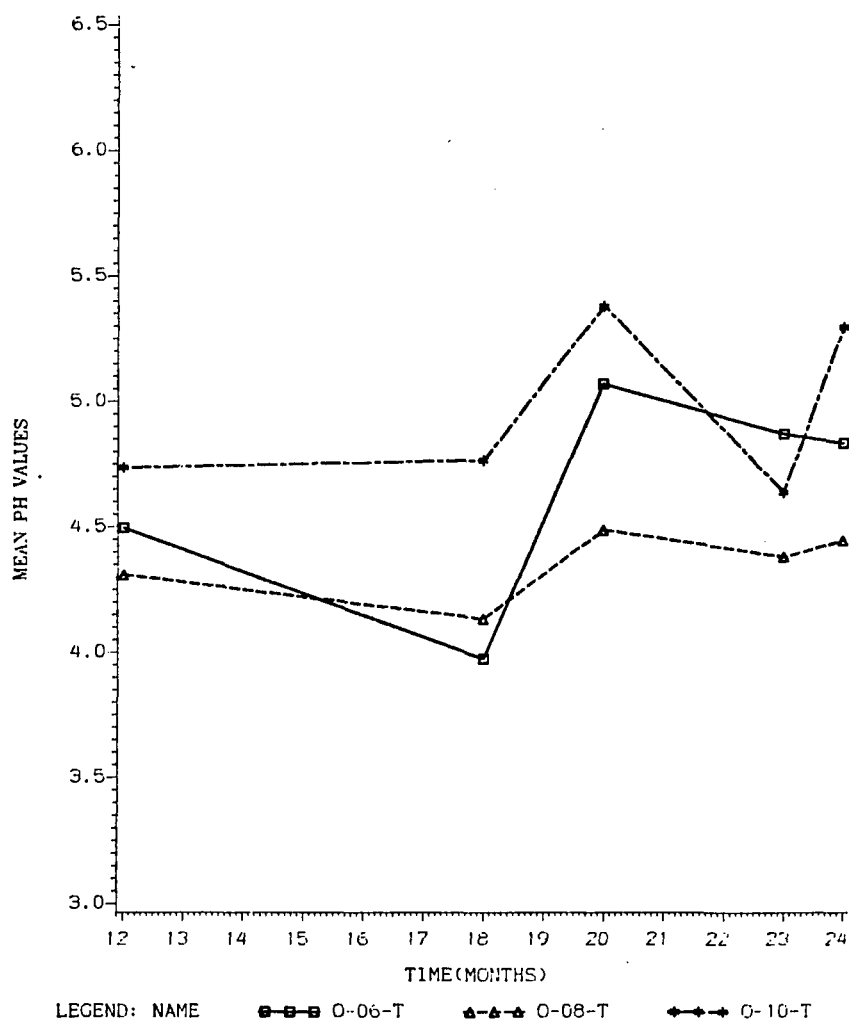
It appeared that most of the differences in the pH recorded in the 6, 8 and 10% salt levels occurred during the first six months of aging followed by small changes during the next six months.

The pH also dropped slowly during the first six months of all the second year samples followed by a sharp increase during the rest of the experiment especially in the samples of top mash in both oak and plastic barrels (Figs. 14-17).

In general, the pH had dropped rapidly from its initial value in all samples tested during the first year (Table 16). This reduction was greater in both oak and plastic bottom samples than in the top samples. The greater drop was seen in the oak barrel samples especially that treated with 6% salt.

During the second year of aging, the pH increased in both top and bottom mash samples in plastic and oak barrels treated with 6% salt, and in all the top samples with 10% salt treatment. In contrast, the 8% salt samples showed little change in their pH values during the second year of aging (Table 16).

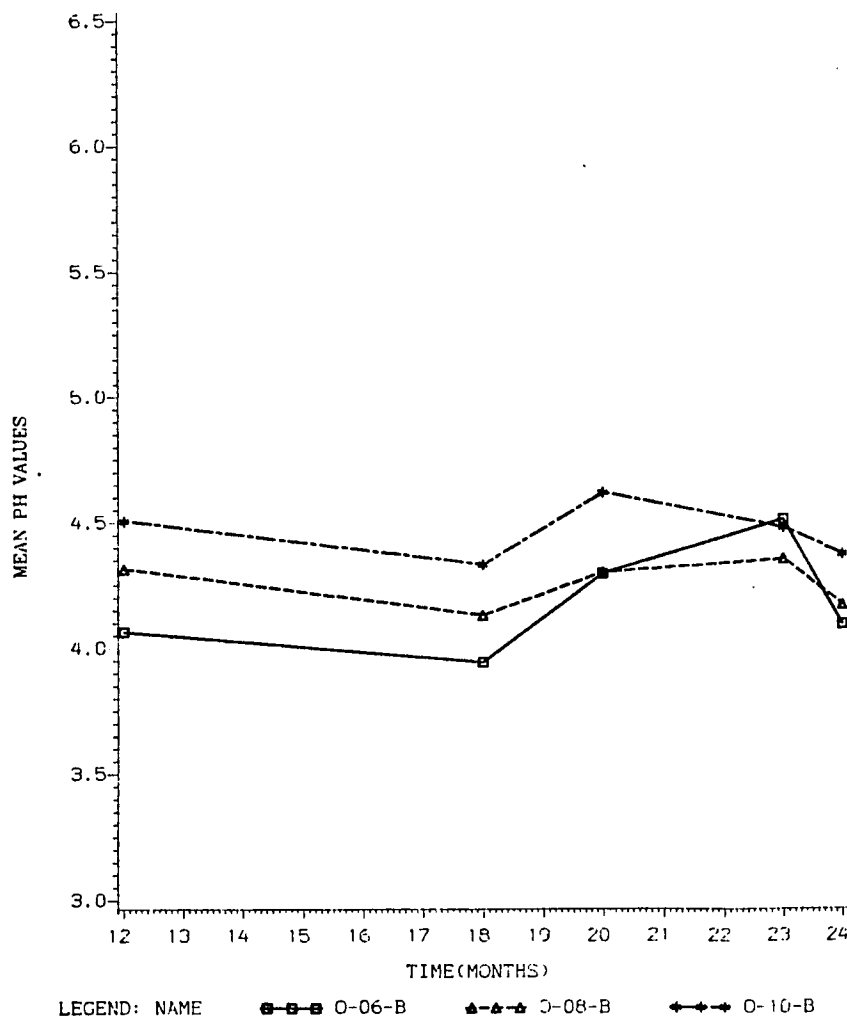
Figure 14--The effect of salt concentration (%) on the mean pH value of the top section of the oak barrel mash sample (Second year section).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

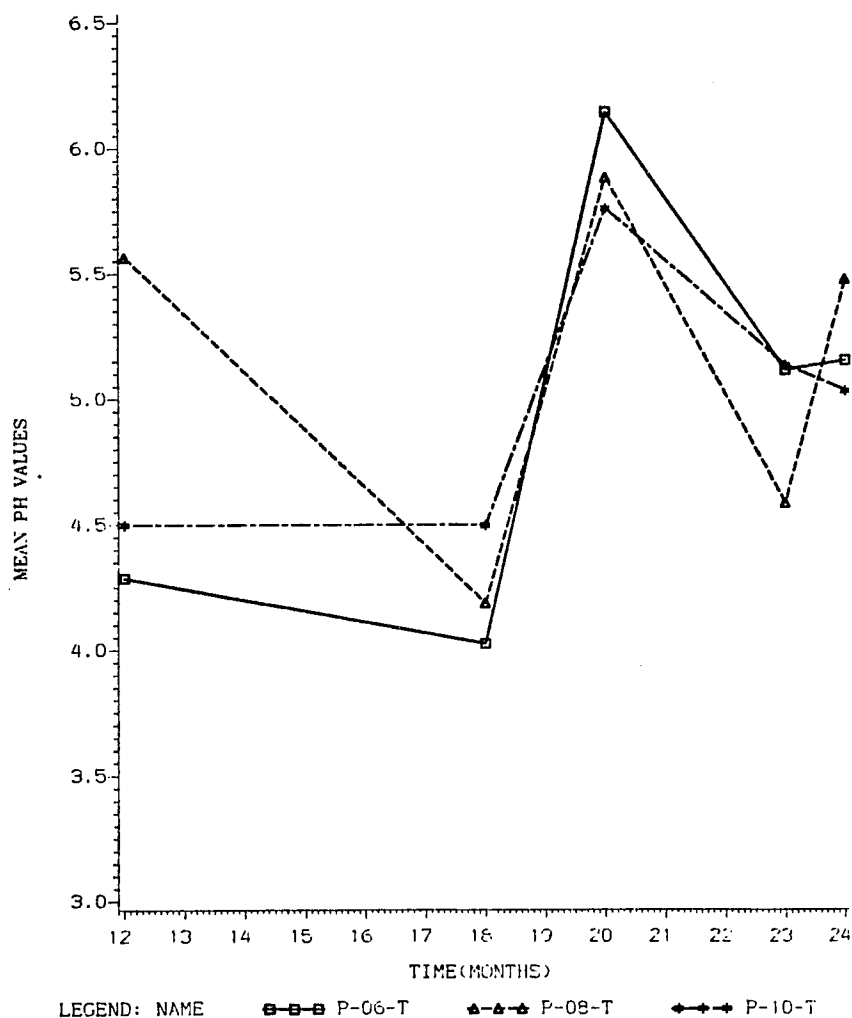
Figure 15--The effect of salt concentration (%) on the mean pH value of the bottom section the oak barrel samples (Second year section).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

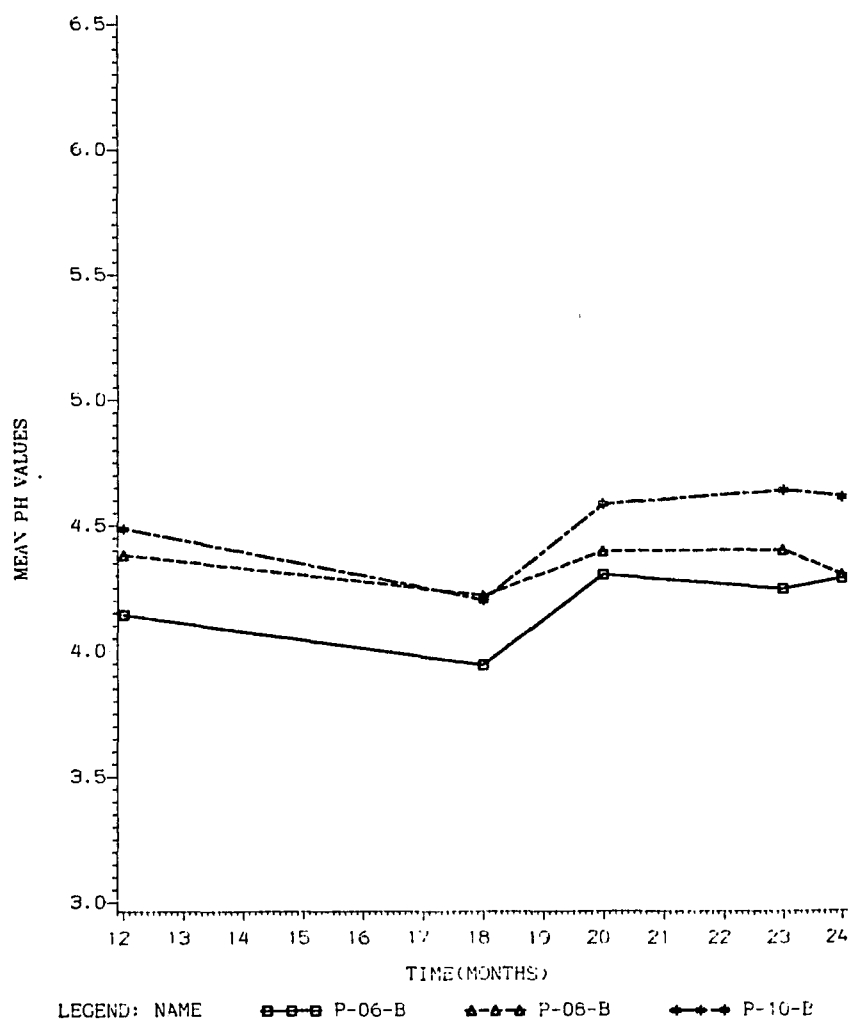
Figure 16--The effect of salt concentration (%) on the mean pH value of the top section of the plastic barrel pepper mash samples (Second year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

Figure 17--The effect of salt concentration (%) on the mean pH value of the bottom section of the plastic barrel pepper mash sample (Second year section).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

Table 16. The effect of salt treatment, barrel type and location of mash sample on the initial and average pH of first and second year mash samples.

	Initial pH	First Year	Second Year
O-6-T	4.77	4.19	4.65
O-6-B	4.77	4.00	4.28
P-6-T	4.84	4.36	4.94
P-6-B	4.84	4.19	4.30
O-8-T	4.77	4.45	4.31
O-8-B	4.77	4.37	4.25
P-8-T	4.86	4.83	5.13
P-8-B	4.86	4.56	4.34
O-10-T	4.73	4.56	4.31
O-10-B	4.73	4.53	4.46
P-10-T	4.78	4.65	4.98
P-10-B	4.78	4.54	4.50

O= Oak barrel

P = Plastic barrel

T = Top section

B = Bottom section

6, 8, 10 = % salt

Acidity:

Titratable acidity of the pepper mash was measured and expressed as percent lactic acid. The acidity of all samples are listed in Tables 1 - 14. The barrel types, depth of samples and aging time greatly affected the acidity of pepper mashes of all salt concentrations.

6% Salt Mash. Figures 18 and 19 indicate that the titratable acidity of the 6% salt treatment of pepper mash increased in most samples. However, the acidity of the top samples had decreased slightly at the beginning of the aging process and then increased rapidly. The reduction in the acidity of these samples might be caused by the action of undesirable microorganisms as a result of low salt concentration in the mash (Desrosier 1963; Heid and Joslyn 1963; Beuchat, 1978).

Many microorganisms were found to grow very rapidly at low salt concentration producing large amounts of gas (Beuchat, 1978; Frazier and Westhoff, 1978). Tables 2 and 3 show that the oak barrel bottom mash samples existed in a liquid phase within a few days after starting the aging process. However, it required six weeks for the plastic barrel bottom mash samples to reach this similar liquid phase. This seemed to indicate that the rate of extraction of the cellular juices occurred more rapidly in oak than plastic barrels. However, all mash samples at the top of

Figure 18--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean total acidity % (acetic acid) of 6% salt pepper mash (First year samples).

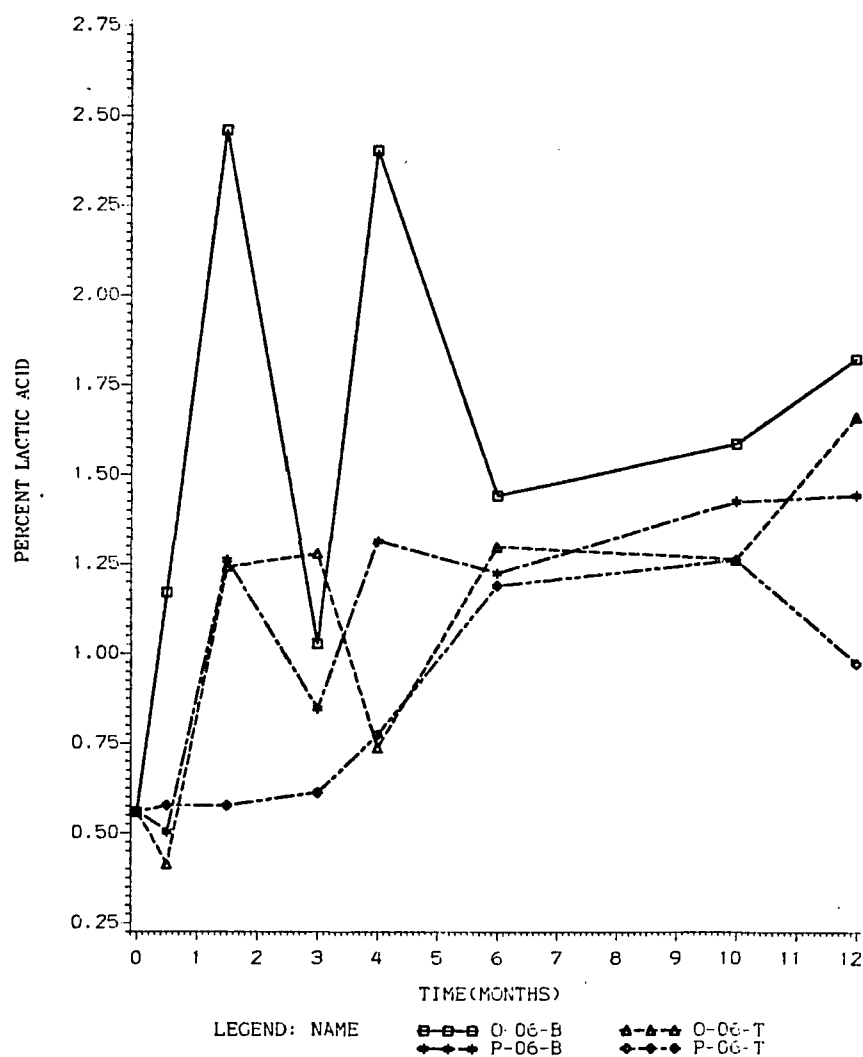
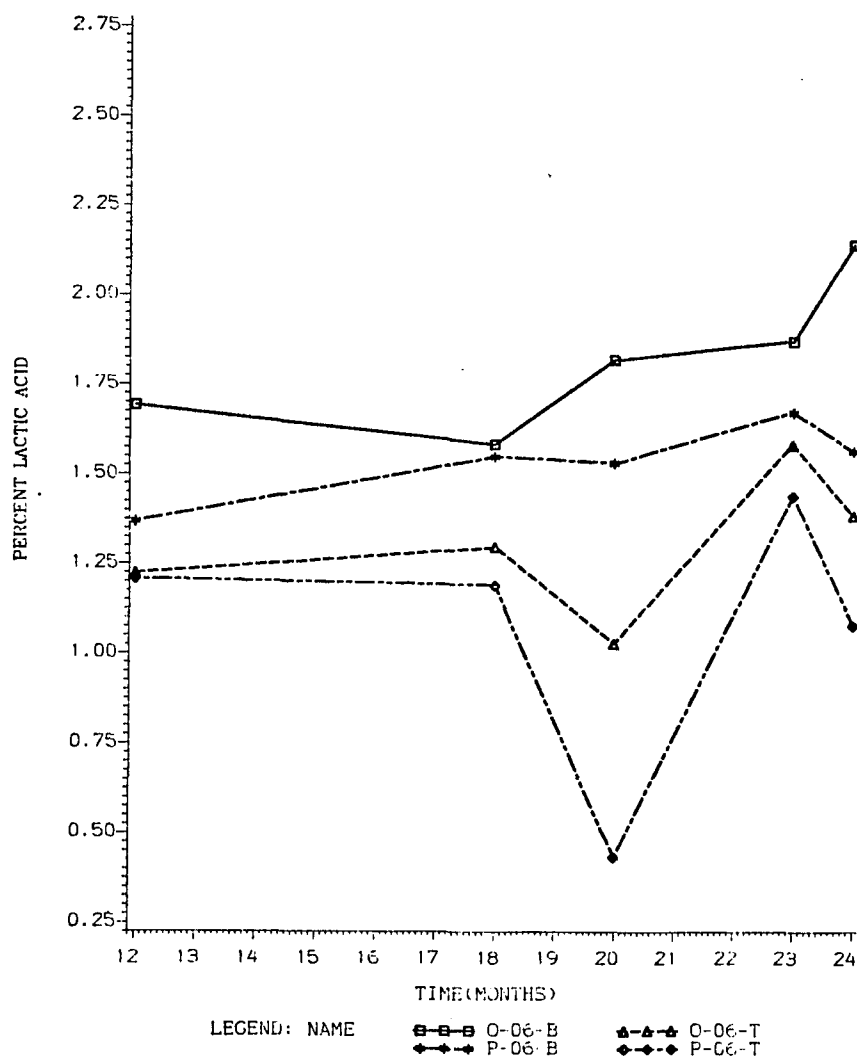


Figure 19--The effect of barrel type (O,P) and depth of the mash sample (T,B) on the mean total acidity % (acetic acid) of 6% salt pepper mash (Second year samples).



O= Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

both oak and plastic barrels were in the solid phase during the entire two years of the aging process. This difference was evident by the higher acidity in the liquid mash samples than the top solid samples of both the oak and plastic barrels. The extraction of cellular juices by salt occurred during the fermentation of many vegetables as a result of the differential in osmotic pressure (Pederson, 1971; Beuchat, 1978).

Acidity was also affected by the type of barrels. The liquid mash samples from the bottom of the oak barrels had a higher acidity than any other section including the liquid mash samples from the bottom of plastic barrel (Figs. 18 & 19). The acidity of the bottom plastic mash samples were very similar to the acidity of the top oak mash samples even though the mash samples were in different phases. This seemed to indicate that the barrel type had an influence on the activity of most of the microorganisms and enzymes present in the mash.

The acidity was affected by the depth of samples in each type of barrel. The results indicated that the bottom sections always had higher acidity than the top sections especially during the second year of the aging process. This would be expected since higher microbial and enzymes activities are expected in the bottom liquid samples than the top solid samples (Desrosier, 1978).

In general, most of the changes in the acidity of 6% salt treated mash occurred during the first six months of aging. During the rest of the aging process, little change was measured except during the warm summer months of the second year. The acidity was reduced sharply during those hot months even though the concentration of salt remained constant. This seemed to indicate that the aging temperature also played a role in the degradation of pepper mash components. It has been demonstrated that in many cured vegetables yeast and molds and some bacteria grow very rapidly at high temperatures causing a rapid destruction in the organic acids of these fermented vegetables (Pederson, 1971).

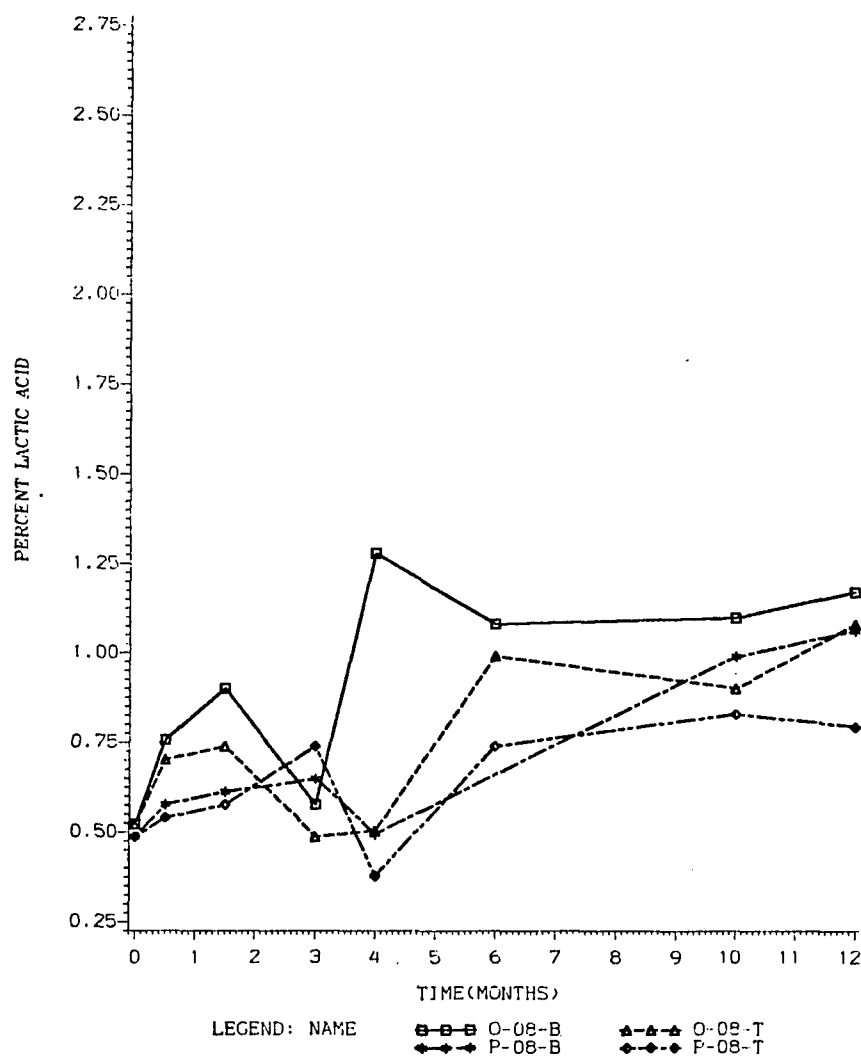
The growth of these yeasts and molds resulted in conditions favorable for the proteolytic organisms to decompose the product rapidly (Desrosier, 1963; Pederson, 1971).

This defect had been noticed in the last months of aging of some mash samples with a noticeable putrefied odor, especially in the plastic samples. The reduction in the acidity during the high temperature season might also be caused by the production of large amounts of buffer components as a result of rapid degradation occurring in the mash protein components (DeMan, 1980).

8% Salt Mash. The acidity of 8% salt treatment had increased in all samples from both the oak and plastic barrels after just few days of aging (Fig. 20). The acidity then decreased in all mash samples from both the oak and plastic barrels after the third and fourth months of the aging process, respectively. It then rose again in all samples to a relatively high level. This seemed to indicate that more than one species of lactic acid producing microorganisms was functioning in the aging process (Beuchat, 1978). The acidity was found to be somewhat higher in the oak barrel samples than in the plastic barrel samples. This was related either to the differential in the initial salt concentration of these two different barrels or to the differential in the rate of juice extraction in each barrel, respectively. The extraction of cellular juices was higher in oak barrel mashes as compared to the plastic barrel mash samples (Table 3).

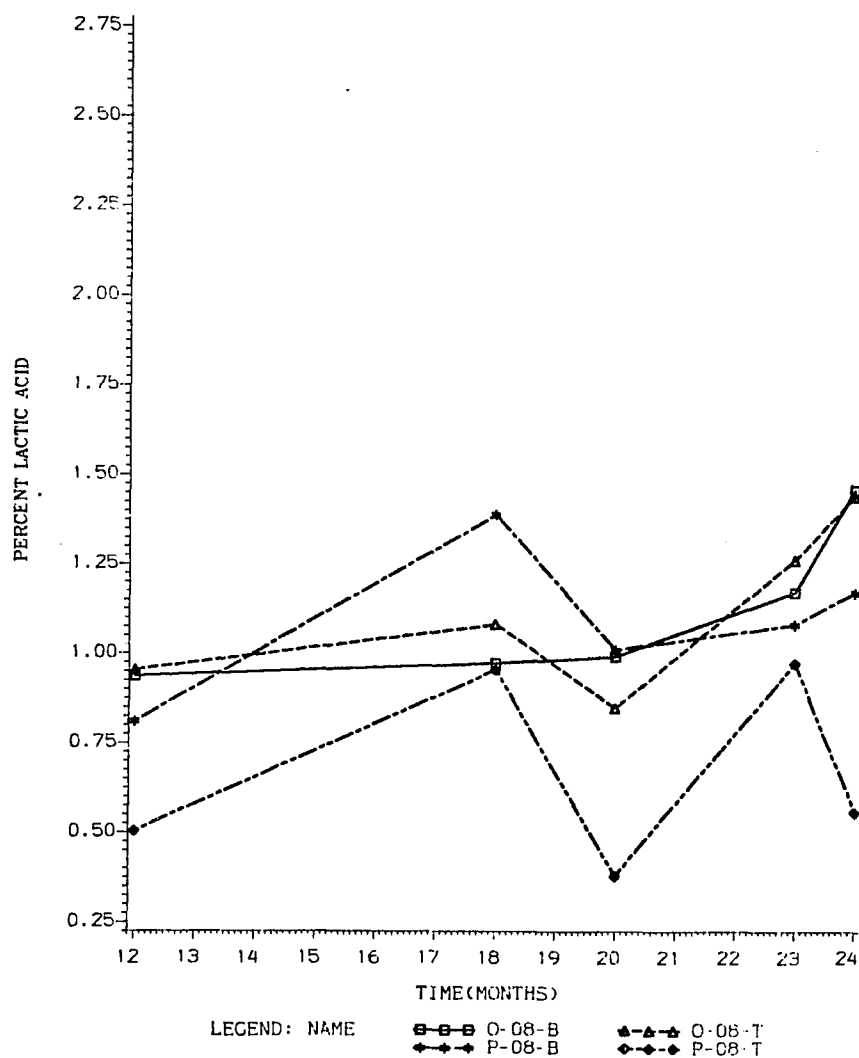
The acidity changed slowly in oak barrel mash samples of the second year. This was affected greatly by the location of the mash samples during the second year of the aging process (Fig. 21). This slow change seemed to indicate that most of the changes in the mash components of the oak barrel mashes were occurring during the first year of aging, while the changes were very slow in the plastic barrel samples which seemed to require a larger period of time to degrade the mash components.

Figure 20--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean total acidity (% lactic acid) of 8% salt pepper mash (First year samples).



O= Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

Figure 21--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean total acidity (% lactic acid) of 8% salt pepper mash (Second year samples).



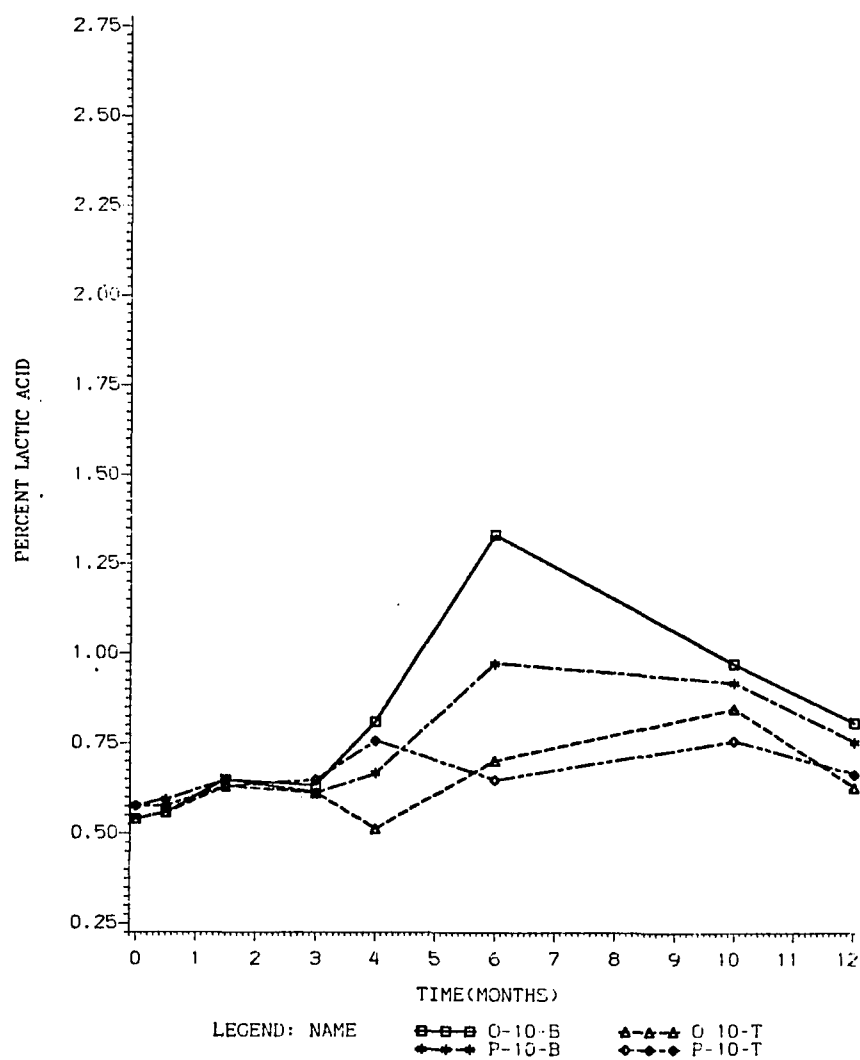
10% Salt Mash. In this high salt concentration the acidity of all samples increased very slowly at a similar rate during the first three months of the aging process (Fig. 22). This seemed to indicate that most of natural microorganisms and enzymes had been inhibited by the high concentrations of sodium chloride (Frazier and Westhoff, 1978; Pederson, 1971).

The acidity changes during this period of time occurred similarly in both oak and plastic barrels and appeared to indicate that the high salt concentration retarded the effect of any other factors.

The effect of the barrel type and depth of mash samples seemed to be initiated after the first three months of the aging process in which the acidity of the bottom mash samples of both barrel types increased rapidly to a very high level. Tables 5 and 6 seemed to indicate that the mash of these samples showed a development of a liquid phase with high concentration of salt. Thus, the acidity at the top of both oak and plastic mash samples increased slowly at this time.

The production of high levels of acid in the 10% salt mash might be related to the presence of a special group of microorganisms. Joslyn and Heid (1963) reported that high concentrations of salt, partially or entirely inhibited the heterofermentative bacteria in vegetable fermentation and favored the more salt tolerant homofermentative species

Figure 22--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the mean total acidity (% lactic acid) of 10% salt pepper mash (First year samples).



especially at high temperatures. These latter species produced lactic acid in large proportions when compared to the former group.

The acidity of the 10% salt mashes increased slowly in most second year oak and plastic barrel mash samples (Fig. 23). It was also affected greatly by the high temperatures of summer season especially in the dry mash samples found in the top sections of the oak and plastic barrels.

Effect of Salt Concentration. The aging process of hot pepper mash in these experiments had been greatly affected by the differential in the salt concentrations. This can be seen clearly by following the production of acids at the different salt concentrations of pepper mash samples during the aging process (Figs. 24 - 31). These data show that greater acidity resulted with low concentrations of salt than with high concentrations in both oak and plastic barrels as well as sampling areas of the mash samples. This suggested that the level of 6% salt enhanced the activities of most of the pepper mash microorganisms and enzymes in utilization of the pepper nutrients and producing more acid.

The results also suggested that the level of 10% salt inhibited most of the microflora except the salt tolerant microorganisms and enzymes which produced little change in the acidity of this pepper mash.

The results also showed that the 8% salt concentration produced an intermediate effect on the acid production when

Figure 23--The effect of barrel type (O,P) and depth of the mash sample (T,B) on the mean total acidity (% lactic acid) of 10% salt pepper mash (Second year samples).

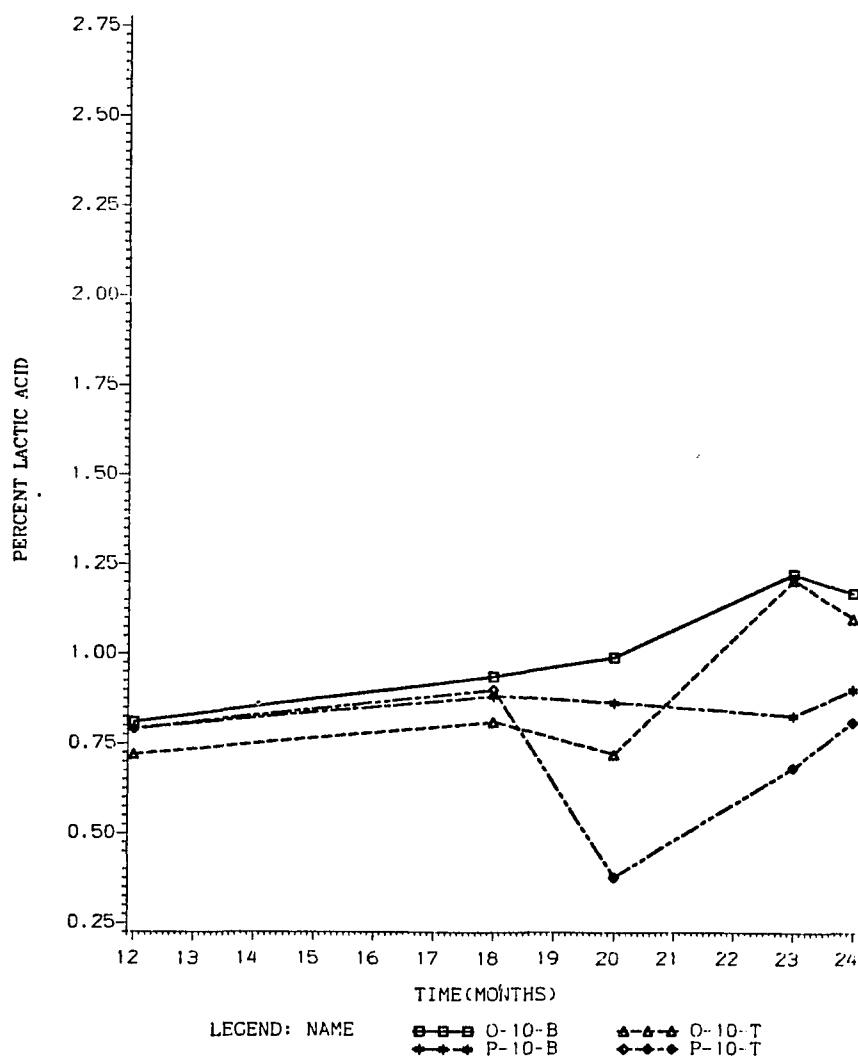


Figure 24--The effect of salt concentration % on the mean total acidity (% lactic acid) of the top sections of the oak barrel pepper mash (First year samples).

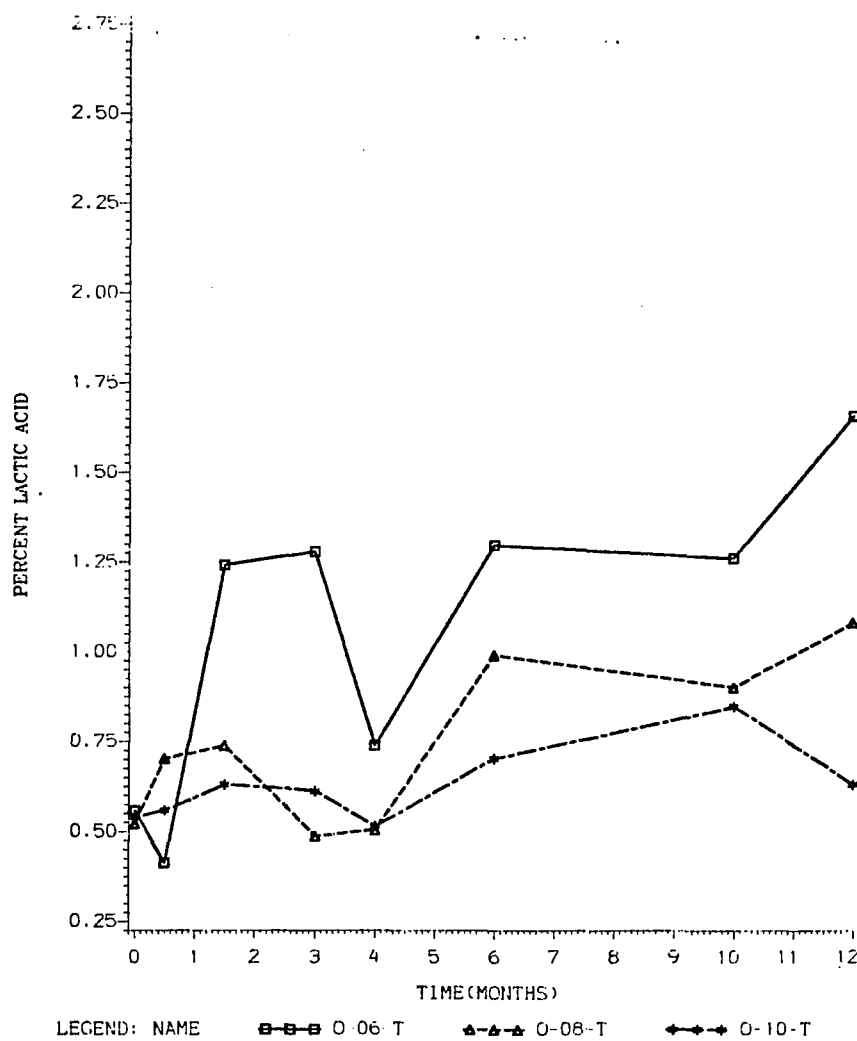


Figure 25--The effect of salt concentration % on the mean total scidity (% lactic acid) of the bottom sections of the oak barrel pepper mash (First year samples).

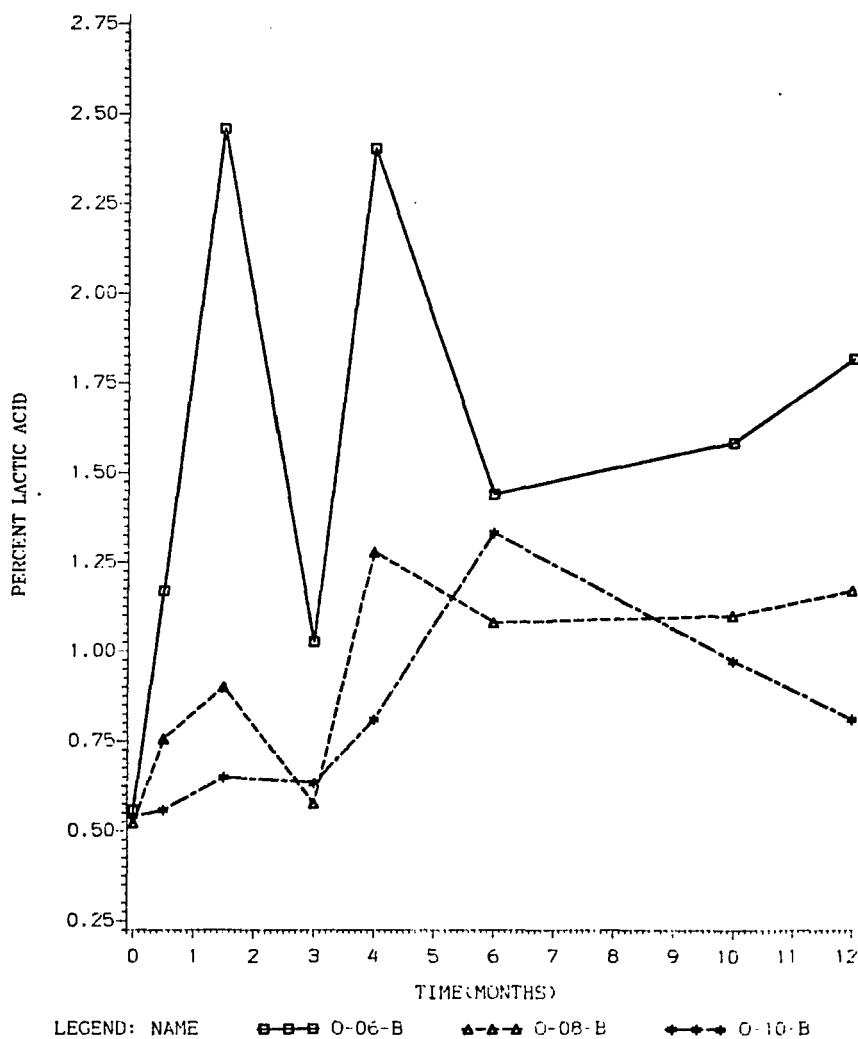


Figure 26--The effect of salt concentration (g%) on the mean total acidity (lactic acid) of the top sections of the plastic barrel pepper mash (First year samples).

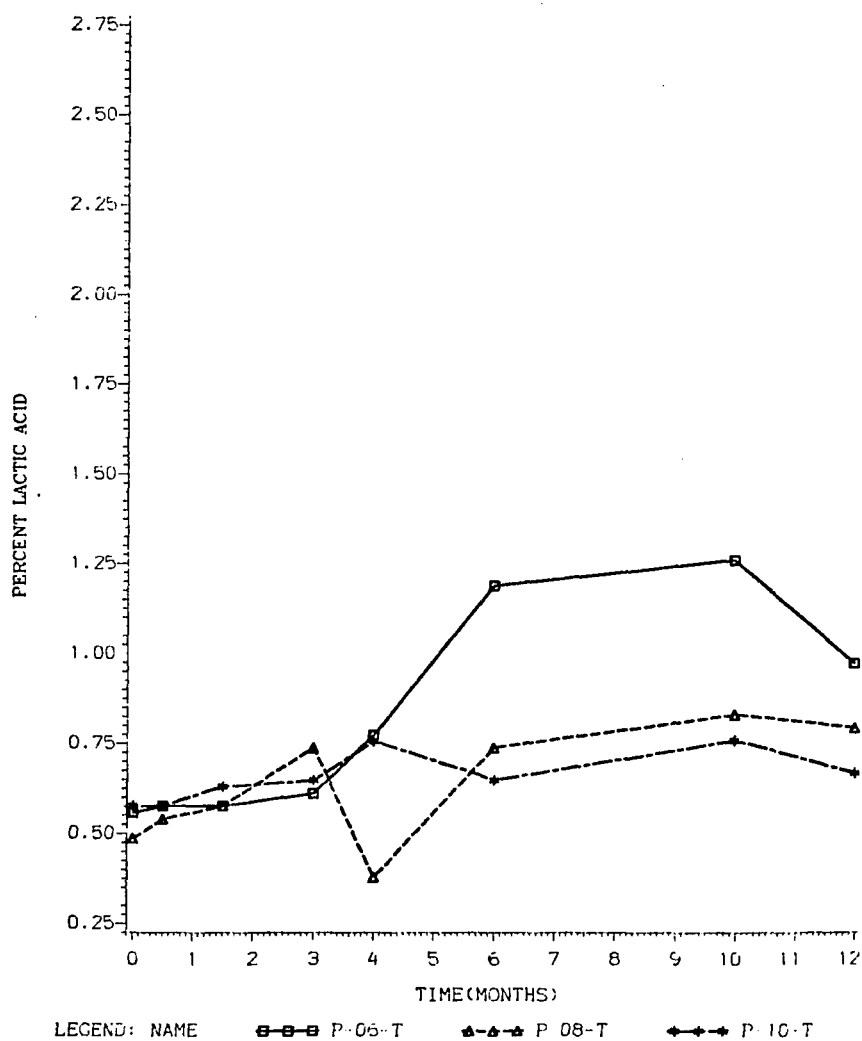


Figure 27--The effect of salt concentration (g%) on the mean total acidity (lactic acid) of the bottom sections of the plastic barrel pepper mash (First year samples).

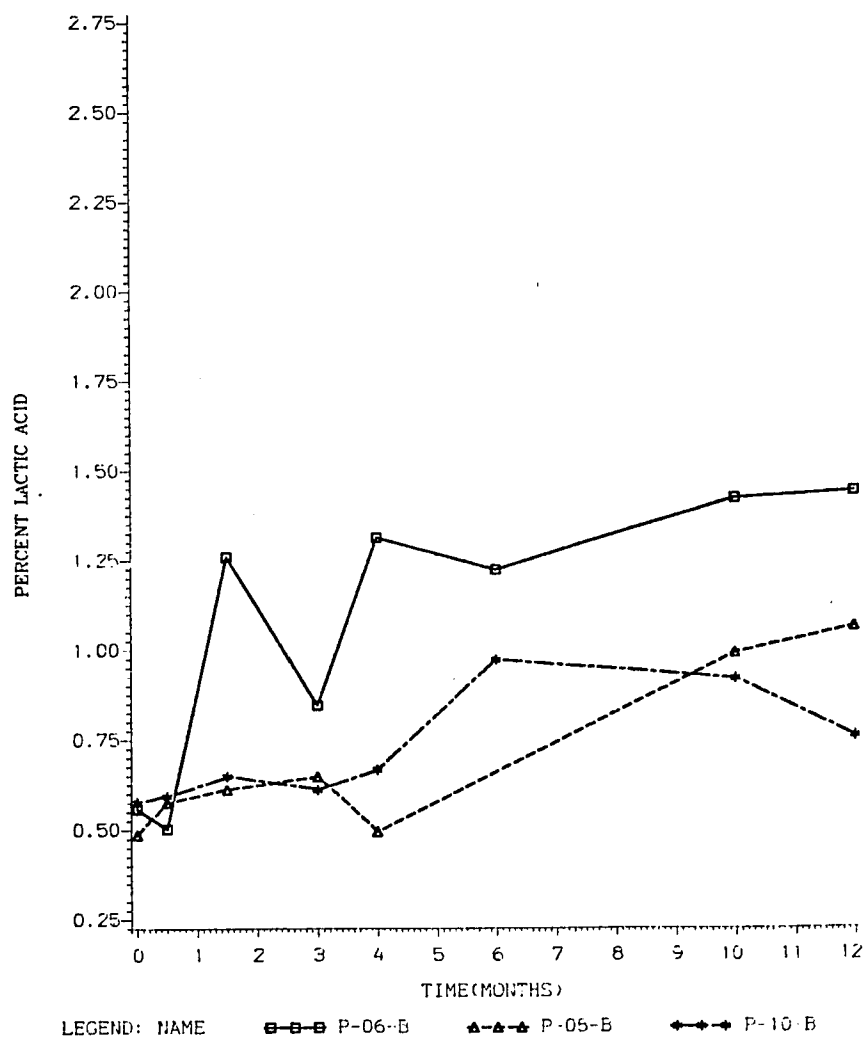


Figure 28--The effect of salt concentration % on the mean total acidity (% lactic acid) of the top sections of the oak barrel pepper mash (Second year samples).

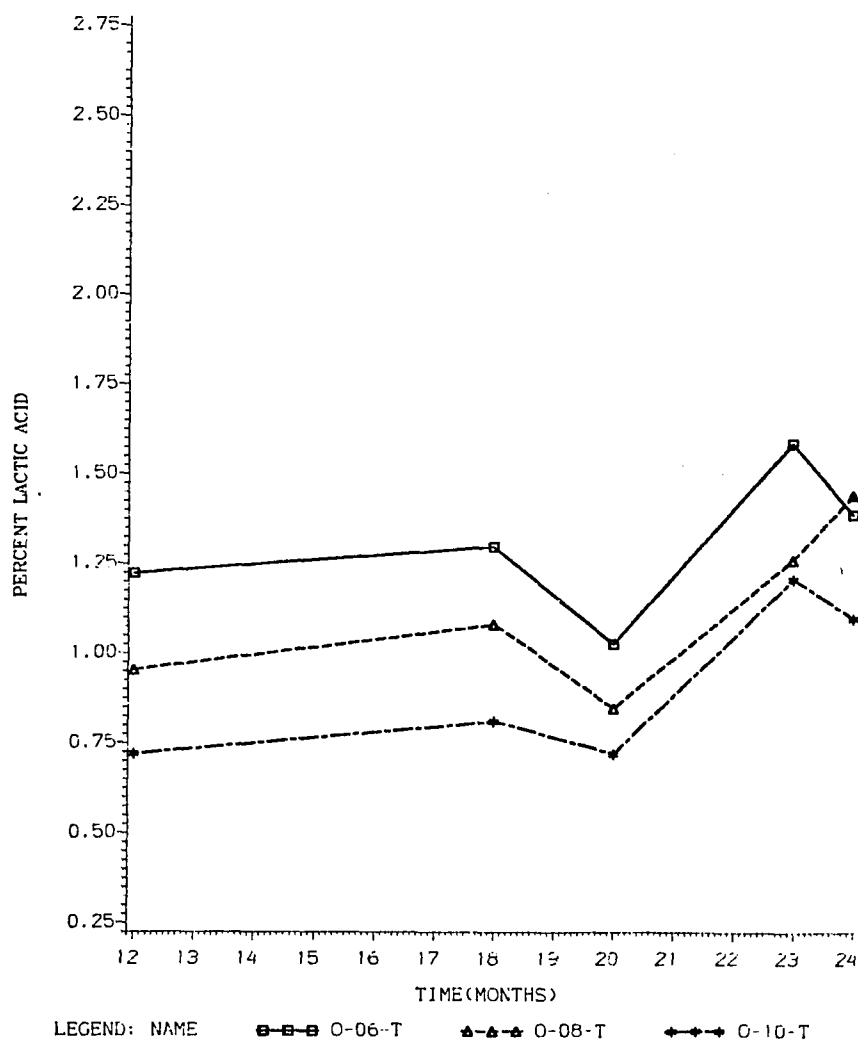


Figure 29--The effect of salt concentration % on the mean total acidity (% lactic acid) of the bottom sections of the oak barrel pepper mash (second year samples).

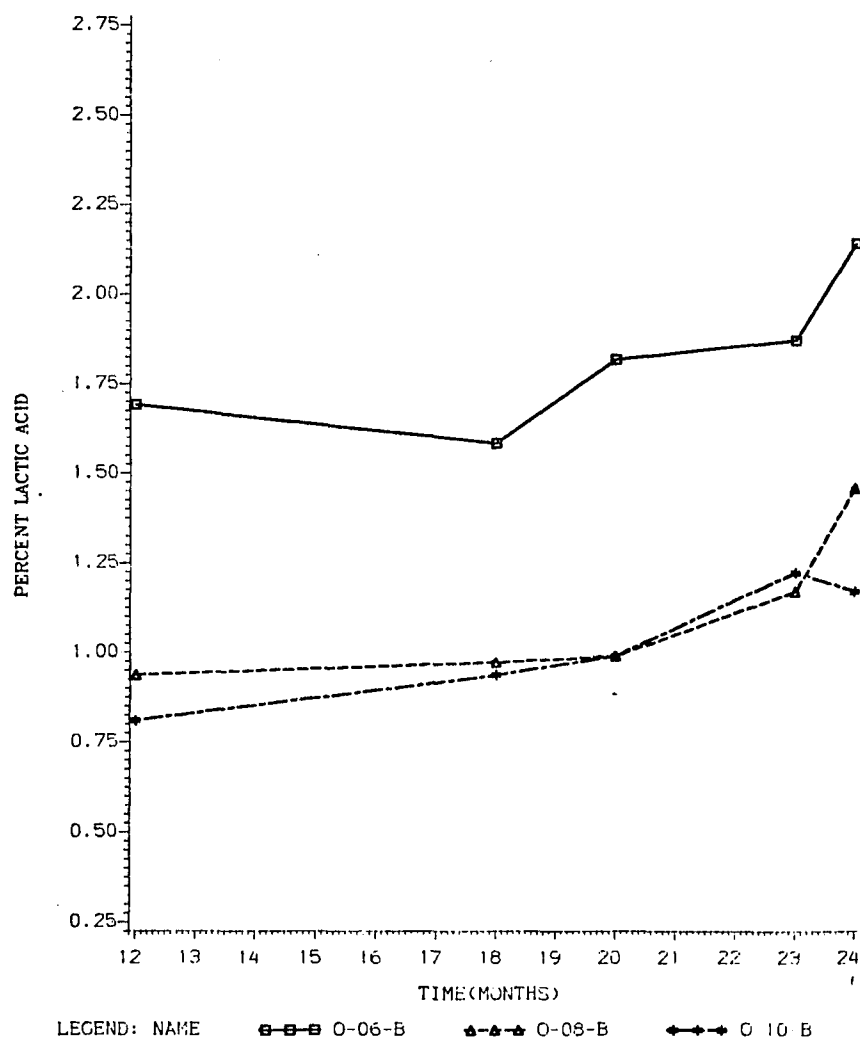


Figure 30--The effect of salt concentration (g%) on the mean total acidity (lactic acid) of the top sections of the plastic barrel pepper mash (Second year samples).

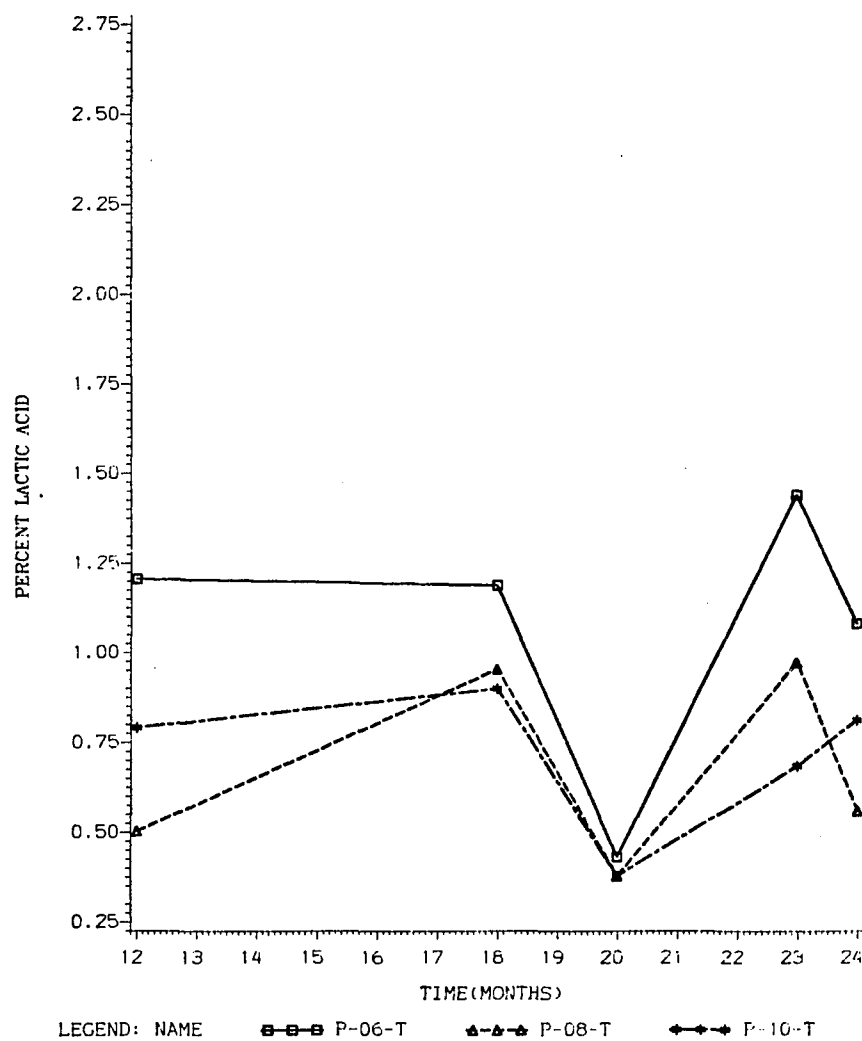
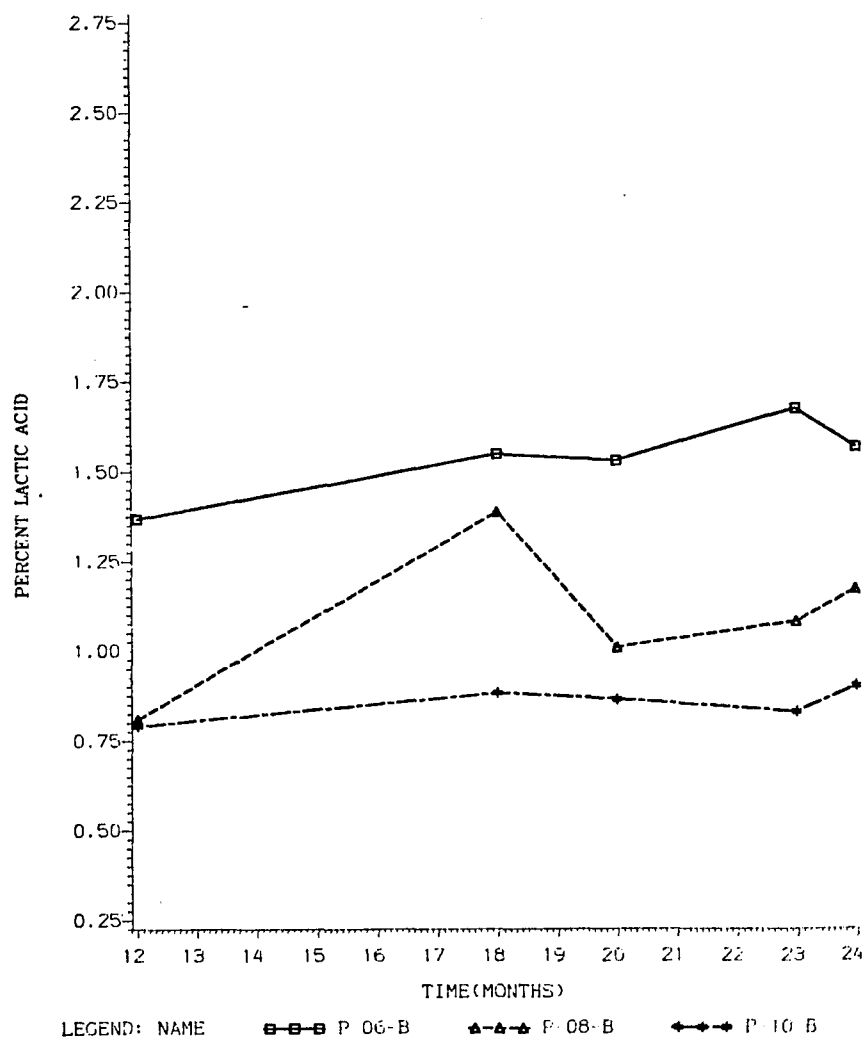


Figure 31--The effect of salt concentration (g%) on the mean total acidity (lactic acid) of the bottom sections of the plastic barrel pepper mash (second year samples).



compared to either the low salt (6%) or high salt (10%) concentration. The acidity found in the 8% salt concentration slightly increased over the acidity produced by the 10% salt treated mash in all mash samples of both types of barrels during the first and second year of the aging process.

A most interesting result which can be seen in Figures 24 - 31 was that the high temperatures had a great effect on the production of acids in the mash samples. This effect was noted clearly in the top samples of both type of barrels at all salt concentrations. This seemed to indicate that the high temperatures during aging encouraged the rapid growth of acid utilizing bacteria and scum yeasts, thereby causing a sharp reduction in the acidity (Joslyn and Heid, 1963; Frazier and Westhoff, 1978). The dryness of the top mash samples also enhanced the activity as the acidity was less when compared to the relatively liquid bottom mash samples.

In general, a more rapid rate of acid production was noted in all oak barrel mash samples, but it was also more rapid in the bottom mash samples especially with low salt concentration in both oak and plastic barrels.

The titratable acidity had increased rapidly during the first year of the aging process in all treatments (Table 17). As the aging continued during the second year, less acid was produced in all mash samples. This suggested that

Table 17. The initial and mean acidity of first and second year mash samples.

	Initial Sample	First Year	Second Year
O-6-T	0.56	1.13	1.30
O-6-B	0.56	1.70	1.82
P-6-T	0.56	0.88	1.07
P-6-B	0.56	1.09	1.54
O-8-T	0.52	0.78	1.12
O-8-B	0.52	1.00	1.10
P-8-T	0.49	0.66	0.67
P-8-B	0.49	0.70	1.09
O-10-T	0.54	0.64	0.91
O-10-B	0.54	0.82	1.03
P-10-T	0.58	0.67	0.71
P-10-B	0.58	0.74	0.85

O= Oak barrel

P = Plastic barrel

T = Top section

B = Bottom section

6, 8, 10 = % salt

most of the degradation of the pepper mash organic components occurred during the first 12 months of the aging process.

The acidity of several oak and plastic mash samples was not correlated negatively with the pH value of the same samples as was expected. The same poor correlation between the pH and acidity was found by Lower and Thompson (1967) in some tomato products. Paulson and Stevens (1974) studied the relationship between acidity and pH value. They concluded that the lack of a constant relationship between hydrogen ion concentration and acidity is due to not only differential buffering capacities among buffers of food solutions, but also to the change in buffering capacity of each buffer with the change in pH.

Salt Content:

The salt content of all mash samples was determined using the Dichromate Salt Analyzer (Tables 1-14). The results indicated that the initial established salt concentrations were approximately 2% lower than the proposed original concentrations in all mash treatments (Figs. 32 - 34). This could be possibly due to an incorrect estimation of the weight of the mash in each barrel when the experiment was originally established by those preparing the mash.

Figure 32--The actual amount of salt (g%) in the 6% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (First year samples).

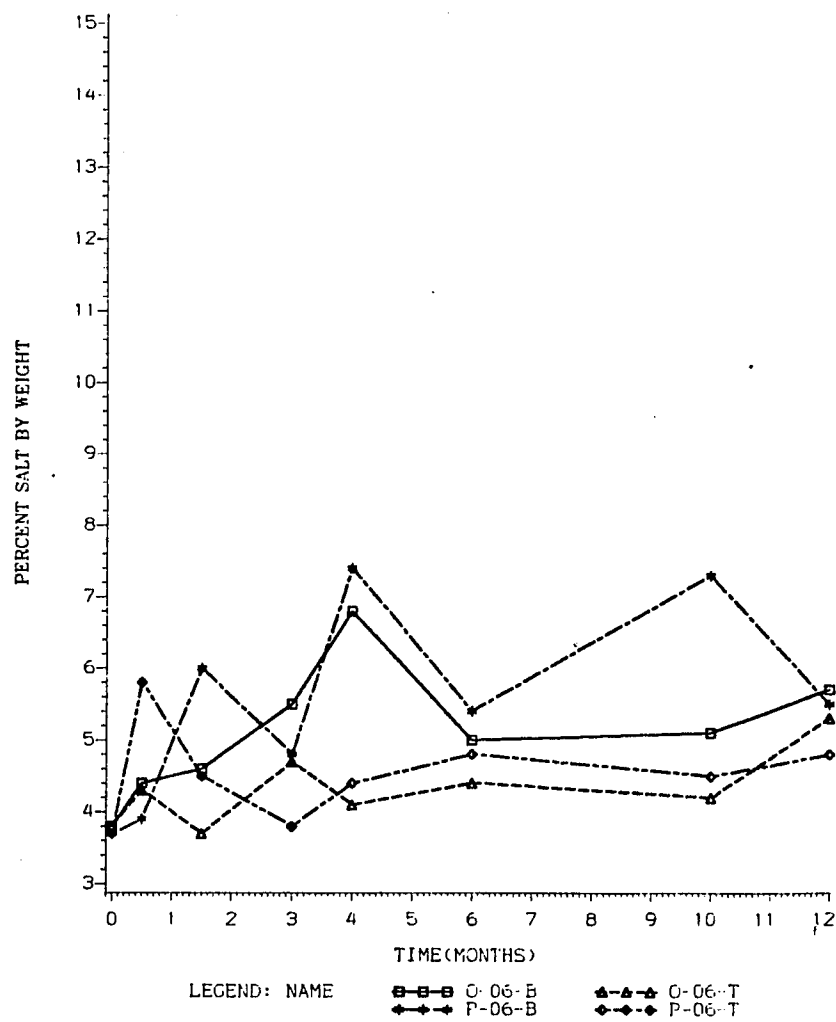


Figure 33--The actual amount of salt (g%) in the 8% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (First year samples).

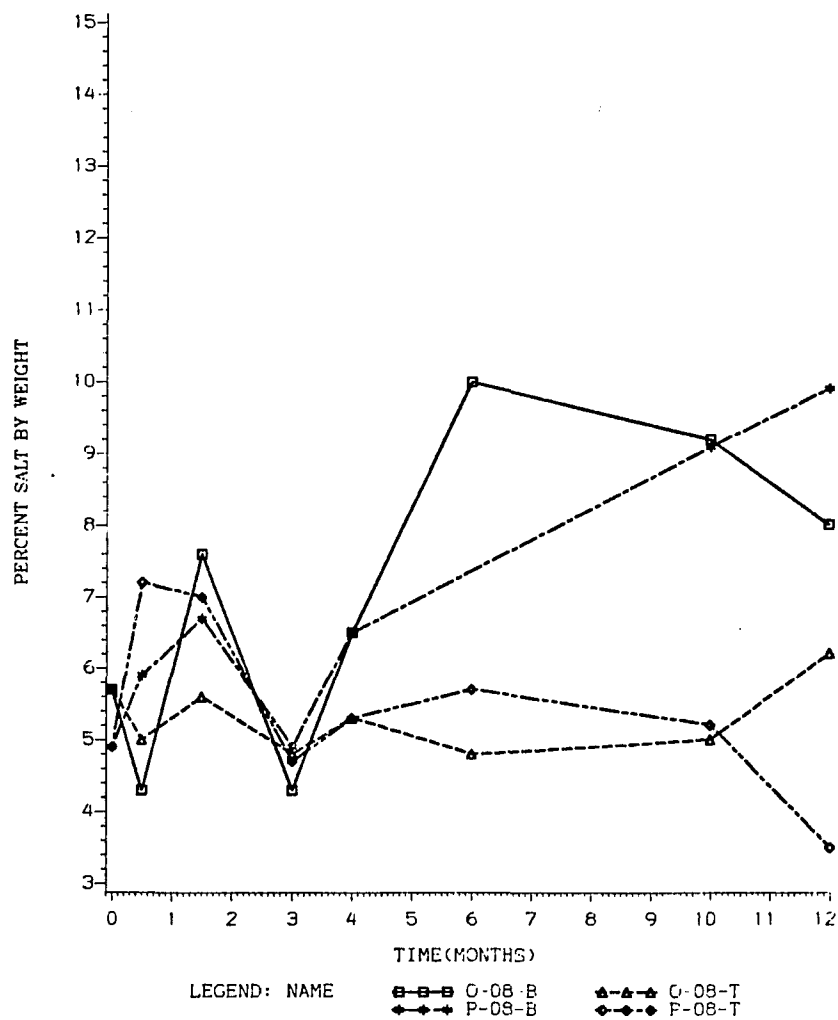
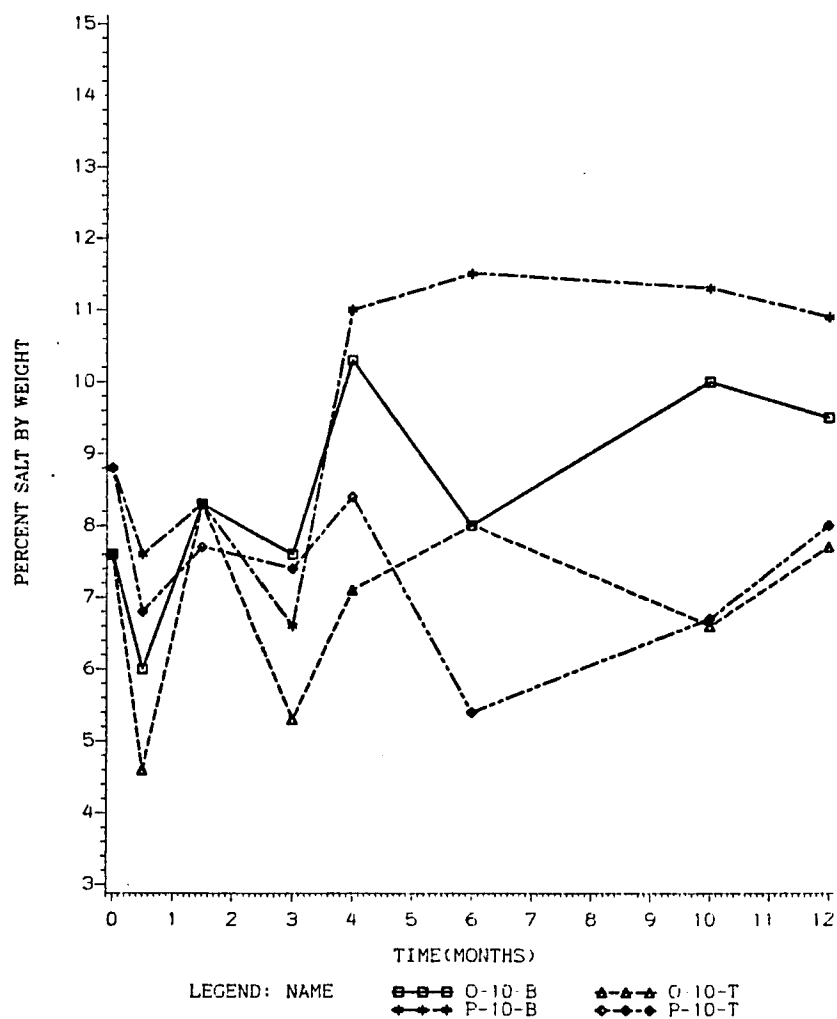


Figure 34--The actual amount of salt (g%) in the 10% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (First year samples).



Small changes in the concentration of salt of all mash samples were noticed during the first few months of the aging process. The concentrations then increased rapidly in the bottom sections of both the oak and plastic barrels (Figs. 35 - 37). This was expected since most of the extracted cellular juices were drained to the bottom sections of these barrels. Therefore, most of the mash salts in both types of barrels were expected to dissolve in the resulting liquid mash at the bottom of these barrels.

The plastic barrel mash samples were also found to have greater salt concentrations than the oak mash samples especially between the bottom sections. This could possibly be due to the leaking of some of the salt solution from the oak barrels (Table 18).

By the end of the second year of the aging process a putrefied odor was noted in the 6% salt oak and plastic barrel mash samples. This putrefaction was higher in the top mash samples of the plastic barrels. These were also found to have the lowest salt concentration during this time. This seemed to indicate that the growth of putrefactive microorganisms, especially in the top section of the mash, were responsible for this putrefaction since they were apparently not inhibited by the 6% salt concentration (Crues, 1958, Frazier and Westhoff, 1977).

Figure 35--The actual amount of salt (g%) in the 6% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (second year samples).

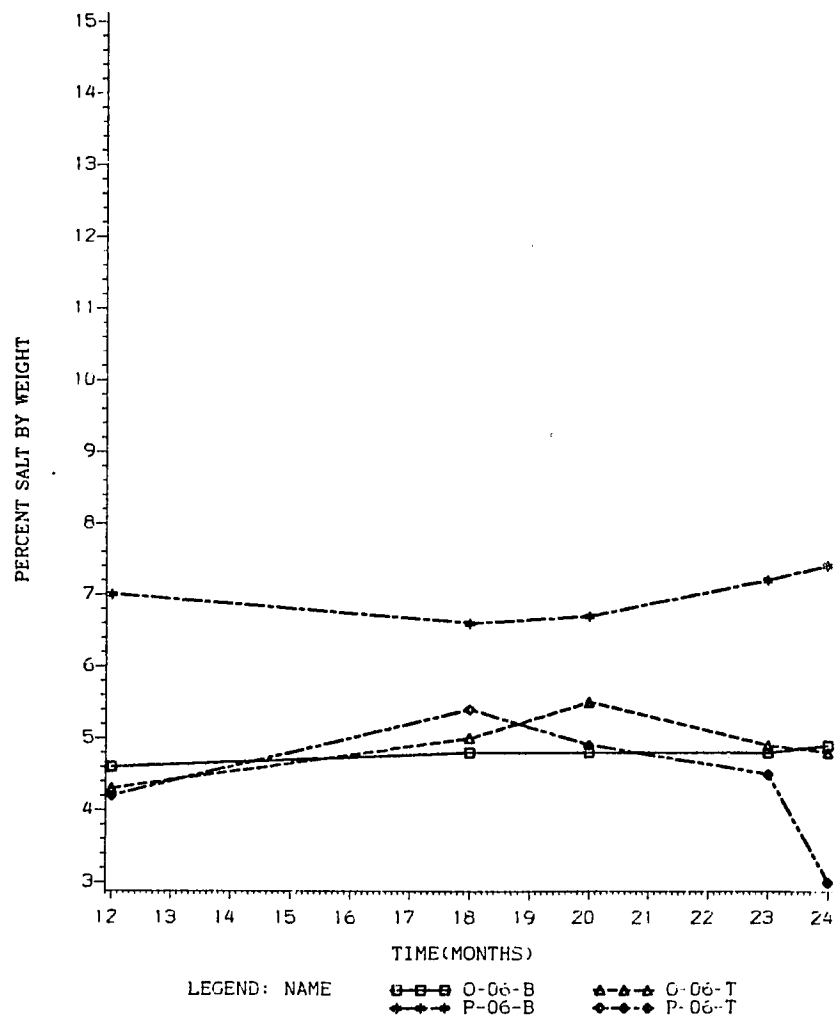


Figure 36--The actual amount of salt (g%) in the 8% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (Second year samples).

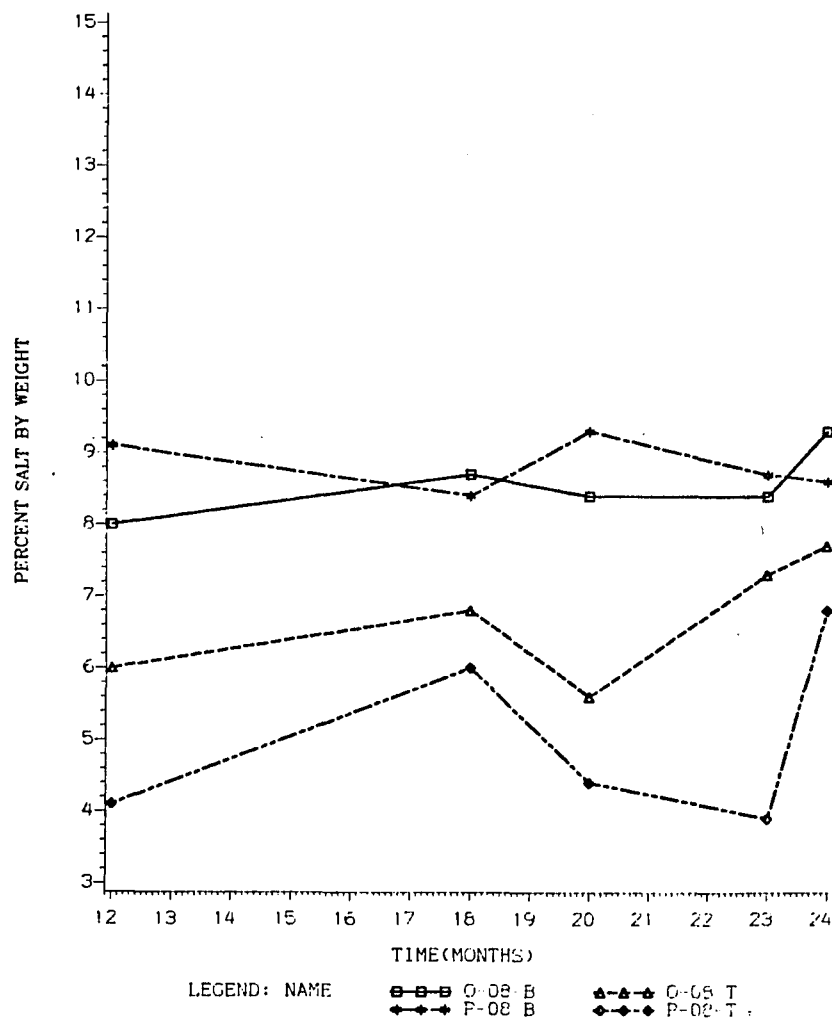


Figure 37--The actual amount of salt (g%) in the 10% salt treatment of the top and bottom pepper mash samples of the oak and plastic barrels (Second year samples).

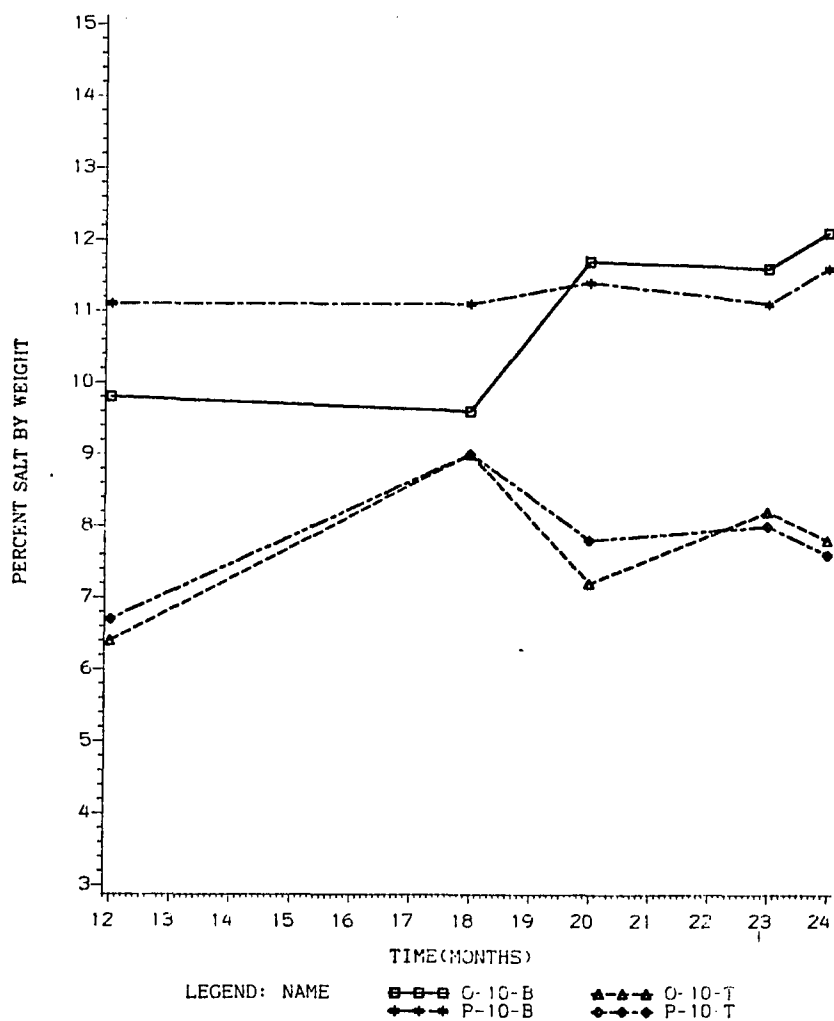


Table 18. The initial and mean salt concentration (g salt/100 g sample) of first and second year pepper mash samples.

	Initial Sample	First Year Sample	Second Year Sample
O-6-T	3.80	4.37	4.78
O-6-B	3.80	4.54	4.90
P-6-T	3.70	4.80	4.40
P-6-B	3.70	5.76	6.98
O-8-T	5.70	5.24	6.68
O-8-B	5.70	7.13	6.56
P-8-T	4.90	5.69	5.04
P-8-B	4.90	6.79	8.82
O-10-T	7.60	6.80	7.72
O-10-B	7.60	8.53	10.96
P-10-T	8.80	7.20	7.82
P-10-B	8.80	9.60	11.26

O= Oak barrel

P = Plastic barrel

T = Top section

B = Bottom section

6, 8, 10 = % salt

Total Color Differences (dE):

Total color difference (dE) of all aged mash samples was determined using a HunterLab Color Difference Meter (Tables 1-14).

The first sample of each treatment was used as a standard and the total color difference was calculated between each sample and this standard.

The total color difference (dE) was affected greatly by the salt concentrations and time of aging. It was also affected by the barrel type and location of the mash sample in each barrel.

The results showed that all mash samples had a greater dE value after the first 15 days of aging than any other period during the aging process (Figs. 38 - 40). These dE values were highest with the 8% salt and lowest with the 6% salt treatment. The dE then began to drop rapidly during the next three months of aging when it reached the lowest values. It then increased again at a different rate, depending on the salt concentration, in both oak and plastic mash samples. This increase was more rapid in the 8% salt treatment and was slower in the 6% mash samples. The increase in the dE values was also higher in the mash samples taken from the bottom section of the barrels than those taken from the top section of the barrels. These results suggested that greater color changes were to be

Figure 38--The effect of barrel type and depth of the mash samples on the total color differences (dE) of 6% salt pepper mash (First year samples).

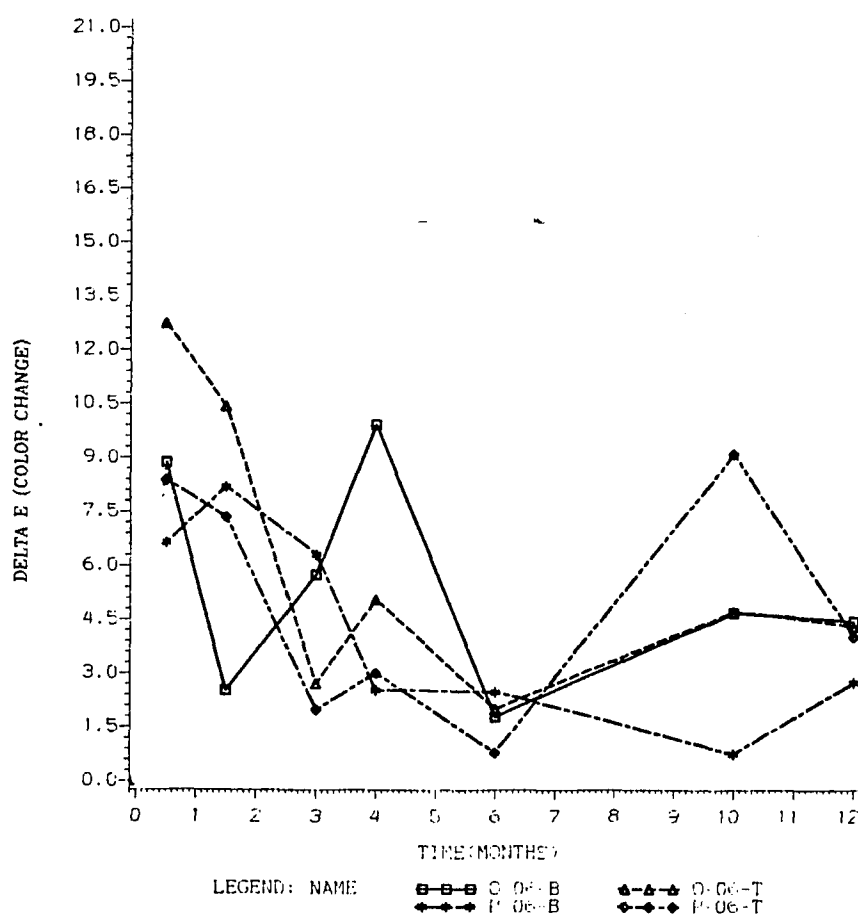


Figure 39--The effect of barrel type and depth of the mash samples on the total color differences (dE) of 8% salt pepper mash (First year samples).

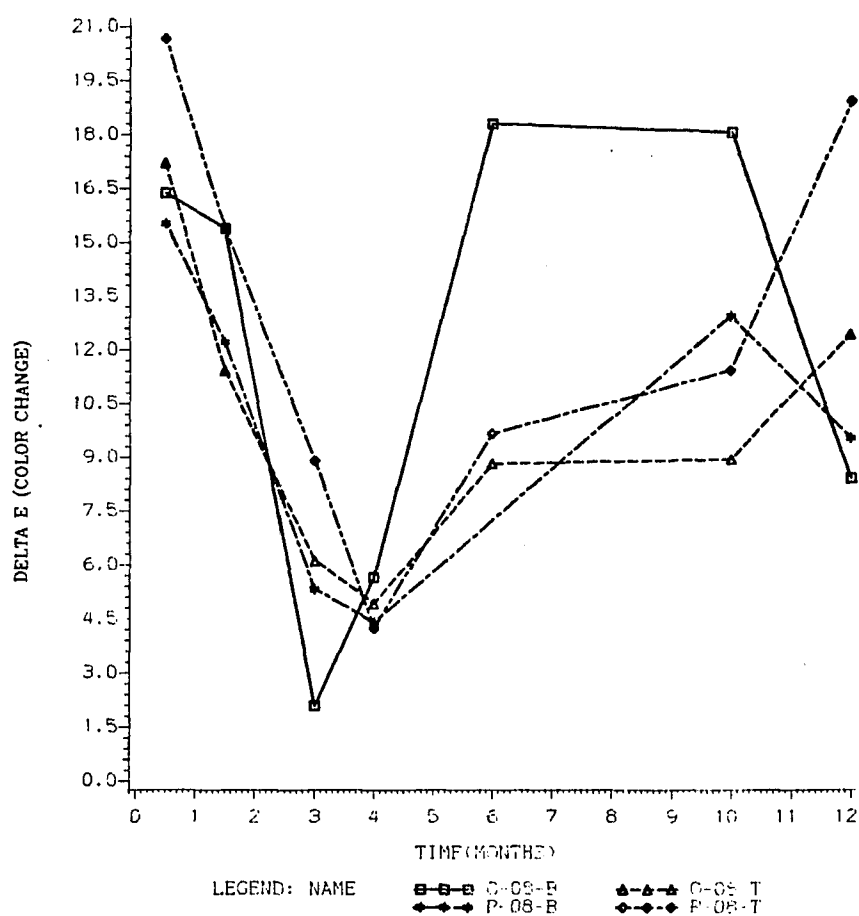
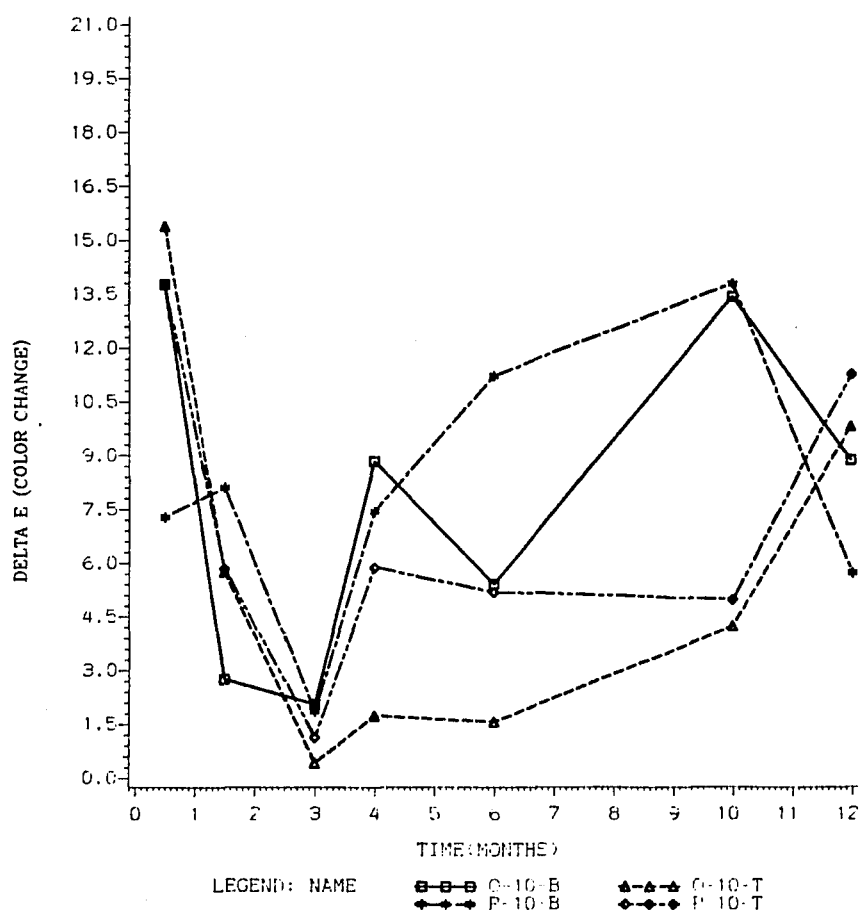


Figure 40--The effect of barrel type and depth of the mash samples on the total color differences (dE) of 10% salt pepper mash (First year samples).



expected in the more liquid mash of the bottom samples than the drier mash samples from the top sections of both the oak and plastic barrels. The liquid samples were found to have a more rapid degradation in their mashes with the production of higher amount of acid.

Small changes in the dE were observed in all mash samples during the second year of aging (Figs. 41 - 43). The changes were greater in the plastic mash samples than in the oak mash samples. This seemed to indicate that the plastic barrels enhanced the changing of the mash pigment components as a result of its lighter transparency characteristics.

The changes in the dE values were found to be related to the changes in the lightness or darkness of the products. The increase in the dE values were related to the increase in the darkness of the preserved products (MacKinney and Little, 1962).

This darkness could have been caused by a non-enzymatic browning reaction due to the presence of reducing sugars, proteins and amino acids (Joslyn and Ponting, 1951).

The carotenoid, β -carotene and lycopene could have also decomposed to cause changes in the redness and yellowness of the aged products (Dougherty and Nelson, 1974; Michael and Eskin, 1979).

Many studies have reported that processed fruits and vegetables always have a different color than the fresh

Figure 41--The effect of barrel type and depth of the mash samples on the total color differences (ΔE) of 6% salt pepper mash (Second year samples).

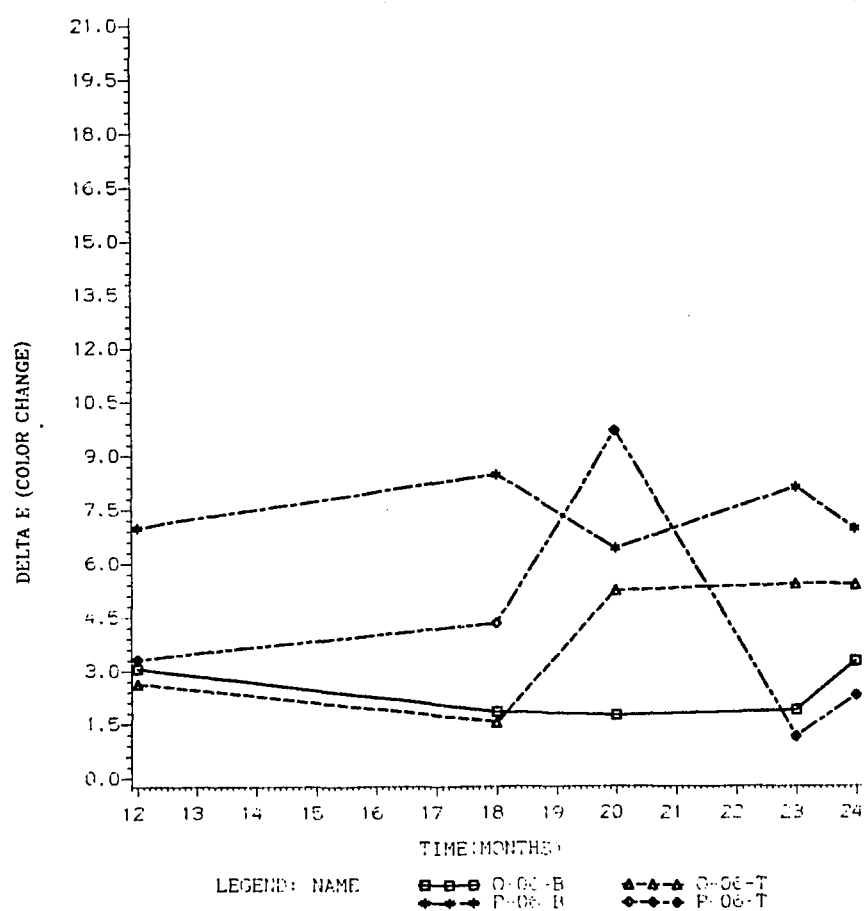


Figure 42--The effect of barrel type and depth of the mash samples on the total color differences (dE) of 8% salt pepper mash (Second year samples).

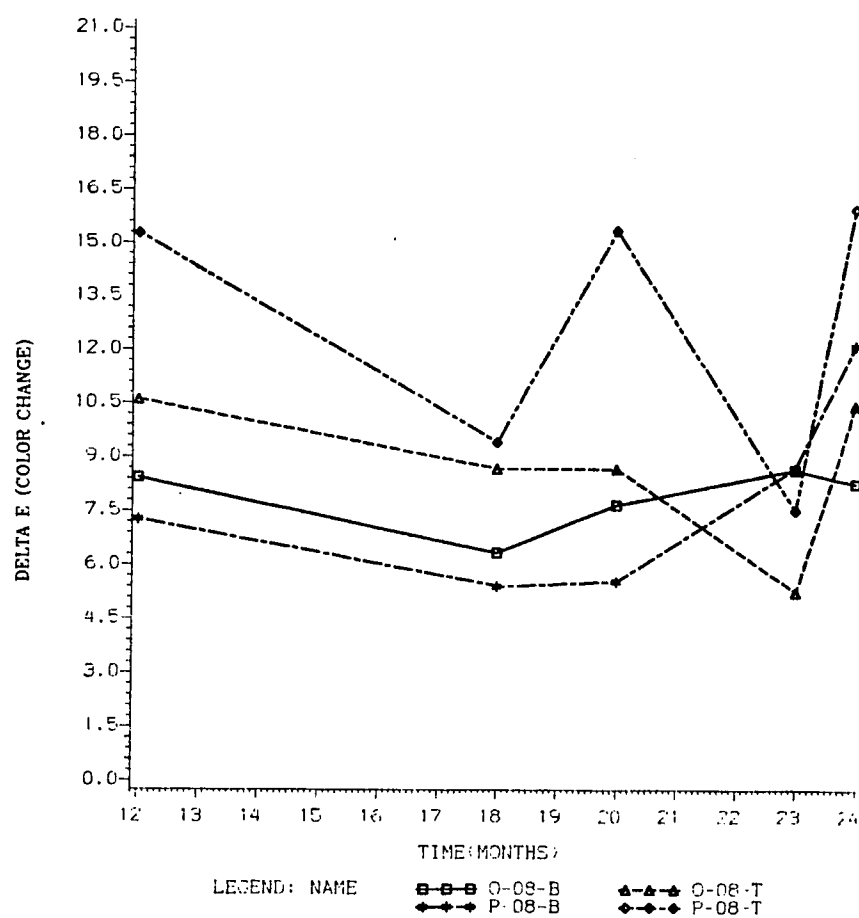
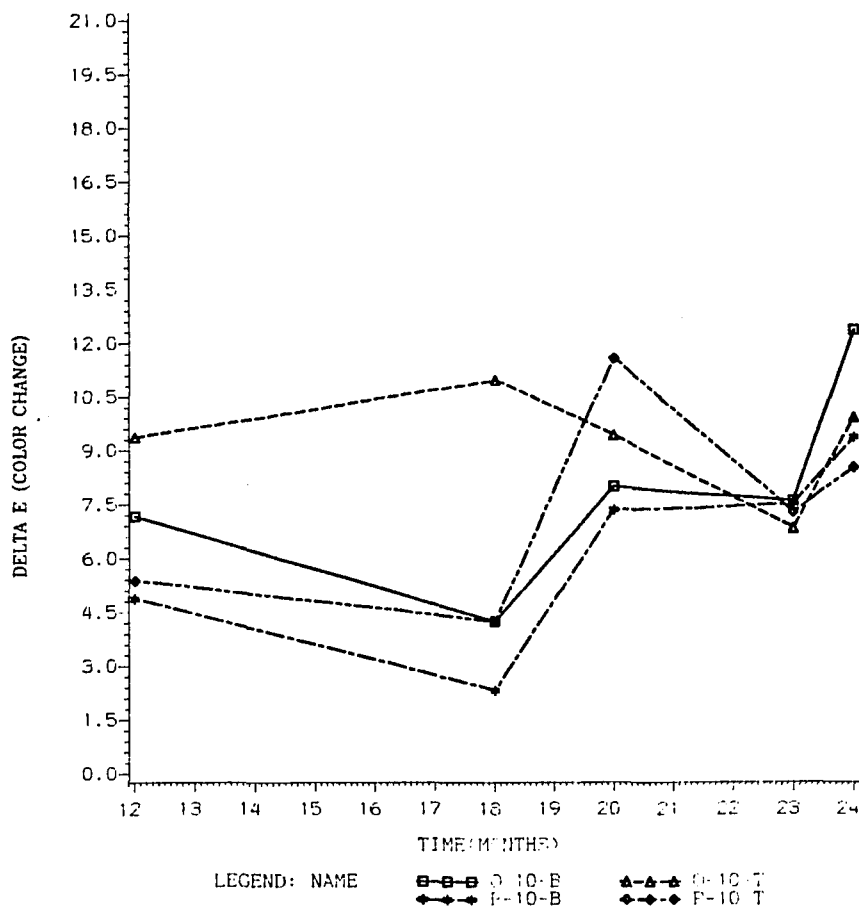


Figure 43--The effect of barrel type and depth of the mash samples on the total color differences (dE) of 10% salt pepper mash (Second year samples).



product. This change in color was found to be related to the actions of minerals, oxidation, hydrolysis by acids or enzymes, and conversion of the pigments by high temperature treatment (Clydesdale and Francis, 1968; Clydesdale and Francis, 1969; DeMan, 1980; Joslyn and Ponting, 1951; Francis and Clydesdale, 1975; MacKinney and Little, 1962; Smith and Cline, 1984).

The high amounts of acids produced during the aging of vegetables was found to increase the conversion of the chlorophylls and chlorophyllides to their respective pheophytins and pheophorbides with the loss of the typical green color (Clydesdale and Francis, 1969; MacKinney and Little, 1962; Schanderal et al., 1962; Schanderal et al., 1965; Jones et al., 1961).

Carotenoid components such as capsanthin were also affected by the light and temperature during the fermentation process of vegetable products (Dougherty and Nelson, 1974; MacKinney and Little, 1962; Michael and Eskin, 1979).

The oxidative enzymatic browning reaction was also found to occur in apple juice which catalyzed the polyphenol oxidase enzyme (Matthew and Parpia, 1971). The action of this enzyme could be inhibited by the presence of ions such as Cl^- and by compounds such as ascorbic acid (Joslyn and Ponting, 1951; Taufel and Voigt, 1964).

Total Pectic Substances:

Total pectic substances as polygalacturonic acid were determined in aged samples of pepper mash by the method of Bitter (1962) and Dekker and Richards (1972). The results are presented in Tables (1-14). The total pectin of the fresh mash samples shown in Table 1 represent the first sample that was taken from each barrel at the beginning of the experiment. The effect of barrel type, depth of mash, and aging time was studied in 6, 8 and 10% salt treatments during the two years of the aging process.

6 % Salt. The total pectic substances were different among the different aged mash samples of the 6% salt treatment. The results shown in (Fig. 44) indicated that there was a sharp decline in the total pectic substances of all mash samples during the first three months of the aging process. This suggested that the pectic enzymes, PE and PG, were very active during that period of time in degrading the pectin into its smaller units consisting of galacturonic acids. The same effects were reported by Stier et al. (1956), McColloch (1950) and Kertesz (1938) on the pectic changes during storage and processing of tomatoes to tomato paste. These studies showed that in crushed unheated tomatoes about 70 - 80 percent of the pectin was lost within the first 10 minutes of processing. This loss in pectin was reported to be due to the action of PE and PG enzymes in the

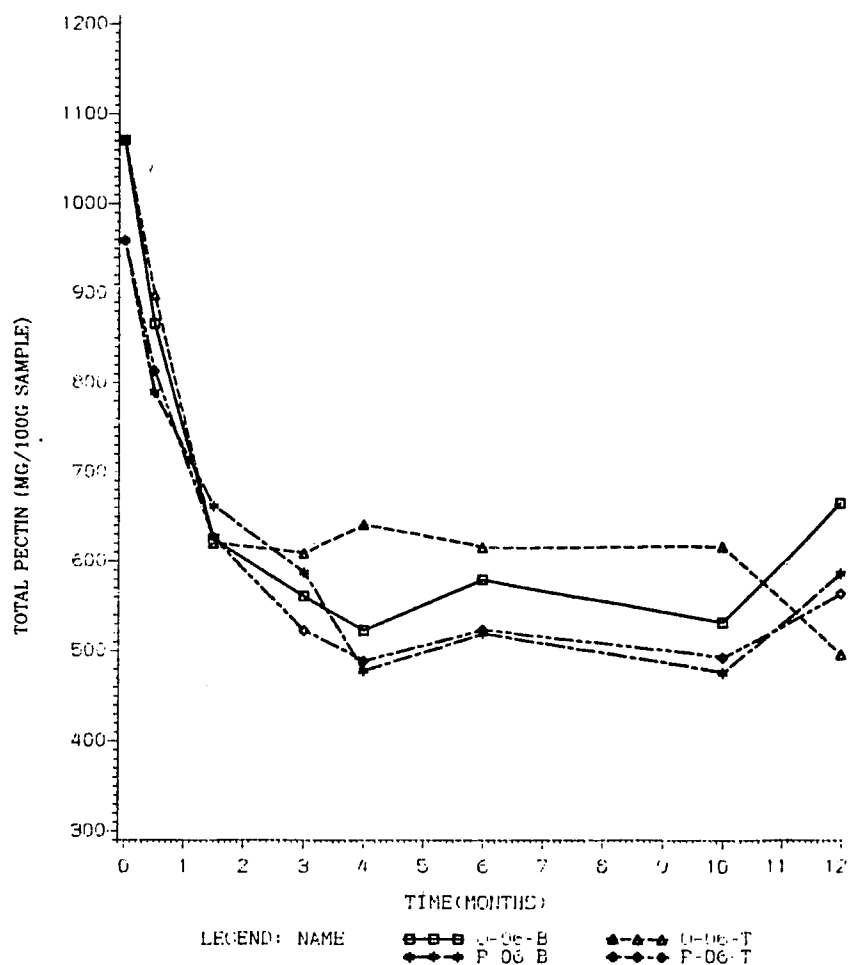
early stage of processing (Deual and Stutz, 1958). However, the destruction rate of pectin in the 6% salt pepper mash was slower than that of tomato paste as seen in (Fig. 44). This probably occurred due to the presence of salt which retarded the activity of these pectic enzymes.

The destruction rates of pectin were very similar in the oak and plastic mash samples during the first 2 months of the aging process. However, the destruction of pepper mash pectin continued to occur at a slower rate in the plastic barrel during the third and fourth months of aging. Small changes of the total pectin then occurred after that period of time in all pepper mash samples.

The results also showed that seemed to be slow increase in the total pectin in most of the pepper mash samples during the second year of the aging process (Fig. 45). This slow increase in total pectin might be due to the accumulation of new soluble pectin as a result of the transformation of insoluble protopectin to soluble pectin by protopectinase enzymes (Doesburg, 1957; Dougherty and Nelson, 1974).

8% Salt. The total pectin of the 8% salt mash samples also decreased rapidly after initiating the aging process (Fig. 46). The decrease in the total pectin was very rapid in the plastic barrel pepper mash as compared to the oak barrel pepper mash samples. Thus, it appears that a longer period of time was required to breakdown the oak barrel mash

Figure 44--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 6% salt pepper mash samples (First year samples).



Legend:

O = Oak barrel
P = Plastic barrel
T = Top section
B = Bottom section

Figure 45--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 6% salt pepper mash samples (Second year samples).

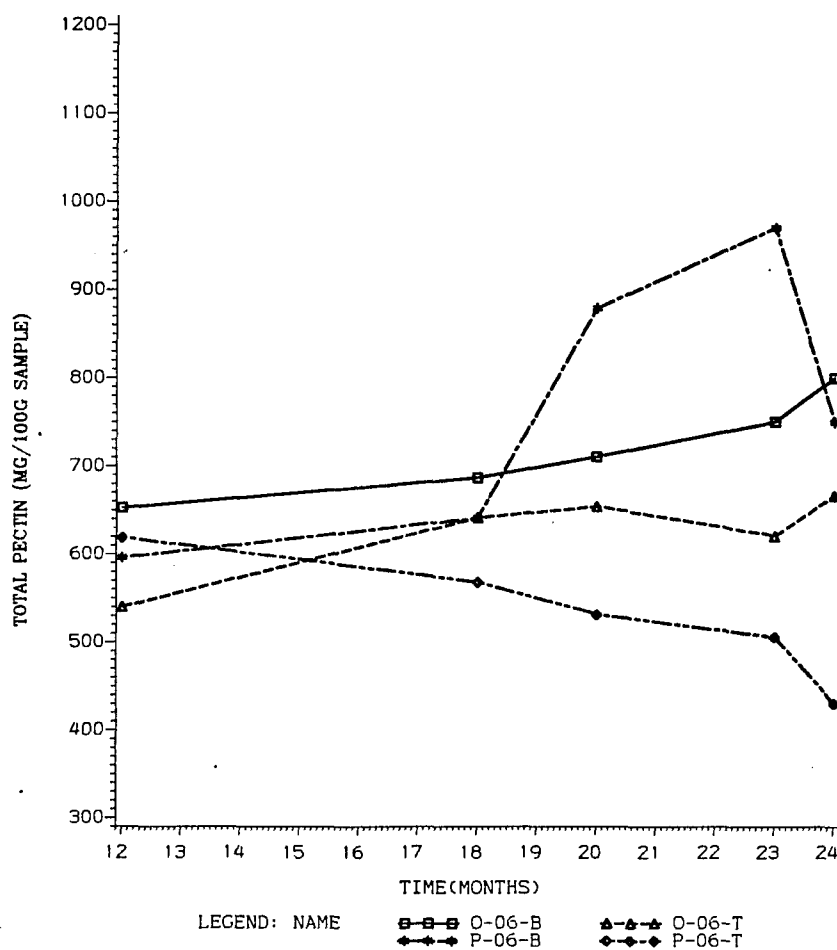
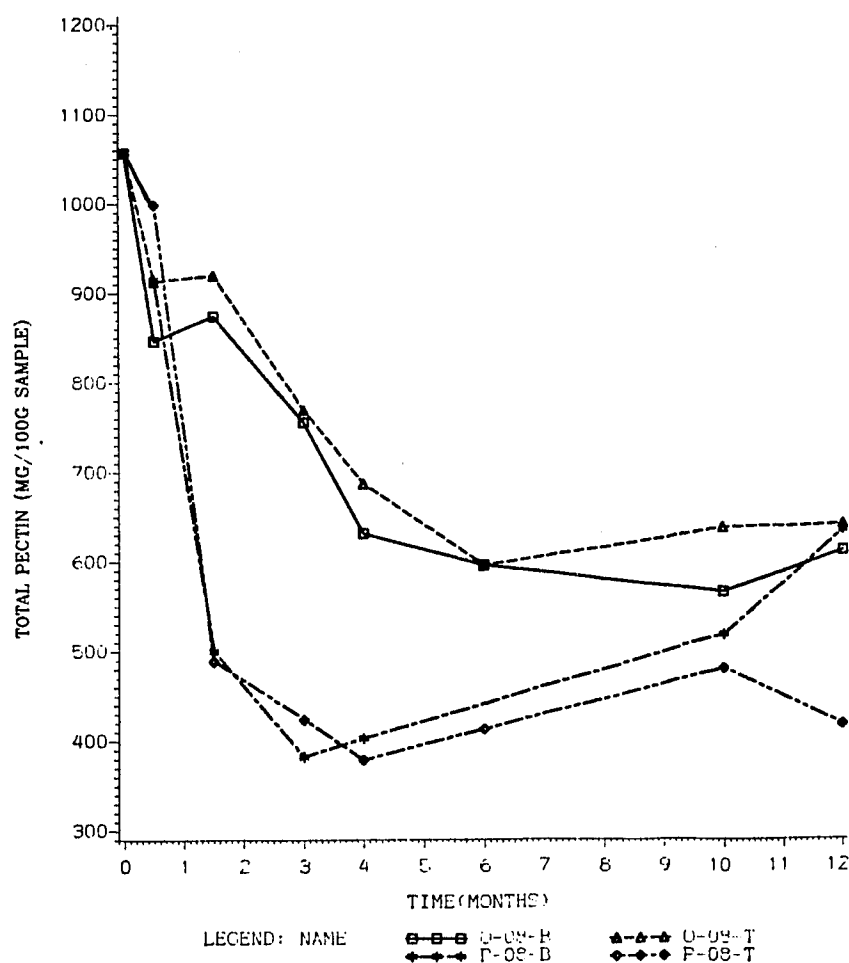


Figure 46--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 8% salt pepper mash samples (First year samples).

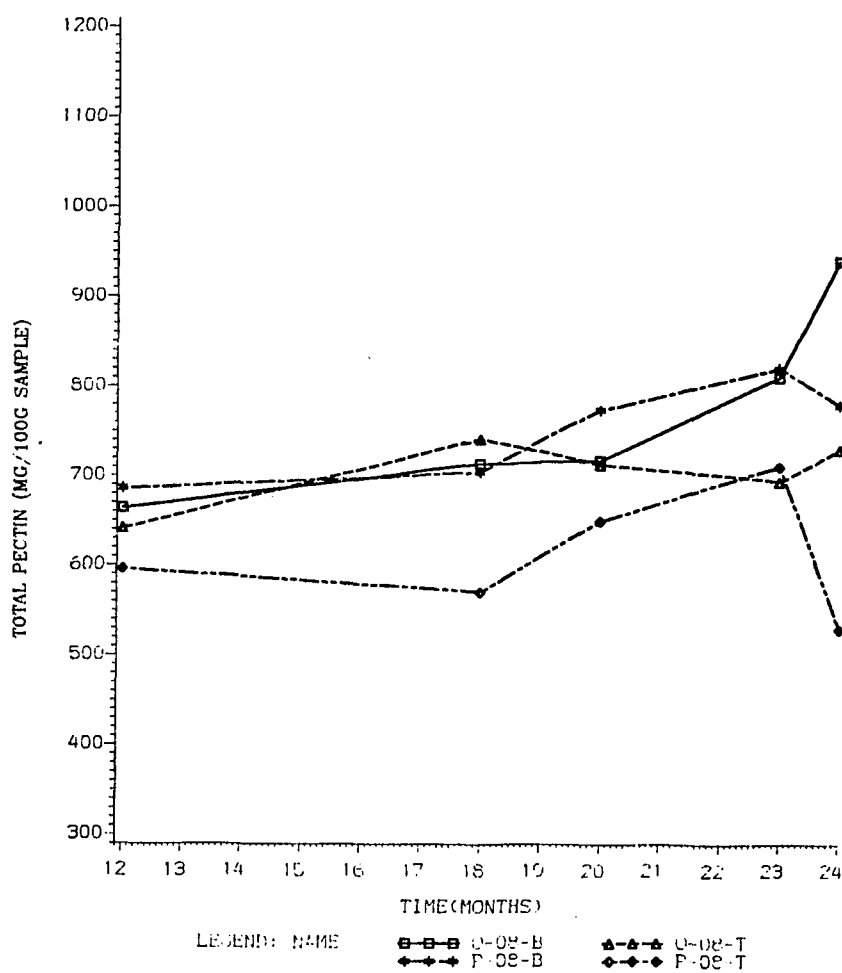


pectins as compared to the plastic barrel mash samples. This seemed to indicate that the activities of the pectic enzymes were higher in the plastic than the oak barrel pepper mash samples. These differences in the activity of the pectic enzymes in the two types of barrels might be due to the differences in their respective pH values. The results (Tables 3-6) indicated that the oak barrel pepper mash had a mean pH value of approximately 4.3 as compared to 4.6 of the plastic barrel pepper mash samples. This relationship between the pH and pectic enzymes activity was also found in tomatoes by McCulloch and Kertesz (1949) and Wagner et al. (1968).

Luh (1971) and Fonseca and Juh (1977) showed a similar correlation in tomato juice. They found a high pH level was always related to the cold break product, and low pH level was found with hot break tomato juice. The reduction in pectin of the 8% salt pepper mash samples was minimized during the second year (Fig. 47) as the pH was found to reduce from the favorable pectic enzymes pH range (Patel and Phaff, 1960). These results suggested that the optimum pH value for the 8% salt pepper mash pectic enzymes is either equal to or greater than pH 4.6.

The results also indicated that there were no differences between the total pectin of the top and bottom pepper mash samples in both oak and plastic barrels during the first year of the study. However, the bottom pepper

Figure 47--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 8% salt pepper mash samples (Second year samples).



mash samples of the plastic barrels were found to contain more pectin than the top section pepper mash samples during the second year of the aging process. This was expected since most of the water soluble pectin seemed to migrate from the top solid mash area to the more liquid bottom section of pepper mash that formed during the second year. The increase in the bottom mash pectin might also be due to the effect of pH on the activity of pectin enzymes (Miers et al., 1967). This relationship can be seen in (Table 19). The pH of bottom section pepper mash samples of the plastic barrel was approximately 4.33 while it was 5.13 in the top section samples. This same difference between the total pectin of the top and bottom pepper mash samples also occurred in the last two samples from the oak barrels.

10% Salt. The total pectin of the 10% salt pepper mash samples decreased rapidly during the first 3 months of the aging process (Fig. 48). The rate of this decrease was very similar between the oak and plastic barrel pepper mash samples. The total pectin continued to decrease rapidly in the top pepper mash samples of both types of barrels until the fourth month of the aging process. Thus, the top pepper mash samples contained less total pectin than the bottom pepper mash samples in both years of the study (Figs. 48 - 49). This might be due to the migration of most of the soluble pectin from the top to the more liquid bottom pepper mash samples which begin to form at that period of time

Table 19. The effect of salt treatment and location of mash on the average pH of the plastic barrel mash samples during first and second years of the aging process

	1st year mean pH value	2nd year mean pH value
P-6-T	4.47	4.97
P-6-B	4.19	4.18
P-8-T	4.94	5.13
P-8-B	4.66	4.33
P-10-T	4.73	4.98
P-10-B	4.54	4.50

P = Plastic barrel

T = Top section

B = Bottom section

6, 8, 10 = % salt treatment

Figure 48--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 10% salt pepper mash samples (First year samples).

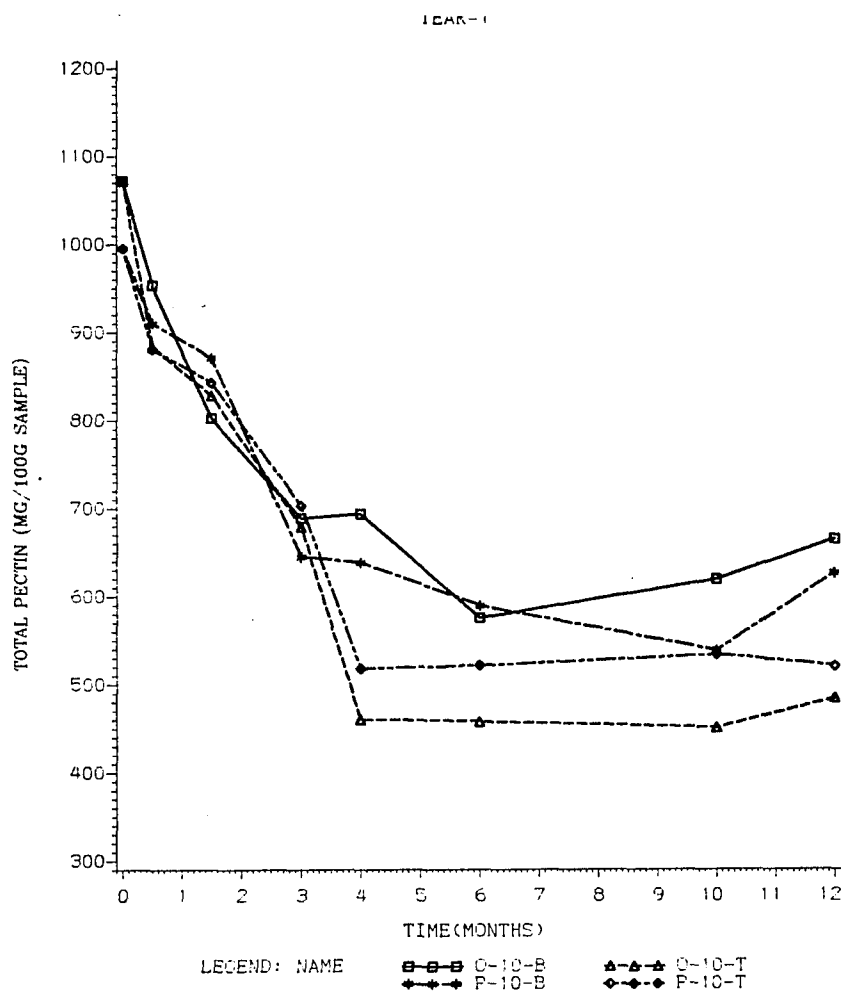
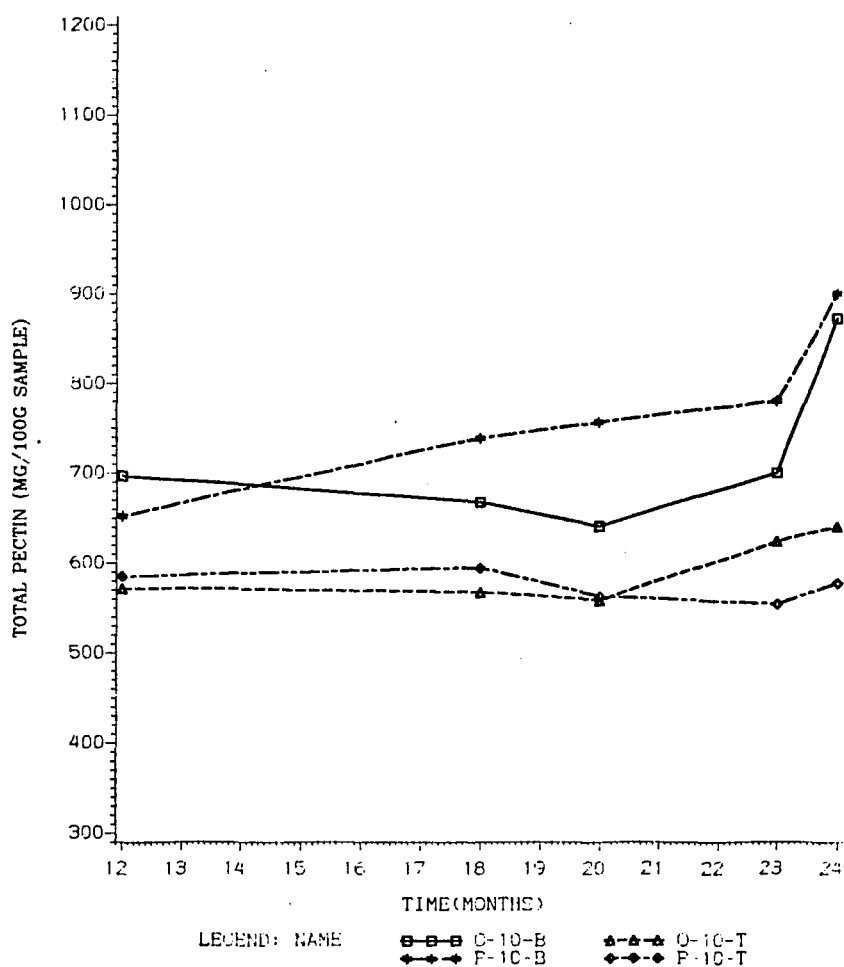


Figure 49--The effect of barrel type (O,P) and depth of the mash samples (T,B) on the total pectic substances content (mg/100g) in 10% salt pepper mash samples (Second year samples).



(Tables 4-14). The pH values of the bottom samples were also lower than that of the top samples (Tables 19-20). Thus, more pectic enzymes activity was expected to occur in the high pH pepper mash samples of the top section than the lower pH of the bottom samples as was found by Miers et al. (1967).

The results also indicated that the high concentration of salt in this treatment minimized the effect of the barrel types on the activity of pectic enzymes. Thus, both oak and plastic barrel pepper mash samples had similar amounts of total pectic substances during the first and second year of the study.

Effect of salt concentrations. The amount of salt present in the pepper mash samples was found to have an effect on the total pectic substances. A difference was found to occur when comparing the oak and plastic pepper mash samples.

In the oak barrels, the total pectic substances of the top and bottom pepper mash samples were affected similarly by the different concentrations of salt. The results indicated that the total pectic substances dropped very rapidly in all salt concentration treatments after the first few months of the aging process (Figs. 50-51). This drop in the amount of total pectin was more rapid in the 6% salt concentration when compared with the 8% and 10% salt treatments of both the top and bottom pepper mash samples.

Table 20. The effect of salt treatment and location of mash on the average pH value of the oak barrel mash samples during the first and second year of the aging process.

	First year mean pH value	Second year mean pH value
O-6-T	4.27	4.65
O-6-B	4.10	4.28
O-8-T	4.49	4.35
O-8-B	4.42	4.25
O-10-T	4.58	4.96
O-10-B	4.56	4.46

O = Oak barrel
 T = Top section
 B = Bottom section
 6, 8, 10 = % Salt treatment

Figure 50--The effect of salt concentration (g%) on the total pectic content (mg/100g) of the top sections of the oak barrel pepper mash (First year samples).

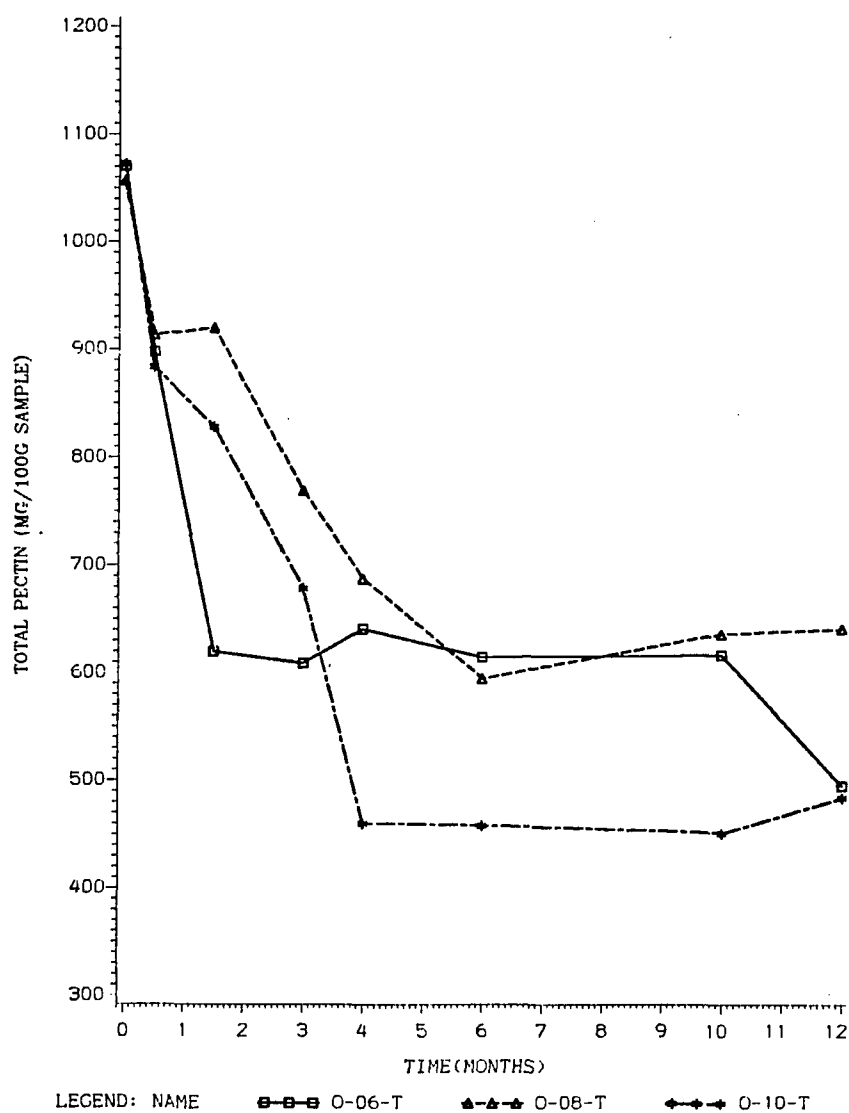
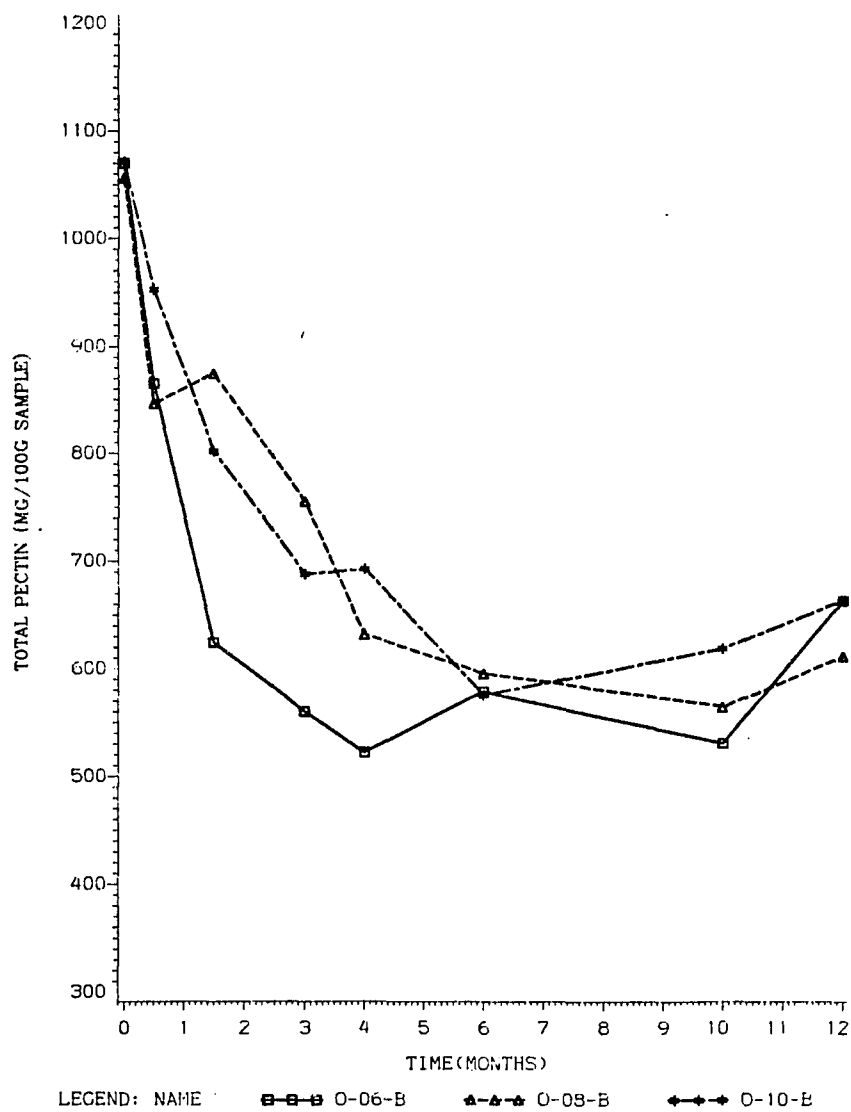


Figure 51--The effect of salt concentration (g%) on the total pectic content (mg/100g) of the bottom sections of the oak barrel pepper mash (First year samples).



This seemed to indicate that the 6% concentration of salt was not able to retard the action of the pectic enzymes in these pepper mash samples as compared to the 8 and 10% salt treatments. The pH value of the 6% salt pepper mash samples was found to be lower than 4.0 during these first few months (Table 2). This result suggested that the low pH (4.0) was favorable for the PG enzymes which converted the pectic acids to galacturonic acids (Kertesz, 1938; Wagner and Miers, 1967; Patel and Phaff, 1960).

However, more total pectin was converted to galacturonic acid in the 10% salt pepper mash samples collected from the top section as compared to the all other salt concentration samples. This might also be due to the high activity of the pectic enzymes as the pH of those mash samples increased to their optimum level (pH 4.6).

Small increases in the total pectic substances were measured in all oak barrel pepper mash samples during the second year of the aging process (Figs. 52 & 53). These increases in the total pectin were higher in the bottom pepper mash samples, especially at the end of the aging process. This seemed to indicate that most of the pectin in these bottom section pepper mash samples were water soluble pectin, while the top sections were expected to contain more oxalate soluble pectins, low methoxyl (pectinic acid) as reported by Peters et al. (1954). The increase in the amount of total pectin might be due to transformation of

Figure 52--The effect of salt concentration (g%) on the total pectic content (mg/100g) of the top sections of the oak barrel pepper mash (Second year samples).

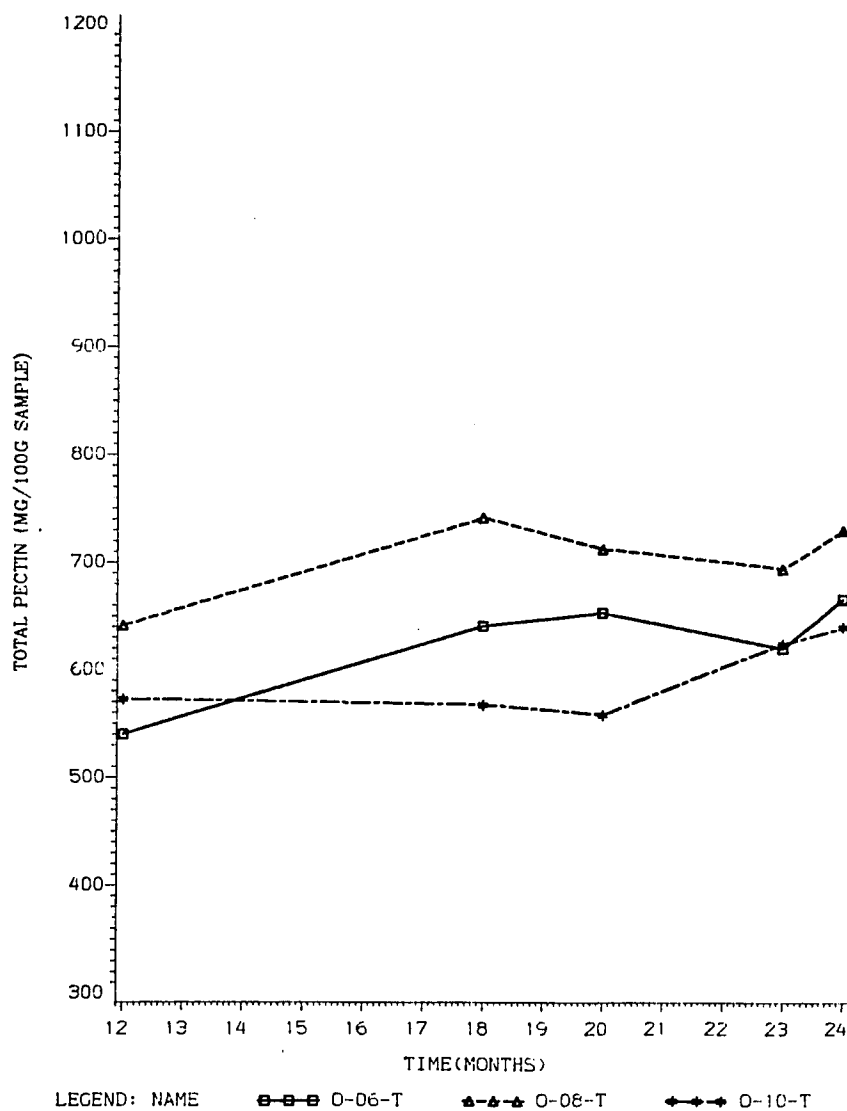
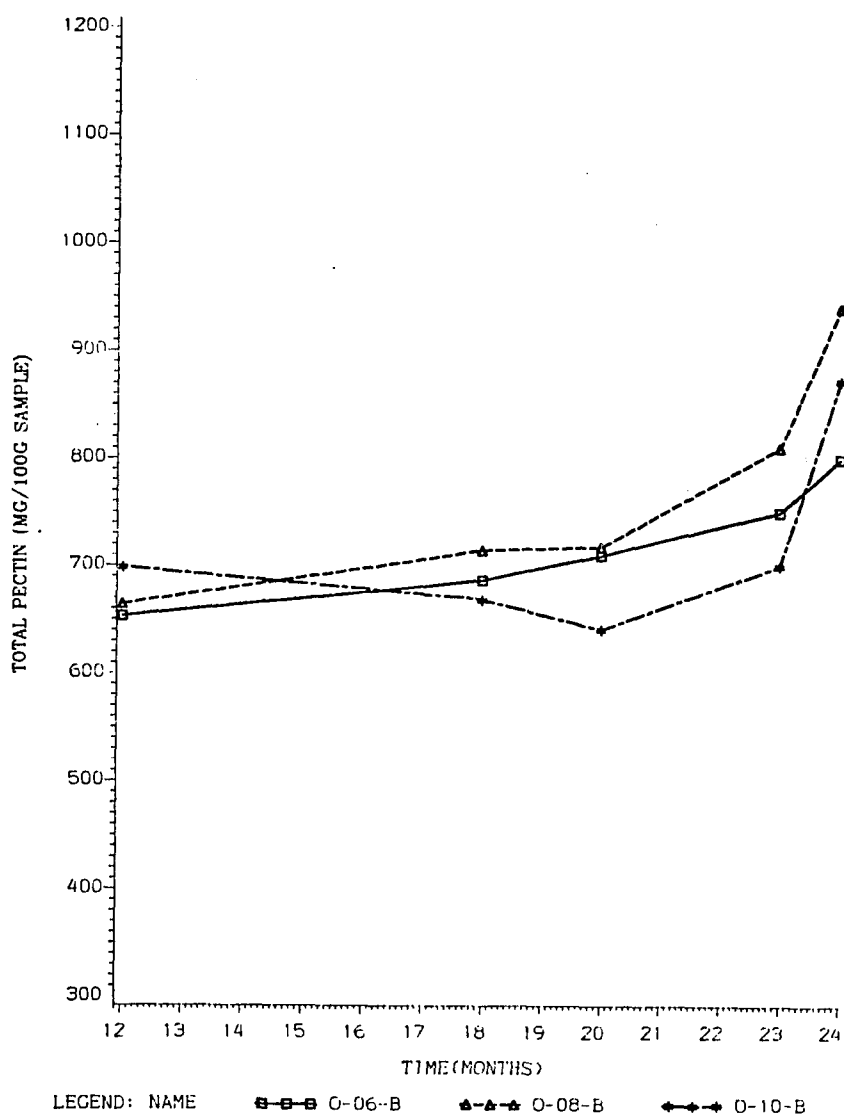


Figure 53--The effect of salt concentration (g%) on the total pectic content (mg/100g) of the bottom sections of the oak barrel pepper mash (Second year samples).



insoluble protopectin to the more soluble pectin by protopectinase enzymes (Doesburg 1957, Dougherty and Nelson, 1974). The newly formed soluble pectin was not degraded to galacturonic acid probably due to the reduction in the activities of PE and PG enzymes at the end of the aging process (Wagner et al., 1975).

Results also indicated that the 8% salt mash contained more total pectin than any other of the salt treatments. These results seemed to indicate that the moderate 8% salt concentration and moderate pH value (4.2 - 4.4) were necessary for the higher total pectin content.

The total pectin substances also dropped rapidly in all of the salt treatments in the plastic barrel pepper mash samples during the first four months of the aging process (Figs. 54 & 55). The decrease in total pectin was found to be greatest in the 8% salt concentration pepper mash samples as compared to the 6 and 10% salt treatments. This suggested that the activities of the pectic enzymes in the 8% salt concentration pepper mash samples were higher than that of the other salt treatments. The mean pH values of the 8% salt pepper mashes were found to be either very high (4.94) at the top of the barrel (4.66) for the bottom mash samples.

The 10% salt treatments were found to have less chemical conversion in their total pectin content, even though their pH values were approximately 4.73. This

Figure 54--The effect of salt concentration (g%) on the total pectin content (mg/100g) of the top sections of the plastic barrel mash (First year samples).

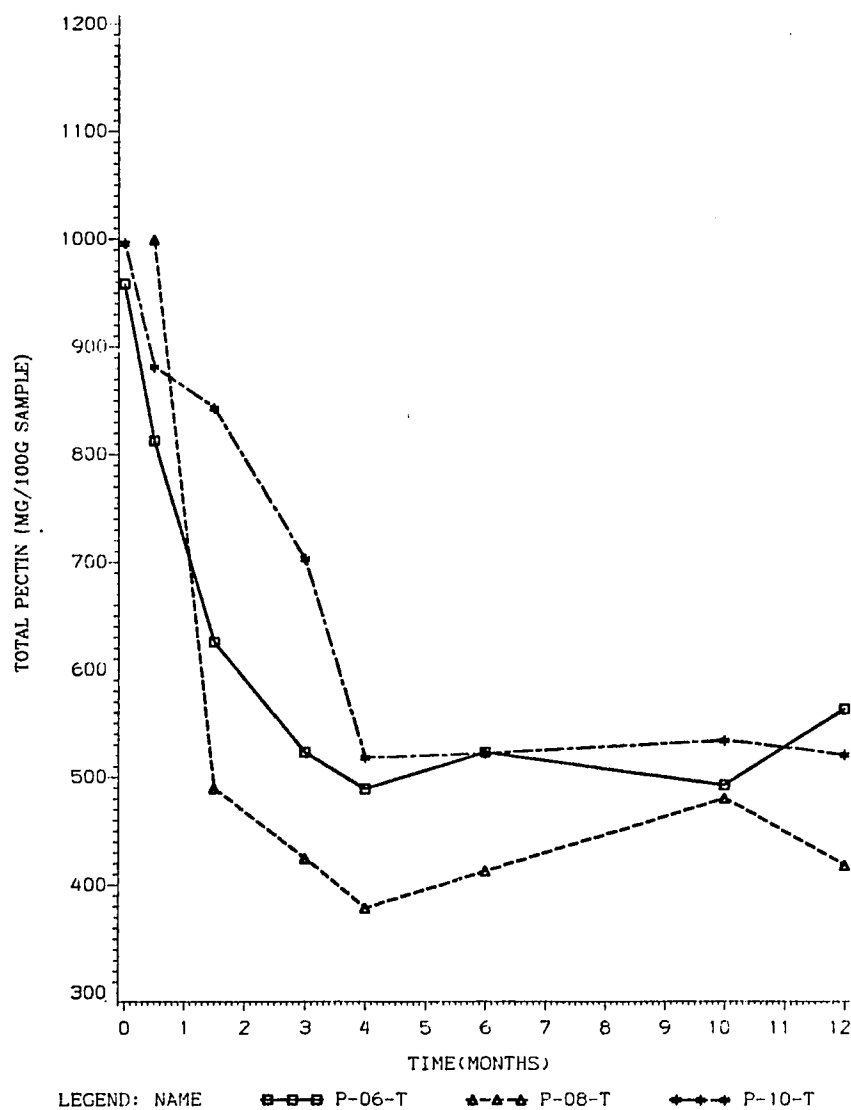
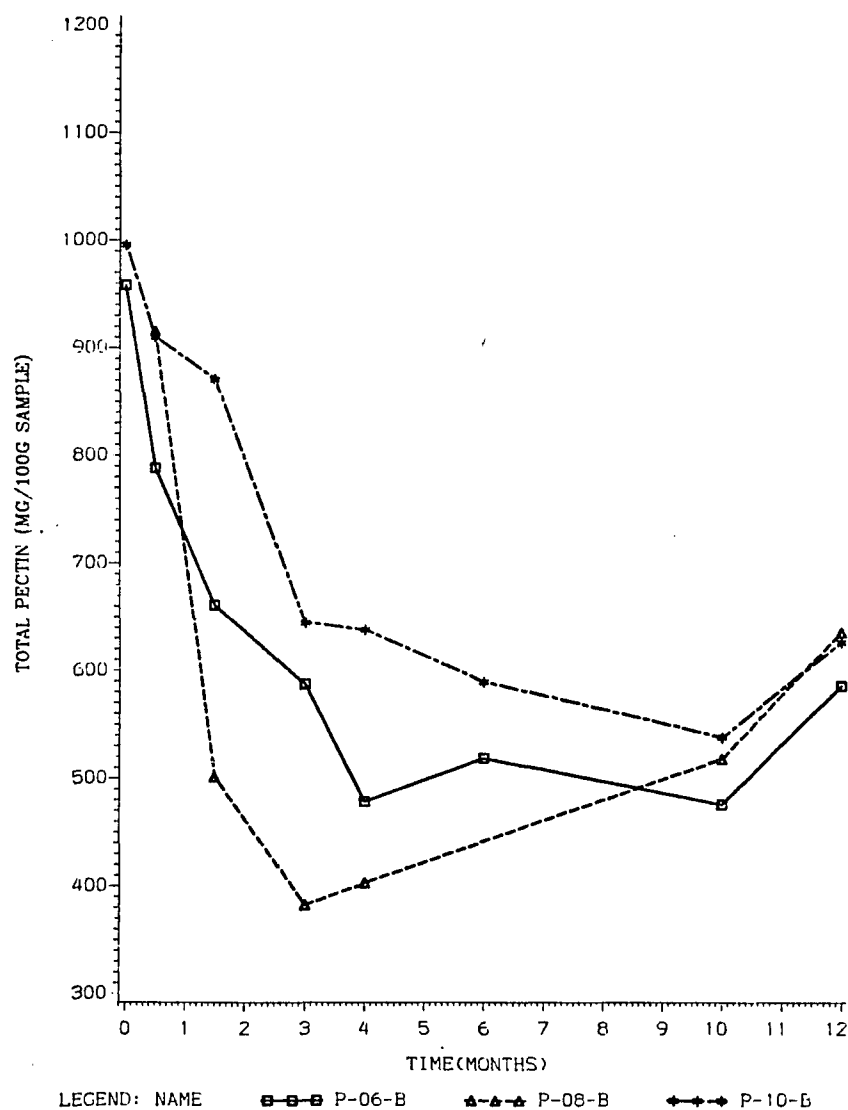


Figure 55--The effect of salt concentration (g%) on the total pectin content (mg/100g) of the bottom sections of the plastic barrel mash (First year samples).



seemed to indicate that the high concentration of salt could inhibit the overall activity of the PE enzymes (Kertesz 1939).

The total pectic substances did not change greatly in the top pepper mash samples as occurred in the bottom section pepper mash samples during the second year (Figs. 56 & 57). The total pectin increased in all bottom pepper mash samples especially in the 8% salt treatment. This increase in the total pectin might be due to increased accumulation of soluble pectin in the more liquid pepper mash of the bottom sections. The pH values of these samples might have prevented the degradation of the soluble pectin by the PG enzymes (Patel et al., 1960).

In general, the results indicated that most of the changes in the total pectic substances of the hot pepper mash samples were found to occur during the first few months of the aging process. These changes occurred more rapidly in the plastic barrels as compared to the oak barrel at all salt concentrations. The changes in total pectin were reduced to a minimum during the last six months of the first year of the aging process. The total pectin then began to increase slowly in all mash treatments throughout the duration of the aging process.

These results also suggested that most of the changes in total pectin occurred when the pH values of the pepper mash were either less than 4.2 or greater than 4.6.

Figure 56--The effect of salt concentration (g%) on the total pectin content (mg/100g) of the top sections of the plastic barrel mash (Second year samples).

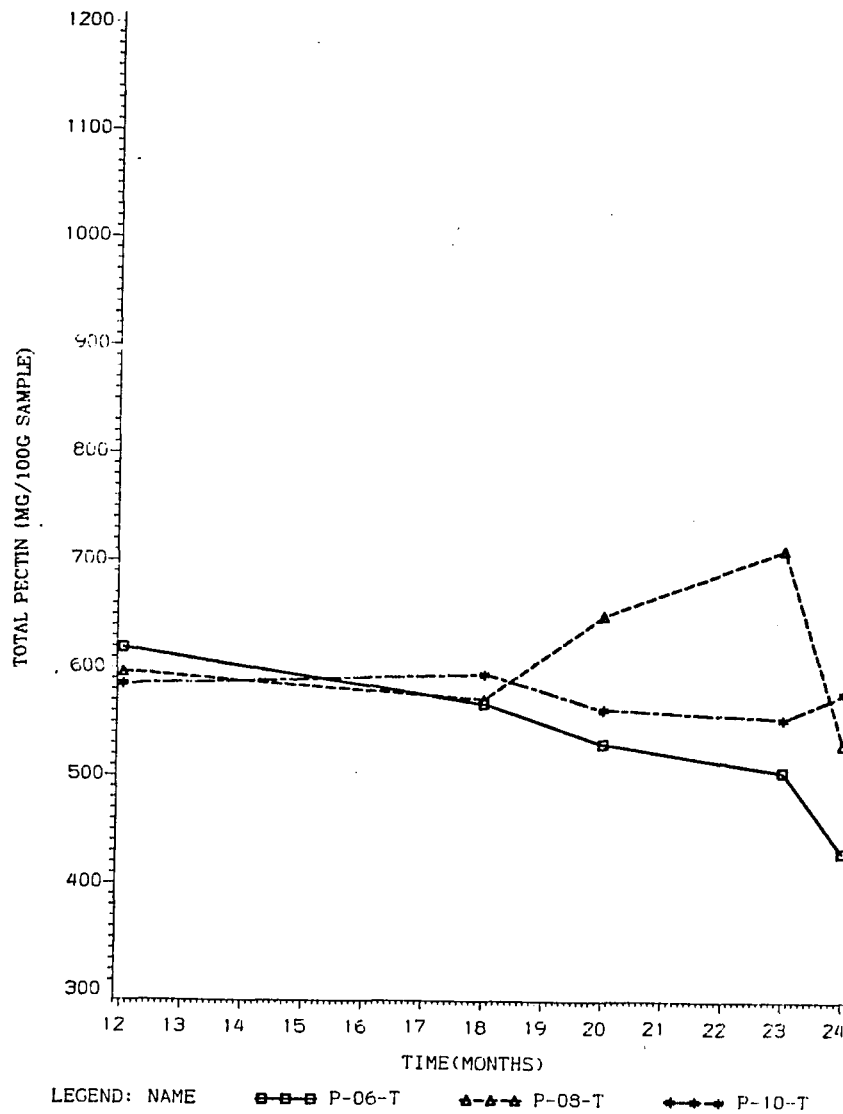
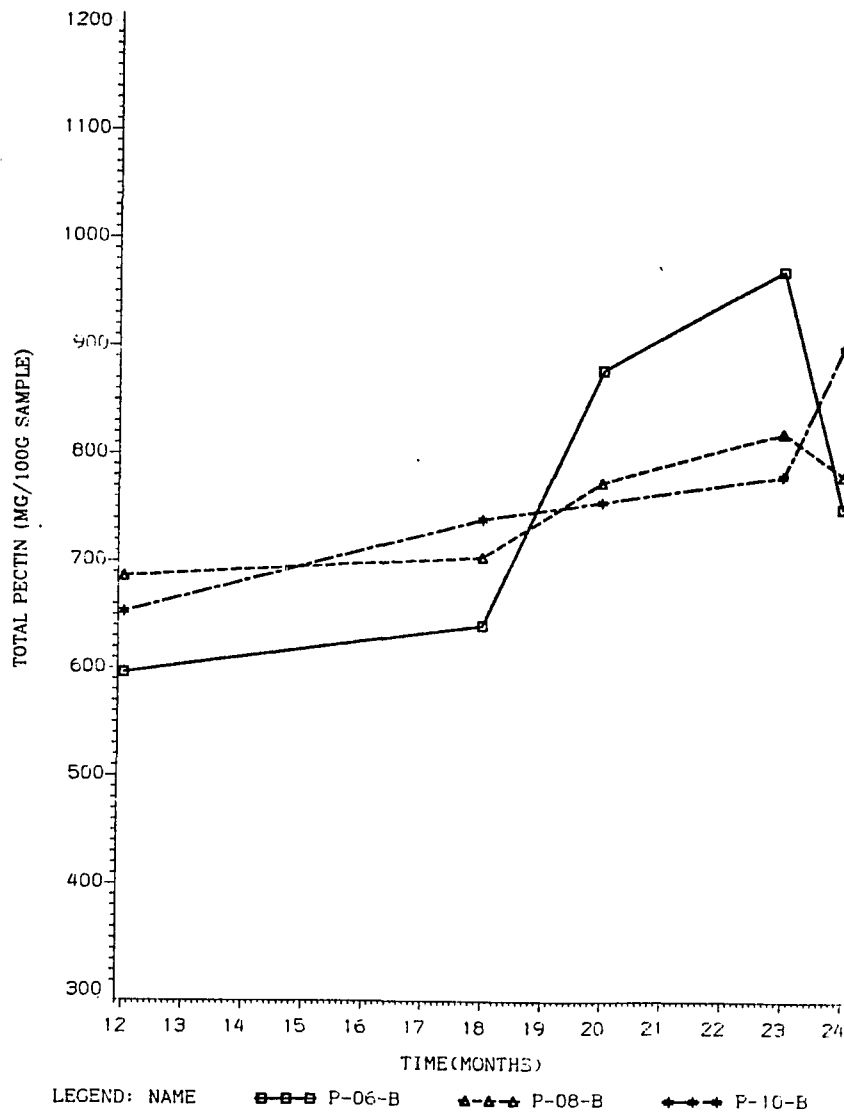


Figure 57--The effect of salt concentration (g%) on the total pectin content (mg/100g) of the bottom sections of the plastic barrel mash (Second year samples).



This seemed to indicate that the PG and PE enzymes were responsible for this degradation as the pH changed to less than 4.2 or above 4.6, respectively as was confirmed by many other investigators (Miers et al., 1967, Wagner et al., 1969, Patel and Phaff 1960).

Stability of Hot Sauce

There is limited data in the literature dealing with the factors that cause sauces to settle. When this defect occurs the volume of suspended solids contracts leaving a pale yellow serum in the upper portion of the sauce. This settling out occurs during the holding of the sauces for varying periods of time and following the transportation of sauces over long distances.

Effect of Shaking. In order to study the stability of hot sauces subjected to holding and transportation effects, shaking of the hot sauce was used to simulate the effect of these factors. Twenty bottles (2 oz.) of hot sauce were shaken for a total period of 6 hours. The number of stabilized bottles of hot sauce after each 1 hour interval of shaking were reported (Table 21). The results indicated that most of the bottles separated after 3 hr of shaking. The suspended particles in these unstable sauces are apparently not able to bind water and maintain the sauce in suspension.

Table 21. The effect of shaking on the stability of commercial hot sauce (2 oz bottle) after shaking for 6 hr.

# of bottles	# of stable bottles after shaking					
	1 hr	2 hr	3 hr	4 hr	5 hr	6 hr
20	19	13	5	4	4	1

Table 22. The effect of type of shaking and container size on the stability of three different types of sauces.

Sauce	Shaking Method	Container Size	Stability after shaking	
			3 hr	6 hr
Italian Creamy	In line	Large	Separated	Separated
		Medium	Stable	Separated
Thousand Island	In line	Large	Separated	Separated
		Medium	Stable	Separated
Hot Pepper Sauce	In line	Large	Separated	Separated
		Medium	Separated	Separated
		Small	Stable	Separated
Italian Creamy	Rotational	Large	Separated	Separated
		Medium	Separated	Separated
Thousand Island	Rotational	Large	Separated	Separated
		Medium	Separated	Separated
Hot Pepper Sauce	Rotational	Large	Separated	Separated
		Medium	Separated	Separated
		Small	Stable	Separated

Effect of container size and type of shaking. The separation of solids in the hot sauce might also be affected by the size of shipping container. For this reason three different types of commercial sauces were shaken in different sized containers for 3 and 6 hours. They were shaken using straight line and rotational motion. The results indicated that both container size and type of shaking had an effect on the stability of the sauce (Table 22). The straight line shaking was found to have a more pronounced effect than the rotational type on the stability of these sauces. The smaller the size of the container, the relatively more stable the sauce was even in the rotational shaker. This indicated that in a large size container more physical stress was placed on each suspended particle than in the small container.

The results indicated that the type of sauce itself also affected the stability. Heavy solid products such as Italian Creamy and Thousand Island dressings were found to be more stable in a medium sized container than the more dilute hot sauce. This indicated that the total solids content of the sauce was very important in product stability. This agreed with the results of Lutt (1954) on the consistency of tomato puree.

TO confirm the previous effect of the type of shaking on stability, sixty (60) 2 oz. bottles of hot pepper sauce were shaken in straight line and rotational shaking. After

3 hr of shaking, 25 out of 30 bottles were found stable in the straight line shaking compared to only 12 of 30 in the rotational shaking (Table 23). These results demonstrated that the movement of the suspended particles in each container was different in each type of shaking. The rotational type of shaking had more of an effect on most of these suspended particles than the straight line type.

Effect of container position. The hot pepper sauce might also be effected by the position of the containers during the transportation and/or storage period of hot sauce. Thus, twenty (20) 2 oz. bottles of hot pepper sauce were shaken by straight line shaking.

Ten of the bottles were placed in a horizontal position and the remainder in a vertical position (Table 24). The effect of shaking on the vertically placed bottles was mostly on the top portion of the bottle (neck) as seen in Figure 58a. However, most of the effect was distributed throughout the whole body of sauce in the horizontal bottles. The effect might be due to the movement of air bubbles in the sauce. In shaking the horizontal bottles, the air bubble moved longitudinally along the large surface of the sauce. Therefore, more suspended particles were affected and clumped together causing separation. While in the vertical bottles the air bubble moved only in the top portion of the bottle resulting in a more stable product.

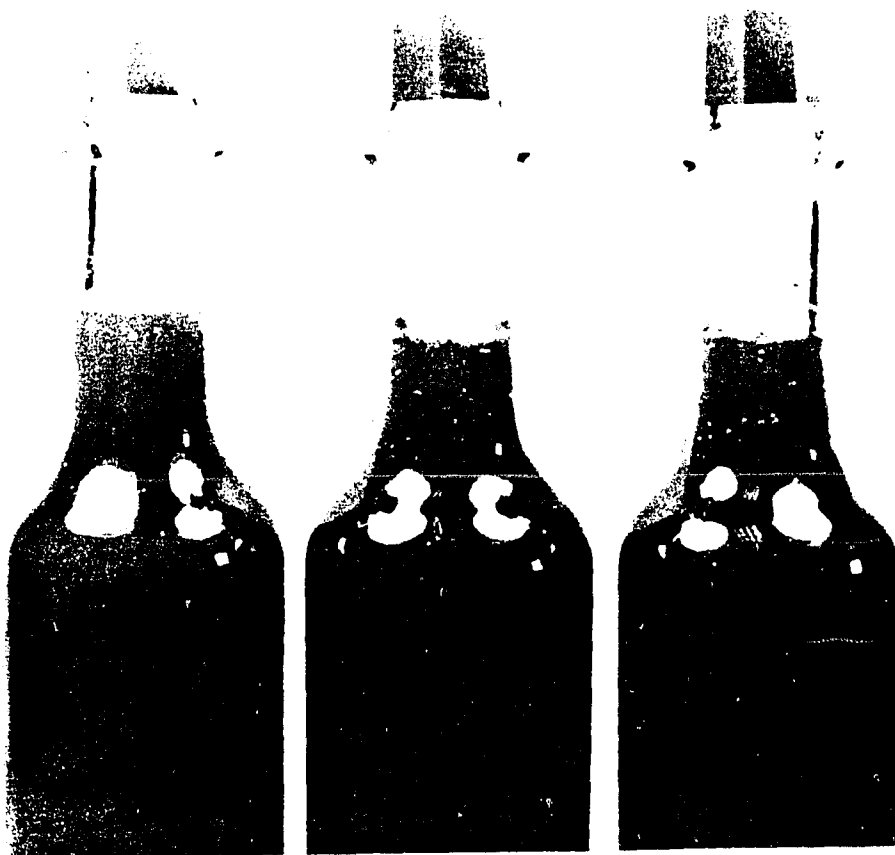
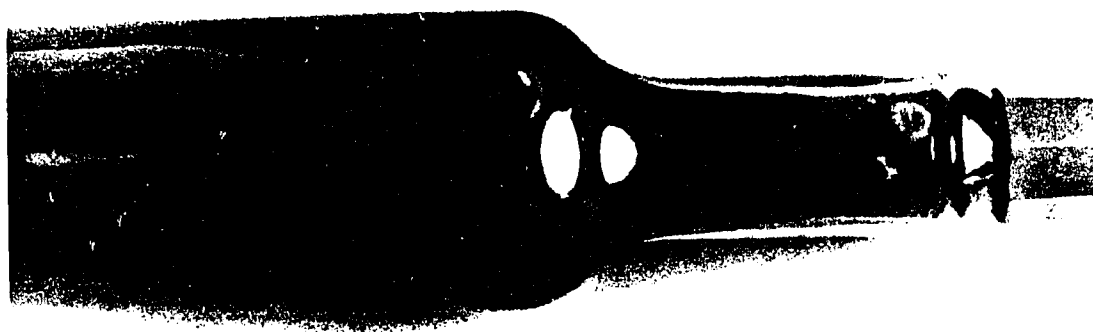
Table 23. Effect of shaking method on the stability of hot pepper sauce (2 oz. bottle) after 1 and 3 hours of shaking.

		<u># of stable bottles after shaking</u>	
		1 hr	3 hr
<u># of Bottles</u>			
In line	30	28	25
Rotational	30	25	12

Table 24. Effect of bottle position on hot pepper sauce stability during in line shaking.

		<u># of stable bottles after shaking</u>	
		1 hr	3 hr
<u># of Bottles</u>			
Horizontal	10	9	7
Vertical	10	6	0

Figure 58--The effect of shaking on the stability of hot pepper sauce. A. Vertically shaken; B. Horizontally shaken.

**A****B**

Sauce making. Hot pepper sauce was made from aged (3 yr old) pepper mash using the traditional and new rapid methods previously outlined. The viscosity and stability of the hot sauces to shaking were determined for each sauce and the results presented in Table 25. The sauce produced by the rapid method was found to be more stable during shaking than the traditional procedure used for the production of hot pepper sauce even though it had a lower viscosity. This indicated that either the viscosity of hot pepper sauce has little to do with the stability of the hot pepper sauce or there were some other factors along with the viscosity that played a role in the stability of this hot pepper sauce.

The most important value of this finding could be the possible reduction of time and energy in hot pepper sauce production. The four-week mixing period of traditional sauce preparation was reduced to only 20 min in the rapid method with the resulting production of a hot pepper sauce of the same or greater quality. This could provide a great financial savings to the hot pepper sauce industry plus a better customer acceptance because of the absence of the separation defect.

Effect of shearing. The rapid procedure for making hot pepper sauce consisted of two steps. In the first step, the mash and vinegar were mixed for 15 min using an Eberbach mechanical stirring device. In the second step, the filtered solution was sheared at very high speed (45,000

Table 25. Effect of hot pepper sauce manufacturing procedure on the viscosity and stability of hot pepper sauce.

	Viscosity (cps)	Stability after shaking
Commercial	71.0	Separated
Rapid Method	49.0	Stable

Table 26. Effect of shearing on the stability of hot pepper sauce.

	Viscosity (cps)	Stability after shaking
Nonhomogenized	16.0	Separated
Homogenized	49.0	Stable

Table 27. Effect of shaking in the stability of nonhomogenized (NH) and homogenized (H) hot pepper sauce prepared by the rapid method.

	Viscosity (cps)	# of Bottles	# of stable bottles after shaking					
			2h	4h	6h	8h	10h	35h
NH	19.5	12	4	1	0	0	0	0
H	43.0	16	16	16	16	16	16	14

rpm) for 5 min using a Virtis homogenizer. In order to study the effect of each of these two steps on the stability of the hot pepper sauce, the viscosity of the sauce was measured after each step and a number of filled bottles were shaken for 3 hr. The nonhomogenized (non-sheared) sauce was found to have a lower viscosity value and the sauce was not stable after shaking (Table 26). However, the homogenized sauce was very stable with a higher viscosity value. This indicated that the homogenization step was very important in reducing the degree of separation and increasing the hot pepper sauce viscosity. This conclusion confirms other previous studies (Luh et al., 1954; Robinson et al., 1956; Whittenberger and Nutting, 1957; Whittenberger and Nutting, 1958; Wagner and Miers 1977).

These studies indicated that the suspended particles and cellular cells of tomato sauce and juices were ruptured by the action of high speed shearing. Thus, the surface area of these suspended particles and cells were increased causing an increase in the cell's electric charges on each particle and insoluble pectin. The high electric charges and pectin helped to maintain the solid particles and cells in suspension and increased the sauce viscosity. To confirm this effect of shearing on the stability, a number of bottles of homogenized and nonhomogenized sauce were shaken for a total period of 35 hr (Table 27). The homogenized sauce was stable even after 35 hr of continuous shaking.

However, it took only 2 hr to notice the separation in the nonhomogenized sauce (Figs. 59 & 60).

The effect of shearing on the stability was also applied to the commercial product. The result was as expected, a stable product with higher viscosity was found to be associated with homogenized samples when compared to the nonhomogenized sauce (Table 28). The same stability was obtained with the new rapid method sauce even though it had a lower viscosity measurement. On the other hand, the regular commercial sauce was not stable after 3 hr of shaking even though its viscosity value was higher than the rapid method sauce viscosity.

The reason for the lower viscosity value of the stable, rapid method hot pepper sauce was due to its lower solids content (Table 29). Luh et al. (1954) found that the total solids of tomato pastes and purees always correlated with the total pectin and viscosity. However, even though the rapid method hot pepper sauce had a low solids content, it was more stable than the commercial hot pepper sauce of high solids content. This indicated that the effect of shearing on improving the stability was a result of reducing the particle size and increasing the surface area as seen under the microscope (Fig. 61). The rapid method homogenized hot pepper sauce was seen to have a large number of small particles as compared to the rapid method nonhomogenized and commercial hot pepper sauce (Figs. 61a, b, & c). These

Figure 59--The effect of shaking on the stability of:

A. Nonhomogenized hot pepper sauce after shaking for;

- 1 - One (1) hour,
- 2 - Three (3) hours,
- 3 - Six (6) hours,
- 4 - Thirty-five (35) hours.

B. Homogenized (Samples 1&2) and nonhomogenized (Samples 3&4) after shaking for;

- 1 - Six (6) hours,
- 2 - Thirty-five (35) hours,
- 3 - Six (6) hours,
- 4 - Thirty-five (35) hours.

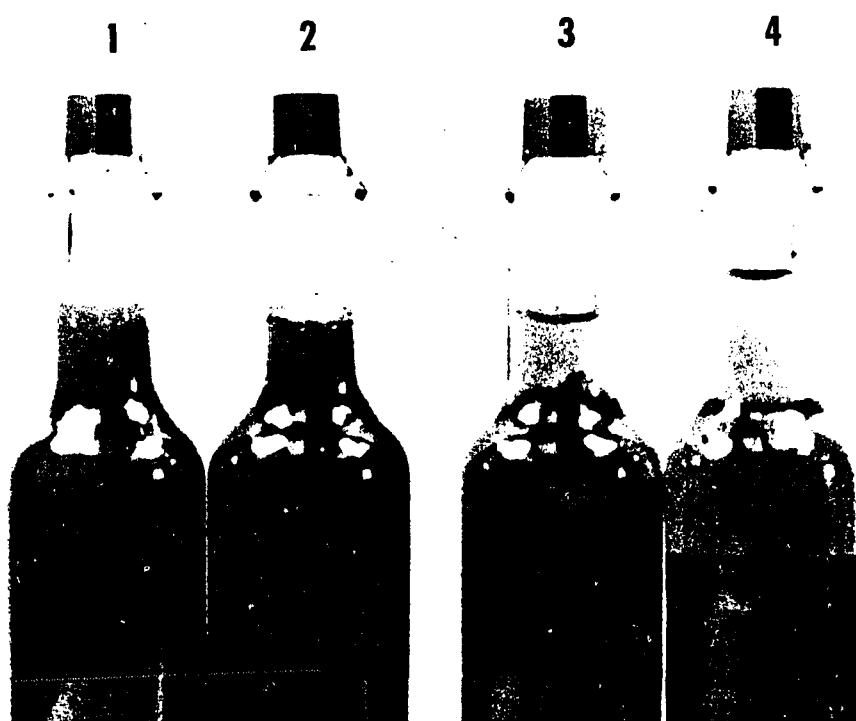
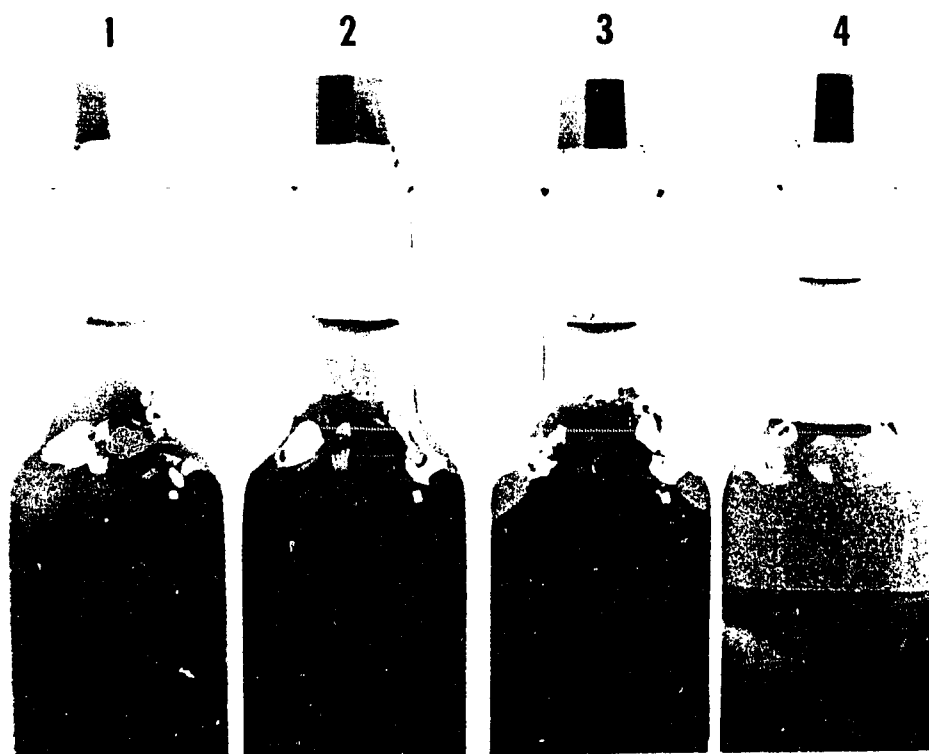


Figure 60--The effect of shaking on the stability of two different commercial hot sauces. A. Before homogenization; B. After homogenization.

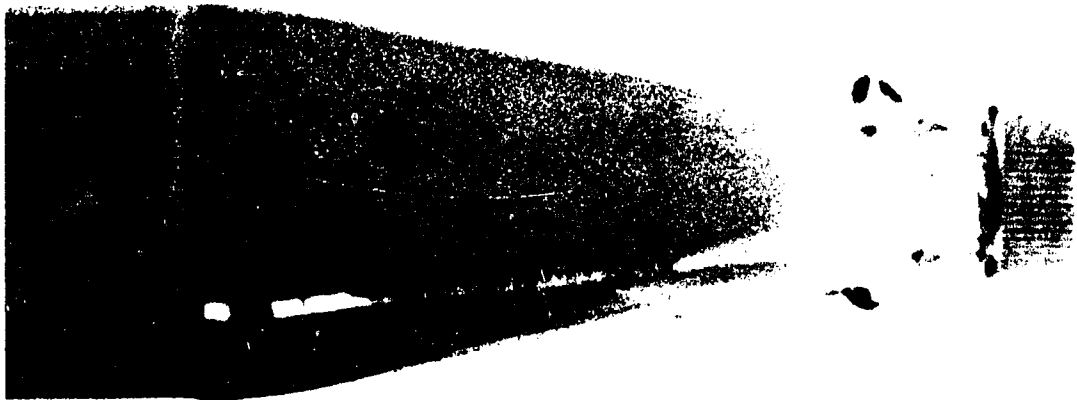
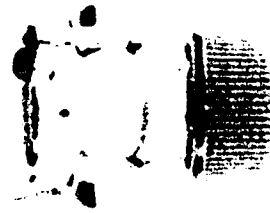
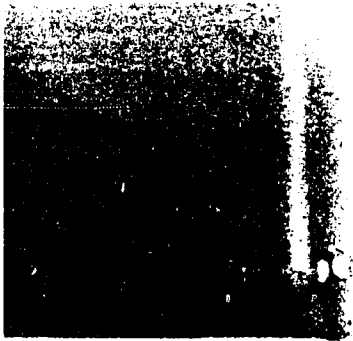


Table 28. Effect of shearing on the viscosity of two types of hot sauce after shaking for 2, 3 and 6 hours.

	Viscosity	# of Bottles	Stable bottle after shaking		
			1 hr	3 hr	6 hr
Commercial	68.0	5	5	3	0
Homogenized Commercial	83.0	5	5	5	5
Non- Homogenized	19.0	5	0	0	0
Rapid Method Homogenized	51.0	5	5	5	4

Table 29. Total solids content (%) of two different types of hot sauce.

Type	% Total Solids
Traditional	5.57
Rapid (L.S.U.)	4.43

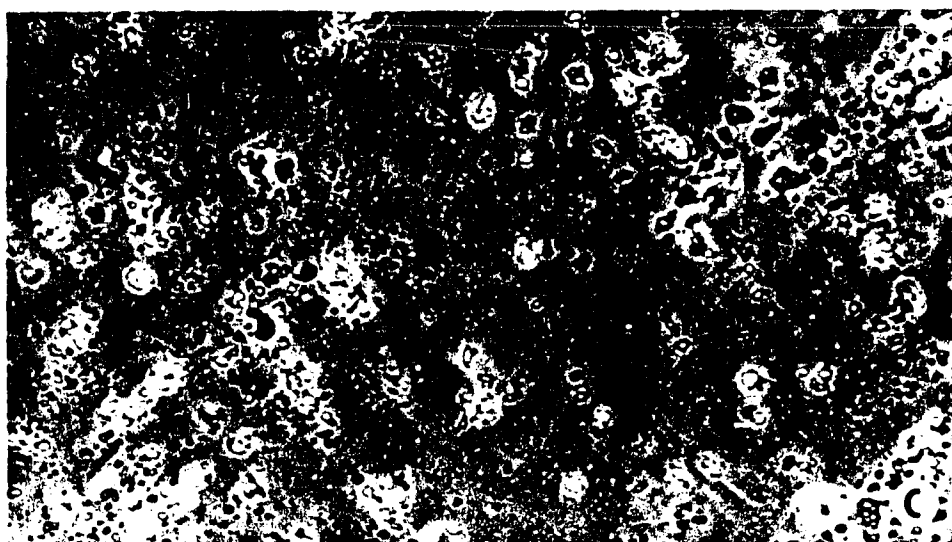
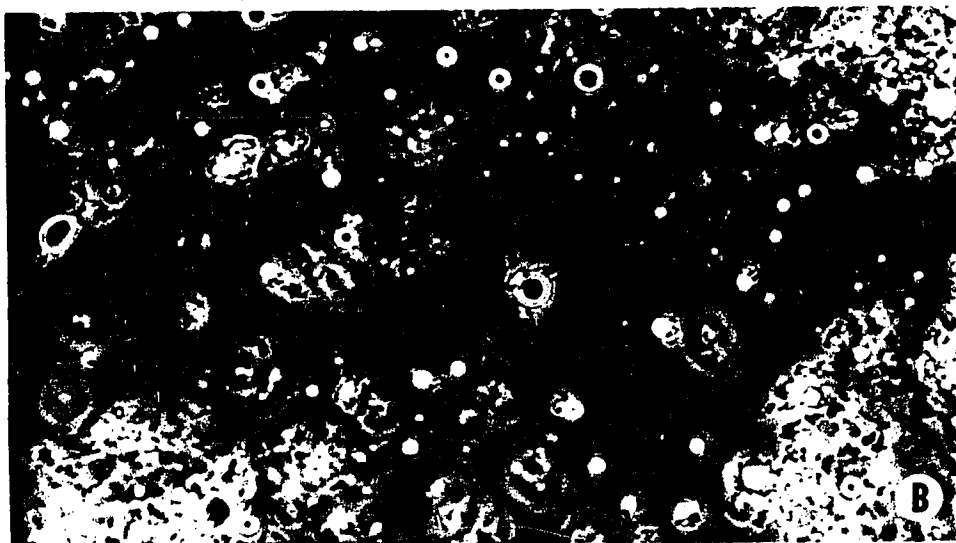
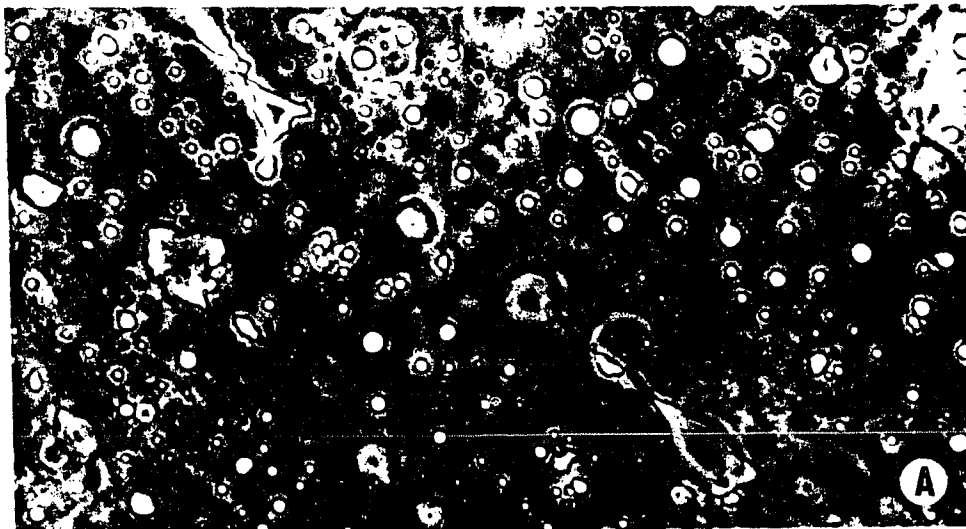
Table 30. The viscosity and stability of hot sauce made by the new rapid method after mixing the mash and vinegar for 3 days.

Treatment	Viscosity (cps)	Stability ^a
Non-homogenized	33	Separated
Homogenized	74	Stable

^aFollowing 35 hr of shaking

Figure 61 Light micrographs of

- A: commercial hot pepper sauce
- B: rapid method non homogenized hot pepper sauce
- C: rapid method homogenized hot pepper sauce



small sized particles were distributed throughout the sauce binding most of the water and lowering the opportunity for separation.

In order to produce a stable hot pepper sauce with a high percent of total solids, another step was added to the rapid procedure of making hot pepper sauce. The mash and vinegar were mixed continuously for 3 days before applying the 2 step rapid procedure. By doing this, the viscosity of the homogenized hot pepper sauce was improved along with retaining its improved stability (Table 30). This indicated the importance of the total solids and the size of particles on the viscosity and stability of hot pepper sauce.

Effect of pectin. In order to test the effect of pectin content on the stability of hot pepper sauce, the hot pepper sauce was made from each top or bottom section of the oak and plastic barrels using the rapid procedure. The viscosity and stability of each sauce was determined against the shaking procedure and are presented in Tables 31-33. The more stable hot pepper sauce with high viscosity was found to be related to the high content of total pectic substances as found in Tables 11-13. The same conclusion could be drawn between the top and bottom sections of 6 and 8% salt barrels and the resulting preparation of hot pepper sauce. The bottom sections which are richer in pectin produced a more stable hot pepper sauce than sauces made from the top layer of mash. On the other hand, the 8% salt

Table 31. Effect of location of pepper mash in oak and plastic barrels on the viscosity and stability of hot sauce before and after homogenization mashes from sample #11.

		Viscosity (cps)		Stability*	
	Phase	Unhomogenized	Homogenized	Unhomogenized	Homogenized
0-6-T	S	22	49	-4	+3, -1
0-6-B	S	13	30	-4	+1, -3
P-6-T	S	8	31	-4	+3, -1
P-6-B	L	XX	XX	XX	XX
0-8-T	S	17	35	+1, -3	+3, -1
0-8-B	S	17	31	+1, -3	+3, -1
P-8-T	S	14	34	-4	+3, -1
P-8-B	L	XX	XX	XX	XX
0-10-T	S	11	26	-4	+2, -1
0-10-B	SL	12	30	-4	+3, -1
P-10-T	SL	11	21	-4	+2, -1
P-20-B	L	XX	XX	XX	XX

X = # of shaken bottles was 4 for each trial

XX = No sauce was made

S = Solid

L = Liquid

SL = Half solid, half liquid sample

Table 32. Effect of location of pepper mash on oak and plastic barrels on the viscosity and stability of hot sauce before and after homogenization mashes from sample #12.

		Viscosity (cps)		Stability	
	Phase	Unhomogenized	Homogenized	Unhomogenized	Homogenized
0-6-T	S	22	42	-4	+2, -2
0-6-B	SL	15.5	34	-4	+3, -1
P-6-T	S	13	30	-4	+2, -2
P-6-B	L	XX	XX	XX	XX
0-8-T	S	10	29	-4	+3, -1
0-8-B	S	8.5	33	-4	+4
P-8-T	S	14	29	-4	+3, -1
P-8-B	L	XX	XX		
0-10-T	S	18	29	-4	+3, -1
0-10-L	XX	XX	XX	XX	XX
P-10-T	S	17.0	22	-4	+3, -1
P-10-B	L	XX	XX	XX	XX

X = Number of shaken bottles were 4 for each case

XX = No sauce was made

S = Solid

L = Liquid

SL = Half solid, half liquid sample

Table 33. Effect of location of pepper mash (top or bottom) in oak and plastic barrels on the viscosity and stability of hot sauce before and after homogenization mashes from sample #13.

		Viscosity (cps)		Stability	
	Phase	Unhomogenized	Homogenized	Unhomogenized	Homogenized
0-6-T	S	14	33	-4	+1, -3
0-6-B	SL	19	37	-4	+3, -1
P-6-T	S	6.5	21	-4	+2, -2
P-6-B	L	XX	XX	XX	XX
0-8-T	S	14.5	35	-4	+3, -1
0-8-B	S	14.5	36	-4	+3, -1
P-8-T	S	13.5	34	-4	+2, -2
P-8-B	L	XX	XX	XX	XX
0-10-T	S	9	25	-4	+2, -1
0-10-B	L	XX	XX	XX	XX
P-10-T	S	7	24	-4	+2, -1
P-10-B	L	XX	XX	XX	XX

X = Number of shaken bottles were 4 for each case

XX = No sauce was made

S = Solid

L = Liquid

SL = Half solid, half liquid sample

mash was found to produce the most stable hot pepper sauce. This was due to its high pectin content as previously indicated. However, no sauce could be made from the liquid mash at the bottom of the barrel with its lower percentage of total solids. Thus, a simulated condition was prepared utilizing the substitution of 10% of the required vinegar by the same amount of liquid mash (obtained from the bottom section) in order to provide the benefit of the high amount of water soluble pectin. The viscosity and stability of this sauce can be seen in Table 34. These results supported further the previous conclusion of the important role of pectic substances in the stability of hot pepper sauces and tomato products.

Effect of pectic enzymes. The pectic enzymes, especially the PG enzyme, were very important in determining the total amount of pectic substances in hot pepper sauces and tomato juice. The PG enzymes were found to be responsible for lowering the consistency and increasing the rate of settling in tomato juices and sauces (Wagner et al., 1975). The same enzyme (PG) was added to aged hot pepper mash four weeks before preparing the hot pepper sauce by the rapid method. The viscosity of the PG treated hot pepper sauce was low as compared with the same mash without the enzyme (Table 35). This indicated that the PG enzyme plays an important role in the reduction of the viscosity of hot pepper sauces as is found also in many other products (Luh

Table 34. Effect of the liquid mash total pectin on improving the viscosity and stability of hot sauce.

	Viscosity (cps)	Stability after shaking for 6 hr
Solid Mash	34	Stable
Solid + Liquid Mash **	56	Stable

** = 10% of the required vinegar was substituted by same amount of liquid mash

Table 35. Effect of pectinase enzyme treatment on the viscosity and stability of hot sauce.

	Treatment	Viscosity (cps)	Stability ^a
Treated with Pectinase Enzyme	Non- Homogenized	6.0	Separated
	Homogenized	9.5	Separated
No Enzyme Treatment	Non- Homogenized	22.0	Separated
	Homogenized	39.0	Stable

^aFollowing shaking for 25 hr

et al., 1956; Patch et al., 1960; Becker et al., 1968; Biggs and Pollard., 1970; Foda and McCullum, 1970; Wagner et al., 1969).

CHAPTER V

SUMMARY

Most of the changes in the chemical characteristics of hot pepper mashes were found to occur during the first year of aging. These changes occurred more rapidly in the plastic barrels as compared to oak barrels. The position of the mash within each barrel also affected the aging process because of the differences in the pH and salt content at the different sites. The bottom area location of the hot pepper mashes always had higher salt concentrations, higher acidity and greater amounts of pectic substances along with lower pH than the top section samples of hot pepper mashes.

Upon examination of the dates, it became apparent that the 8% salt concentration of hot pepper mash aged in the oak barrel was radically different from all the other treatments. This hot pepper mash had an intermediate pH value (approximately pH 4.3) which was determined to be less desirable (inhibitory in activity) for the hot pepper mash pectic enzymes. Therefore, greater amounts of pectin were observed in this hot pepper mash than found in all the other treatments. Thus, an acceptable hot pepper sauce could be made from this mash which would possess a high viscosity and relatively good stability against any type of shaking activity.

The preliminary analysis indicated that the stability of the hot pepper sauce was affected by the size and position of the container bottles when the containers were shaken for a specified period of time.

Furthermore, the amount of pectic substances and size of the suspended particles were found also to greatly affect the stability of hot pepper sauce.

In order to minimize the degradation of pectin by hot pepper pectic enzymes, the pH of the mash must be maintained at approximately 4.4 with an intermediate level of salt (7-8%). On the other hand, when a Virtis homogenizer was used to break down and increase the surface area of the suspended particles increases in the viscosity and stability of the hot pepper sauce occurred.

The utilization of these factors led to the development of a new procedure for preparing a hot pepper sauce. In addition to the possibility of shortening the manufacturing time by the new procedure, the new hot pepper sauce had a higher viscosity and did not separate even after 35 hr of continuous shaking when compared to only 3 hr shaking with the original commercial products. Adaption of this method to large scale production can be expected (if necessary).

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