PN-ABK-235
75201

C5-058

FINAL

Agricultural Research Organization

The Volcani Center

Final Report

Submitted to AID-U.S. Cooperative Development Research Program between Israel and Costa Rica

Project Title: Development of Shelf Stable Fish, Poultry and Other Meat Products Through Energy Saving Fermentative Processes

Project # C-5058 Subject # DPE 5544-G 53 6035

Report Submitted by Samuel Angel and Eliana Mora P.

Principal Investigator, Dep't. of Food Science, ARO, Israel and Co-Principal Investigator, CITA, University of Costa Rica, San Jose, Costa Rica

August 10, 1991

OCT 17 1991

Introduction

This project was undertaken to produce a shelf stable fish-meat product from underutilized fish and meat sources. Another aim was to use as little heat as possible to produce this product. It would be a completely processed product requiring no refrigeration to be eaten without further preparation. It would be nutritious and could help combat protein malnutrition in lesser developed or developing countries.

In Germany fermented sausages are called rohwurst because they are not cooked. The processing temperature is around 20 centigrade. The raw materials are pork and beef and pork fat. The production of rohwurst involves fermentation by bacteria as a result of which organic acids , paricularly lactic acid are produced and the pH is reduced to about 5. (Rodel and Klettner, 1978). Acid production influences the development of firmness and this occurs around pH 5.3, near the gel point of the salt extracted meat protein. After the protein forms a gel, with consequent rapid increase in firmness, subsequent firmness increases with dehydration. The moisture must come down to between 20 and 40% of the starting weight. The pH of around 5 obtained by the lactic acid production is also low enough to prevent production of pathogenic bacteria. (Baird-Parker and Freame, 1967, Collins-Thompson et al, 1975).

A reduction in pH prevents proteolytic and lipolytic breakdown in the meat. Drying which takes place after gel formation lowers the water activity or Aw and this also prevents microbial growth and increases the storage life of the sausage (Laiots, 1981).

An alternative way to lower the pH in meat is to use GDL or gclucono delta lactone - a cyclic sugar derivative which yields gluconic acid upon contact with moisture. However the USDA limits the amounts that can be used in meat so that it makes it difficult to lower the pH sufficiently. Besides that using GDL presents other logistical problems and it may be tricky to use. One of the problems is the rapid decrease in pH on contact of GDL with moisture. One solution was encapsulated GDL. This was followed by encapsulated citric acid. Lower levels of citric acid are needed to achieve the same pH as obtained with GDL. After encapsulated citric acid, encapsulated lactic acid was developed to match lactic acid produced by fermentation. The encapsulated acids are produced by coating solid granules with hydrogenated vegetable oils or mono and di-glycerides. These solid fat coatings release the acids upon melting when heat is applied. Graves (1988) patented a new encapsulate that does not require heat to release the acidulate.

The coating is water soluble and dissolves slowly. Release time is 1-6 hours at low temperature.

The original title of this project emphasized "Development of Shelf Stable Fish and Meat Products" and the second aim was "through Energy Saving Fermentative Processes". After the start of the project the authors realized that the long time required for fermentation of meat products could make the product too expensive. It was therefore decided to compare fermentation with acidulation. Chemical acidulents can however cause a too rapid a release of acid under certain conditions or the release rate for one kind of meat may not be suitable for another. If due to improper release the protein is denatured too rapidly this can result in soft mushy texture or a grainy non integrated texture. According to Graves(1988) successful use of encapsulates requires a study of the formulation processing parameters. Among these are the correct concentration of acids to use - especially when one is using fish and meat combinations which of themselves present a problem of processing parameters in a rohwurst type of sausage.

As a result of the decision to incorporate chemical acidulents into the project a great deal of time was spent testing acidulent concentrations to use and their effect on pH development water loss and texture of the various fish meat combinations.

The development work was equally divided between Costa Rica and Israel with the bulk of the taste panel work carried out in Costa Rica where the target population resides.

Materials & Methods

The materials and methods for the various experiments which were carried out in Costa Ric in 1990-1991 and which have not previously been reported are included in this report.

I. Composition of the sausages tested:

Formulation	Pork	Beef	Fish Mince	Water
0 % Fish	15.8	72.4	0	11.8
25% Fish	17.2	53.2	17.8	11.8
50% Fish	18.0	35.1	35.1	11.8
75% Fish	18.9	17.3	52.0	11.8
100% Fish	19.5	0	68.7	11.8

The fish used were either inexpensive sailfish or underutilized "chatarra"
which are a mixture of various small bony fish from by-catches.

Sausage Preparation:
The sausages were prepared in the CITA pilot plant. The original formulations of the 5 components outlined previously were modified as a result of the recommendations of the taste panel. Methods of preparation of the sausages have been described in previous progress reports on the project.

II. Types and Quantities of the Condiments Used in the Sausage

	Percent
Common Salt	2.8
6.5% Cure	176 ppm
"Tourist" sausage spice mix	1.6
"Cocido" salami spice mix	0.95
Modified "Touriste" Salami spice mix	1.05
Encapsulsulated citric acid	0.7-2.3
Encapsulated lactic acid	0.6-1.2

III Processing Temperatures and Humidities

Time (hrs)		Temperature (°C)		Relative Humidity
Stepwise	Total	Dry Bulb	Wet Bulb	(%)
1	1	32.2	32.2	100
1	2	43.3	37.8	70
1	3	54.4	46.1	66
0.5	3.5	65.5	57.2	63
0.5	4.0	---	---	--

IV. Chemical Analyses :

150 grams of meat or fish was blended and aliquots taken for the various analyses in triplicate. The following analyses were performed:

1). Proximate composition according to AOAC, 1980.
2). pH
3). Caloric content- using a bomb calorimeter. 1 gram sample was placed in the bomb and submerged in water. The sample was ignited at low pressure saturated oxygen. The difference in temperature before and after combustion was measured.
4). Peroxide value was measured according to Koniecko(1979).
5).Water Activity was measured with a Luft hair hygrometer according to Rodel et al (1979) and Kopper (1989).

The following table shows the tests carried out and on what material:

Analyses	Fish flesh	Surimi	Beef Meat	Final Product
Humidity	X	X	X	X
Fat	X	X	X	X
Protein	X	X	X	X
Ash	X	X	X	X
Peroxide value				X
pH	X	X	X	X
Caloric Value				X
Water Activity	X	X	X	X

V. Microbiological Analysis:

The following table lists the analyses carried out:

Analysis	Frozen surimi	Beef Meat	Final product
Total count	X	X	X
Total coliforms	X	X	X
Fecal coliforms	X	X	X
Staphylococcus aureus (detection)	X	X	X
Enterococcus sp.	X		
Salmonella (presence)			X
Lactobacillus sp. (count)			X

VI. Organoleptic Analysis:

The sausages produced in the pilot plant at CITA were compared to similar products on the market in Costa Rica. Exactly the same type of product was not available.

A.

A study was carried out in the Laboratory for Sensorial Analysis at CITA with a taste panel of 7 persons who were chosen at random from the staff at CITA. These people had no previous training. Five taste sessions were hel

Each tasting was carried out in three steps. The first step consisted of tasting the product or products that were produced at CITA. Each panelist noted his
total impression in decending order on an especially prepared form for this study. In the second step there was a session where the panelists exchanged ideas and made comments on the basis of the written impressions. In the third step the panelists chose the preferred products and gave recommendations for product improvement. In the following session only the products chosen in the previous session were presented.

B.

Consumer panel tests were carried out in 110 households distributed according to social class or economic status as follows:

Lower class 10.9%
Lower middle class 36.4%

Total 46.4%

Middle class 40.0%
Upper middle class 12.7%

Total 52.7%

The following parameters were tested.

a) Types of formulation (25 and 50% fish content) in the sausages.

b) Level of information the taster was given; those that were *aware* the sausage contained fish and those that were *not aware* the sausage contained fish.

Accordingly the samples were divided into the following percentages among the households:

	Percent fish in sausage	
	25 %	50%
number of households *not aware* the sausages contained fish	25	29
number of households *aware* the sausages contained fish	29	27

Results

Proximate Analyses:

The proximat analysis of the sailfish were given in a progress report presented earlier.

The proximate analysis of the mechanically deboned "chatarra" fish flesh and of the stabilized fish mince are presented in Table 1:

Table 1

Lot No.	Humidity %	Fat %	Protein %	Carbo-hydrates
Fish 1	81.1±0.3	1.0±0.2	18.3±0.3	0
Mince	77.5±1.6	0.5±0.2	14.1±0.5	7.8
Fish 2	80.4±0.2	0.3±0.1	18.9±0.3	0.5
Mince	75.2±0.2	0.2±0.1	16.8±0.2	7.8
Fish 3	80.1±0.2	0.2±0.1	18.2±0.4	1.5
Mince	78.2±0.3	0.2±0.1	14.4±0.2	7.3
Fish 4	82.7±0.2	0.6±0.2	16.7±0.2	0
Mince	78.1±0.4	0.2±0.1	14.5±0.5	7.3
Fish 5	81.8±0.5	1.3±0.7	15.6±0.2	1.3
Mince	81.3±0.6	0.8±0.3	12.0±0.3	5.8

Note: ± values represent the standard error of the mean

Table 2 shows the proximate analysis of the beef meat.

Table 2

Lot no.	Humidity %	Fat %	Protein %	Carbo-hydrates
1	71.3±4.5	4.3±2.7	20.5±1.1	3.8
2	71.0±2.6	2.9±0.8	23.8±0.5	2.2
3	69.9±0.6	5.8±0.2	19.1±0.6	5.2
4	72.3±1.0	5.5±0.4	20.5±0.7	1.5

The proximate analysis of a final sausage product is shown in Table 3.

Table 3

	50% Fish Sausage (0.9% lactic acid acidification)	25% Fish Sausage (0.95% lactic acid acidification)
	Percent	Percent
Protein	18.5	19.6
Fat	22.6	23.8
Carbohydrates	6.5	4.1
Ash	4.6	4.8
Moisture	47.6	47.8

Microbial Analyses:

The microbiological quality of the stabalized fish mince is presented in Table 4:

Table 4

Analysis	Lots				
	#1	#2	#3	#4	#5
Ttl Count/g	1.5E6	5.4E1	8.1E3	7.3E4	8.1E3
Ttl Coliforms per gram	21	23	3	24	3
Fecal coliforms per gram	3	3	3	3	3
Staphylococcus aureus per gram	neg	neg	neg	neg	neg
Enterococcus	93	28	21	460	93

Note: 1E3=1000

The microbiological quality of the beef flesh is presented in Table 5.

Table 5

Analyses	Lots #1	# 2	#3	#4
Total Count/gram	5.2E4	1.0E5	3.9E4	6.0E5
Total coliforms/g	1.1E3	9.1E2	1.0E3	1.2E3
Fecal coliforms/g	15	16	22	32
Staphylococcus aureus / gram	neg	1E-1	1E-1	neg

Index to Figures showing pH reduction, weight loss or shear force of the fermented and acidulated sausages during processing. Percentages of fish in the sausages such as 25%, 33% etc. are the total initial fish weight divided by the total weight of the other meat or meats., in the sausage.

Figures 1-4 show pH reduction and percent weight loss or shear force of beef sausages and sailfish or silvercarp fish sausages with pork, beef and turkey, following bacterial fermentation.

Figures 5-9 show pH reduction, percent weight losses and shear force of beef sausages and silvercarp and "chatarra" fish sausages following citric acid acidulation.

Figures 10-13 show pH reduction and percent weight loss or shear force in 50, 44 and 25% "chatarra" and silvercarp sausages with pork, beef and turkey following acidulation with citric acid.

Figure 14 compares pH reduction and percent weight loss of beef fermented and 0.65% citric acid acidulated sausages.

Figures 15-17 show pH reduction and percent weight loss of 44% silvercarp fish sausage with pork, beef and turkey.

Figures 18-21 show pH reduction and percent weight loss of beef and "chatarra" fish sausages acidulated with lactic acid.

Figures 22-25 show pH reduction and percent weight loss of 50% and 25% "chatarra" fish sausage with beef following lactic acid acidulation.

Figures 26-27 show pH reduction and percent weight loss in beef and 50% sailfish sausage following 7% lactic acid acidulation.
Figures 28-29 show pH reduction and percent weight loss in 33% sailfish sausage following acidulation with 3% lactic and 0.7% citric acids.

Figures 30-31 compare pH reduction and percent weight loss of 50% sailfish sausages acidulated with 0.5% citric acid, 1% lactic acid and 1% GDL (glucono delta lactone).

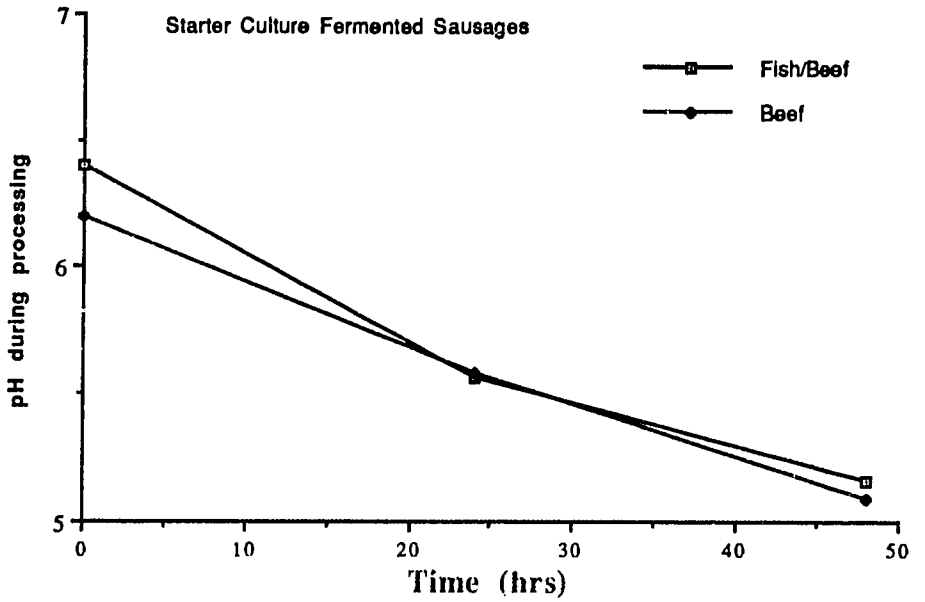


Figure 1. pH reduction in 50% sailfish (Costa Rica) and beef sausages during 48 hours of fermentation with starter culture.

Figure 1 shows the starting pH was 6.4 in the sailfish sausage and this was slightly higher than for the beef sausage (6.2). This relationship continued for the entire 46 hours of fermentation. The final pH was 5.09 for the beef and 5.16 for the sailfish sausage.

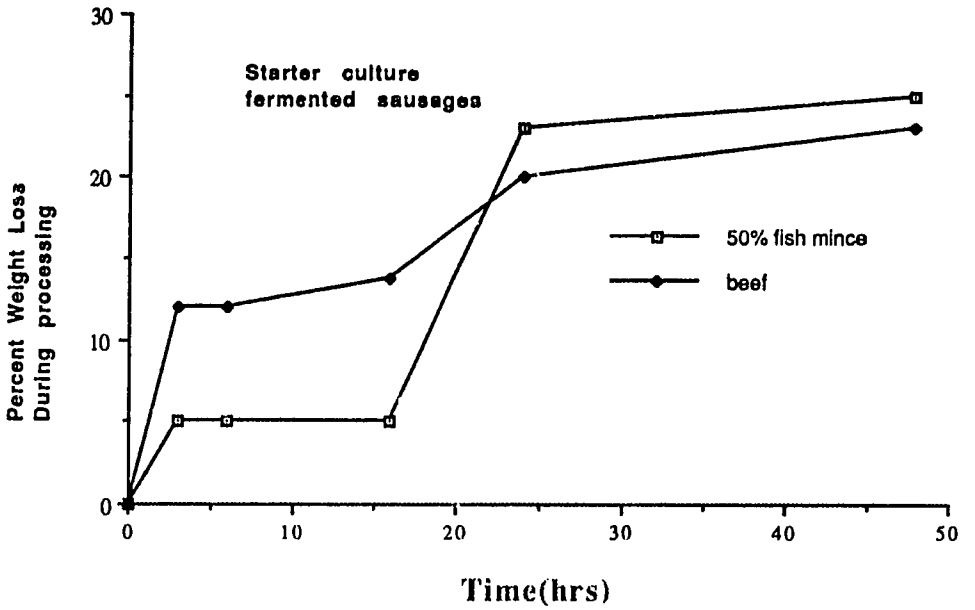
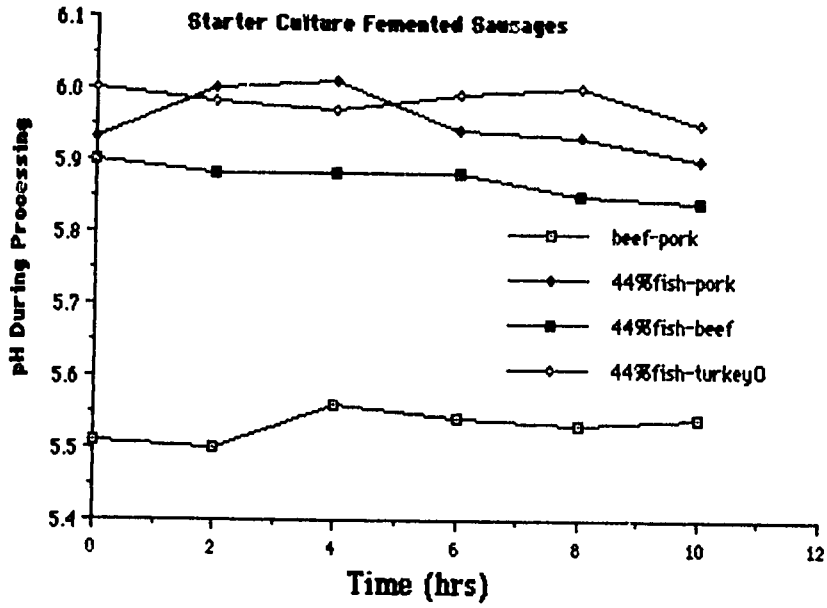


Figure 2. Weight loss in 50% sailfish and beef sausages during 48 hrs fermentation.

In Figure two the weight loss which started out lower in the 50% sailfish sausage was 25% as against only 23% for beef at the end of the fermentation period of 48 hours.



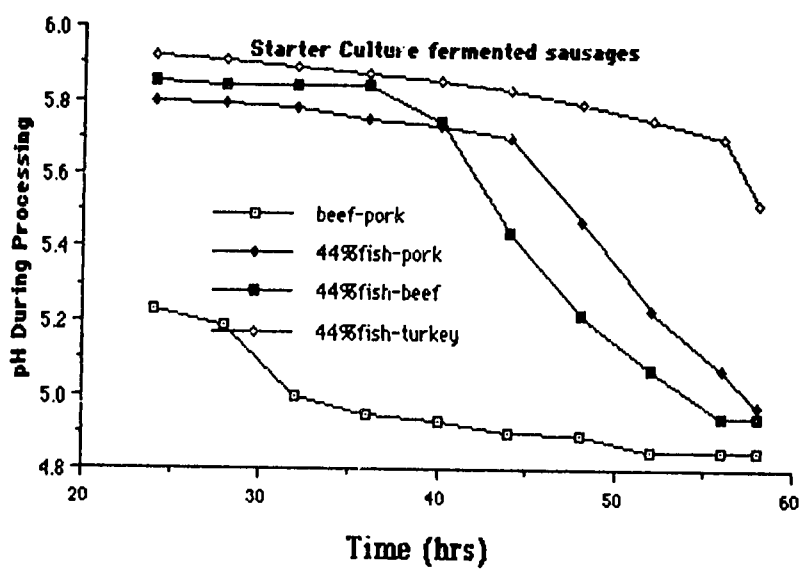


Figure 3. pH reduction in 44% silvercarp fish (Israel) and silvercarp-pork, beef and turkey sausages during 56 hours of fermentation.

sausages during 56 hours of fermentation.

Figure 3 shows the starting pH for the silvercarp fish sausages with pork, beef and turkey were higher than for the beef sausage. The final fish-turkey sausage pH did not descend beyond 5.52 while fish-pork and fish-beef sausage pH started to fall after 40 hours andreached pH 4.97 and 4.94 respectively. After 28 hours of fermentation the pH of the beef sausages remained above 5 and then started to fall reaching 4.85 after 56 hrs of fermentation.

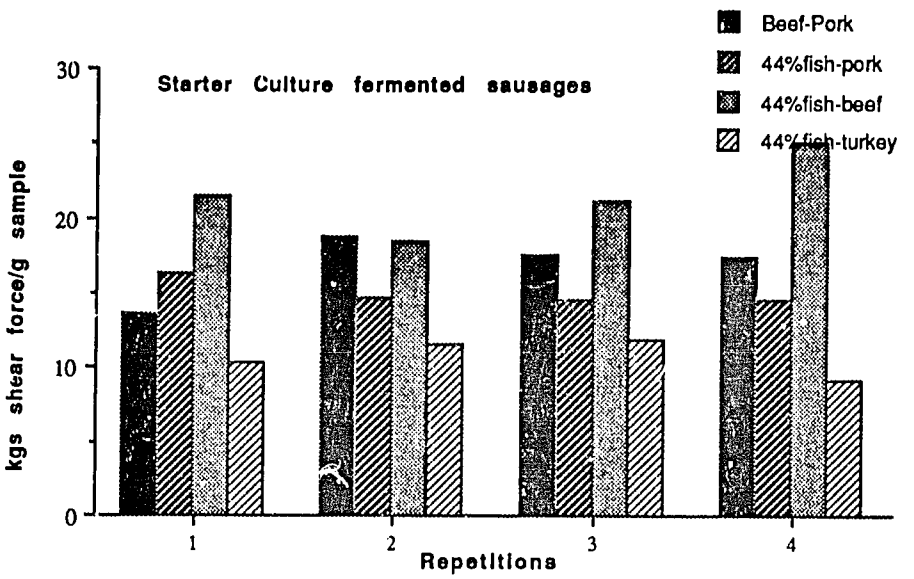


Figure 4. Kilograms force required to shear fermented 44 % silvercarp (Israel) fish-pork, beef and turkey sa usages after sausages after 58 hours of fermentation.

Figure 4 shows the hardness of the various sausages. The fish-beef sausage was the firmest while the silvercarp-fish turkey sausage was found to be the softest.

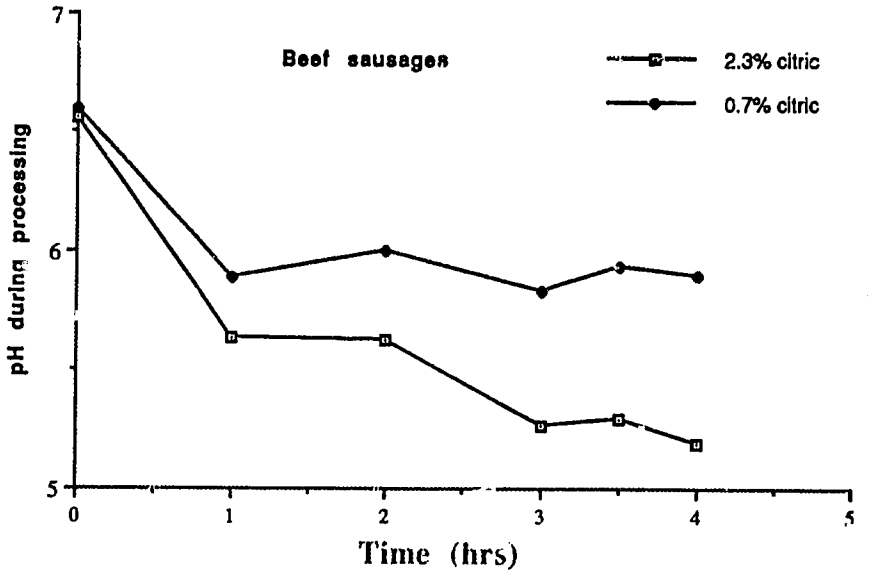


Figure 5. pH reduction in beef sausages following acidulation with 0.7 and 2.3% citric acid

Figure 5 shows that in the beef sausage, containing no fish the pH of the 0.7% citric acid treated sausages which had started out at 6.6 was reduced sharply to 5.88 after one hour and remained at essentially that level after 4 hours. The pH of the 2.3% citric acid sausage also was reduced sharply from 6.56 to 5.6 after one hour but in this sausage the pH continued falling and reached 5.19 after 4 hours.

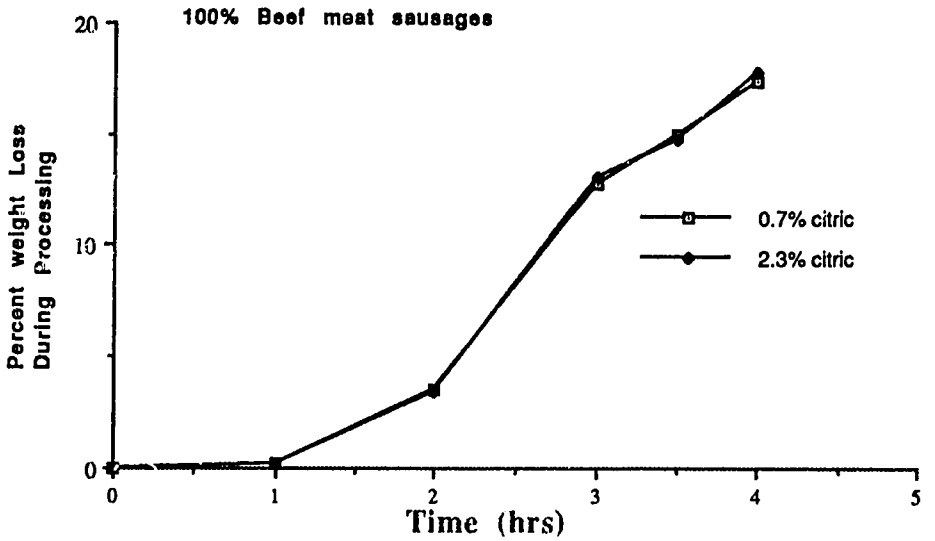
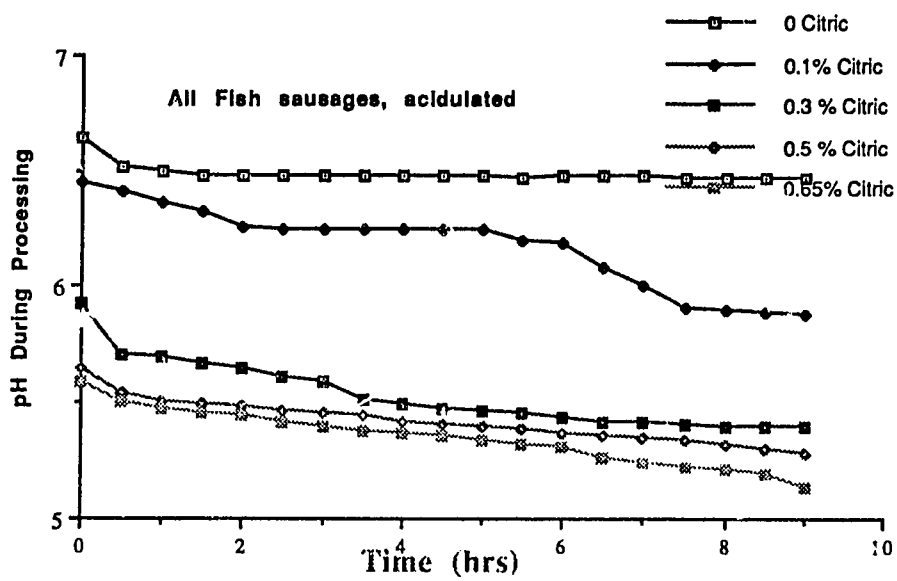


Figure 6. Weight loss in beef meat sausages acidulated with 0.7 and 2. % citric acid.

In Figure 6 it can be seen that the 0.7% and the 2.3% citric acid treated sausages reached 17 and17.8% weight loss respectively after 4 hours of processing.



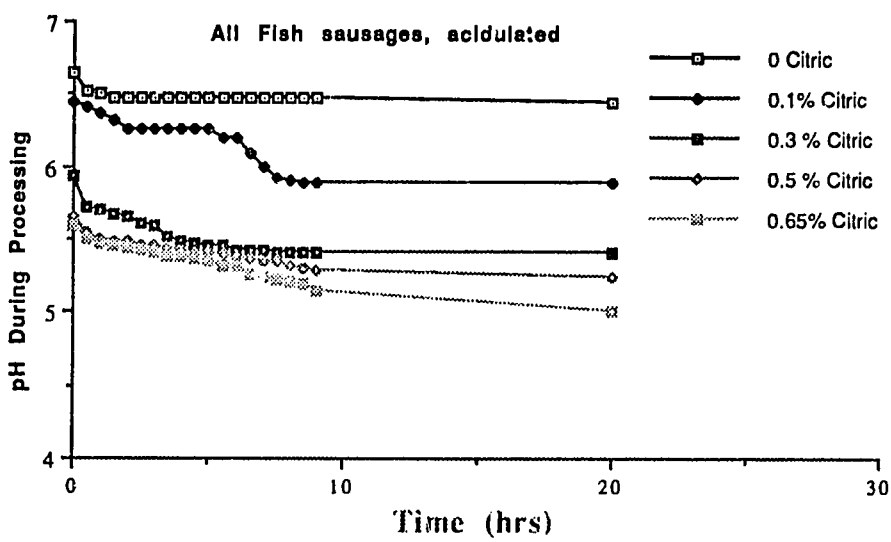


Figure 7. pH reduction during 20 hours in silvercarp (Israel) sausages acidulated with 0.1,0.3, 0.4, 0.5 and 0.65% citric acid.

Figure 7 shows that the all fish sausage without citric acid had a starting pH of 6.64. It fell to 6.48 after 9 hours and to 6.45 after 20 hours. With 0.1% citric acid addition the starting pH was 6.45 and it was reduced gradually to 6.25 by 5 hours and then started to fall sharply reaching 5.88 by 9 hours after which no further drop occurred. 0.3% citric acid gave a starting pH of 5.93. The pH fell sharply to 5.71 after 1/2 hour. Thereafter the pH fell gradually up to 8 hours reaching 5.40 when no further drop occurred. 0.5% citric acid gave a starting pH of 5.65 which gradualy descended for 9 hours to 5.28. At 20 hours of processing the pH was 5.23. .0.65% citric acid treatment gave a starting pH of 5.59. The pH then feil gradually reaching 5.14 at 9 hours and at 20 hours the pH was 5.00.

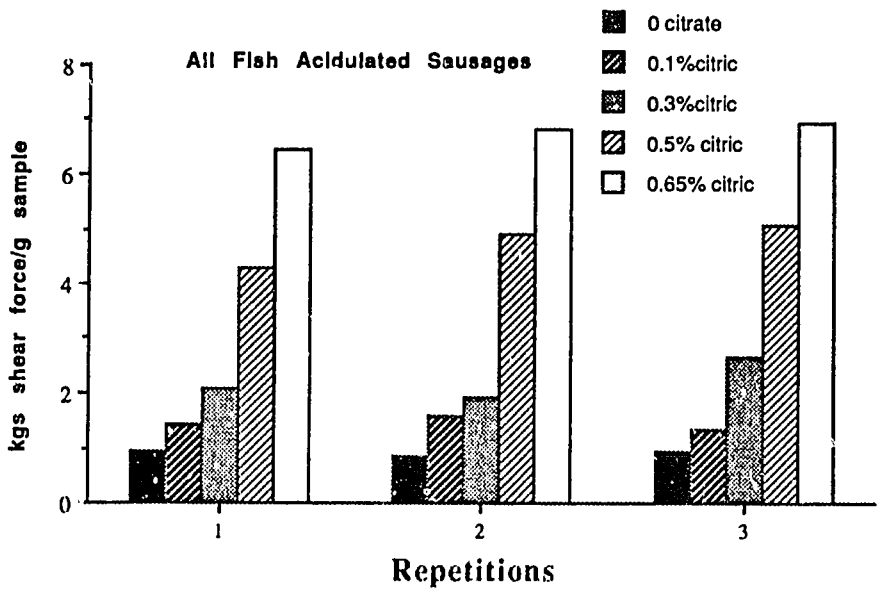


Figure 8. Kilograms force required to shear silvercarp fish after 20 hours of processing. The sausages were acidulated with 0.1, .0.3, 0.5 and 0.65% citric acid.

Figure 8 shows the 0.65% citric acid treatment resulted in the highest shear force for the acidulated silvercarp sausages followed by increasing softness with the lowering of the citric acid concentration.

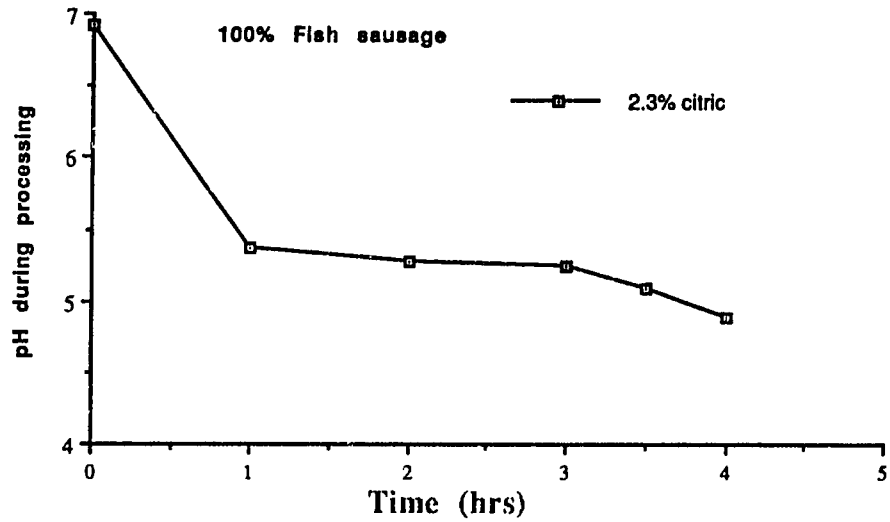


Figure 9. Figure 9 shows the pH reduction in sailfish (Costa Rica) sausage acidulated with 2.3% citric acid and processed for 4 hours.

Figure 9 shows the initial pH of the saifish (Costa Rica) sausage treated with 2.3% citric acid was 6.93 and it fell to 5.37 by 1 hour. The pH continued to fall and reached 4.89 after 4 hours of processing.

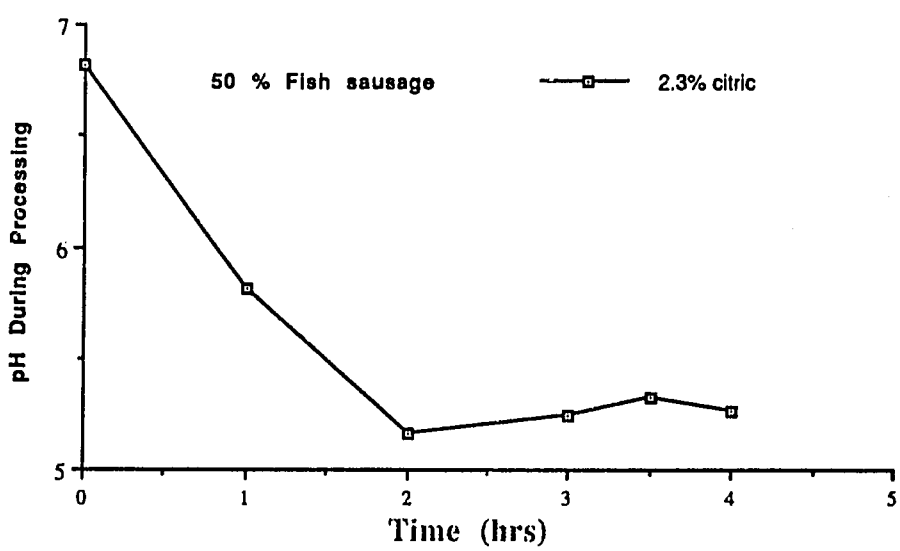
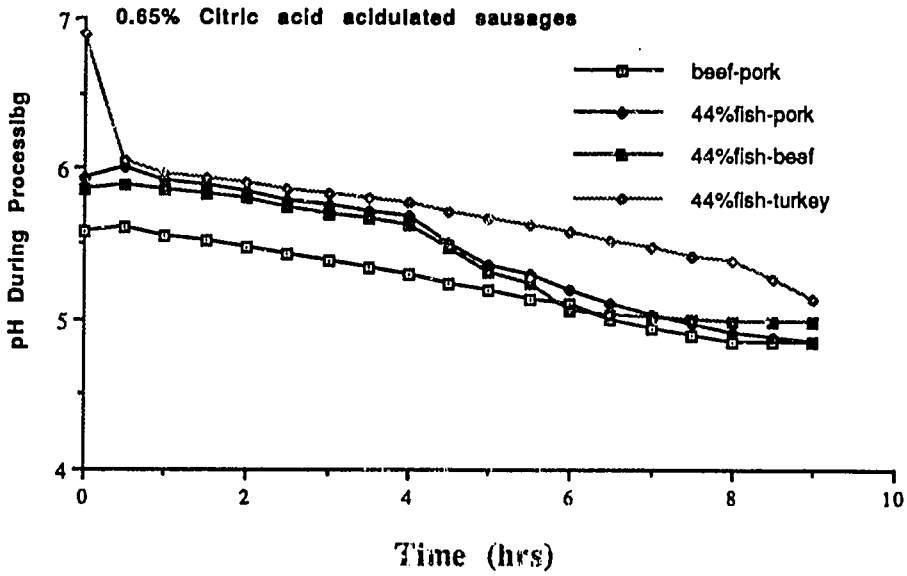


Figure 10. pH reduction in 50% "chatarra: (Costa Rica) sausage acidulated with citric acid.

Figure 10 shows that in a 50% "chatarra" sausage acidulated with 2.3% citric acid there was a rapid decline in pH from 6.82 to 5.16 within 2 hours. Thereafter the pH did not fall further.



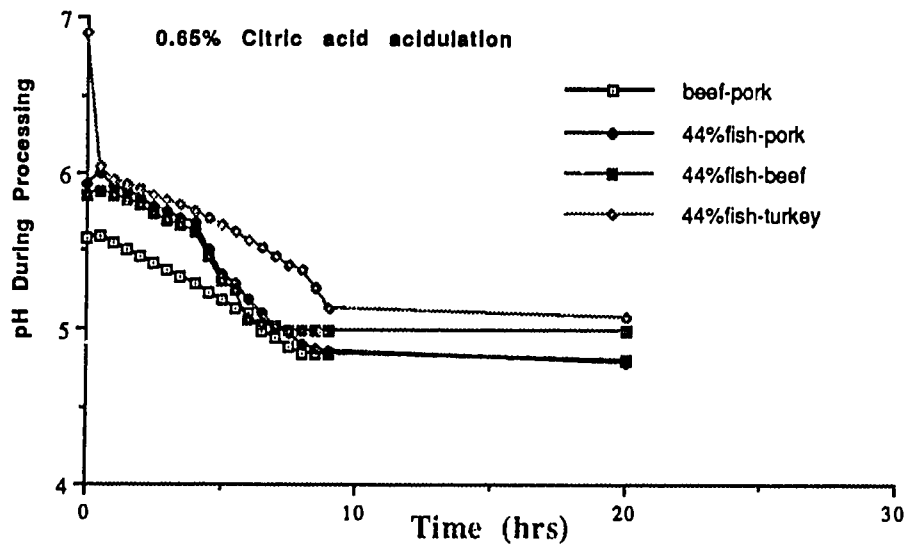


Figure 11. pH reduction in 20 hours in beef sausages and 44% silvercarp (Israel) -pork, beef and turkey sausages acidulated with 0.65% citric acid.

Figure 11 shows the pH of the turkey was 6.9 to start with and it fell abruptly after 1/2 hour to 6.05. Thereafter the fall was gradual and the pH reached 5.26 by 81/2 hours. There was a sharp drop to pH5.13 by 9 hrs of processing and the pH ended up as 5.07 by 20 hours of processing.

The fish-pork sausage pH was reduced gradually from a start of 5.93 to 4.85 by 9 hours of processing and the final pH was 4.78 by 20 hours of processing. Fish-beef sausage pH was 5.85 at the outset and fell gradually similar to the fish-pork sausage.The pH then reached 4.98 by 8.5 hours and did not change after that. In both the fish-pork and the fish beef there was an inflection in the curve downwards after 4 hours and then there began a more rapid fall.

The beef sausage had the lowest starting pH of 5.58. The pH fell gradually without any sharp inflections up to a final pH of 4.84 at 10 hours of processing. Following that no further reduction took place.

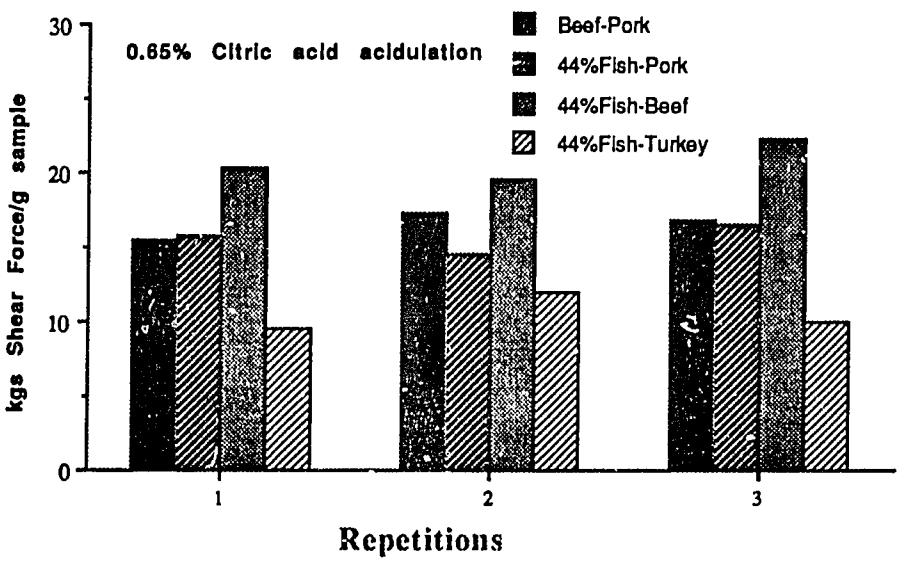


Figure 12. Kilograms force required to shear beef and 44% silvercarp-pork, beef and turkey sausages following acidulation with 0.65% citric acid.

Figure 12 shows the the toughest sausages were the fish-beef and the softest were the fish-turkey. Fish-pork sausages were of medium hardness.

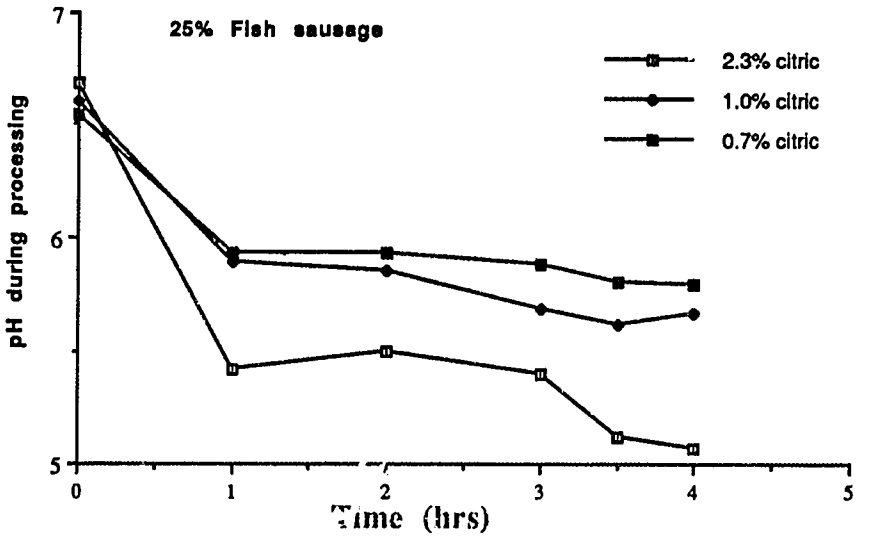
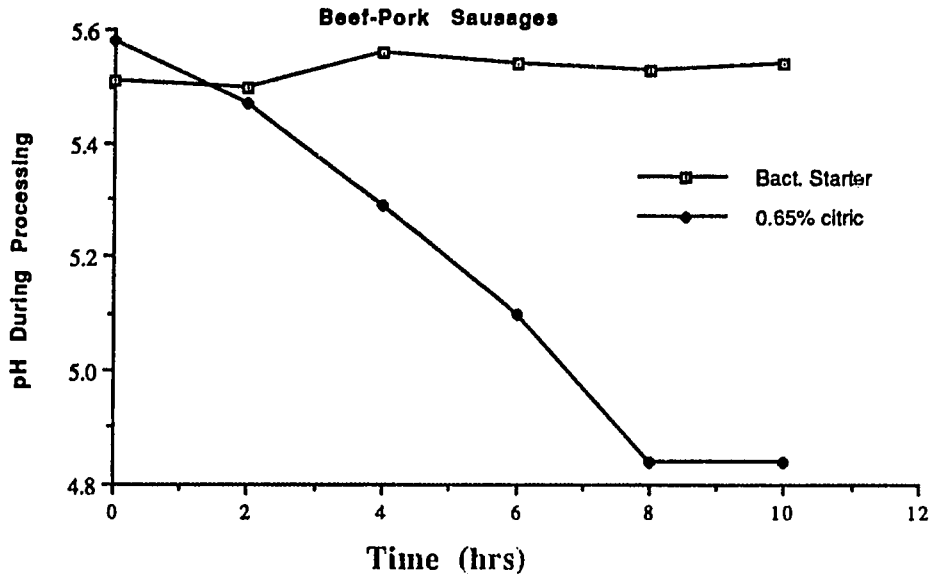


Figure 13. pH reduction in 25% "chatarra" (Costa Rica) fish sausages acidified with 0.7, 1.0 and 2.3% citric acid.

Figure 13 shows the starting pH for the 0.7% citric acid treated sausages was 6.54 and fell to 5.93 after 1 hour, then gradually to 5.79 after 4 hours. The 1 % citric acid acidulated sausages' pH fell rapidly from 6.60 5.89 in 1 hour and it then leveled off at 5.66 in 4 hours.The 2.3% citric acid treated saosages went sharply from 6.68 to 5.42 and then to 5.4 pH within 3 hours. At that time a sharp downward fall occurred and within 4 hours the pH was 5.07



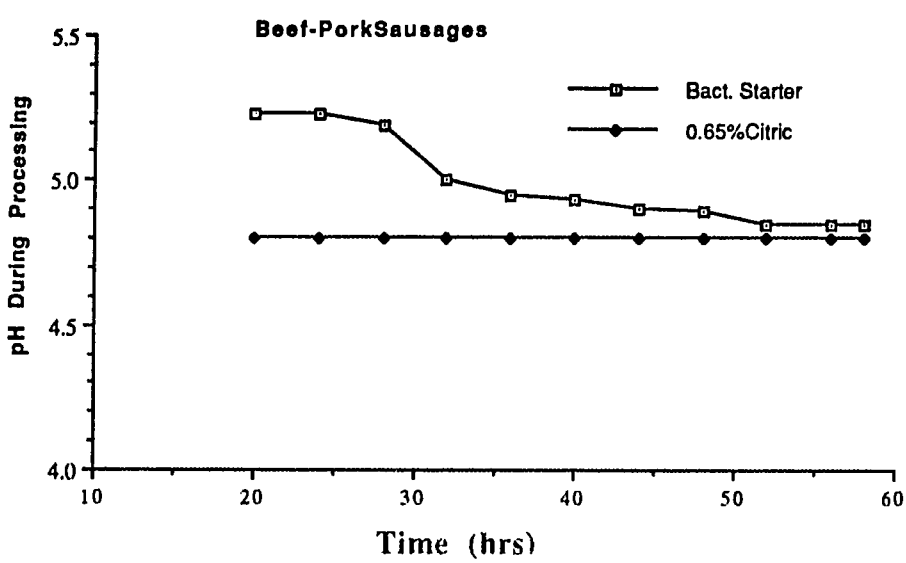
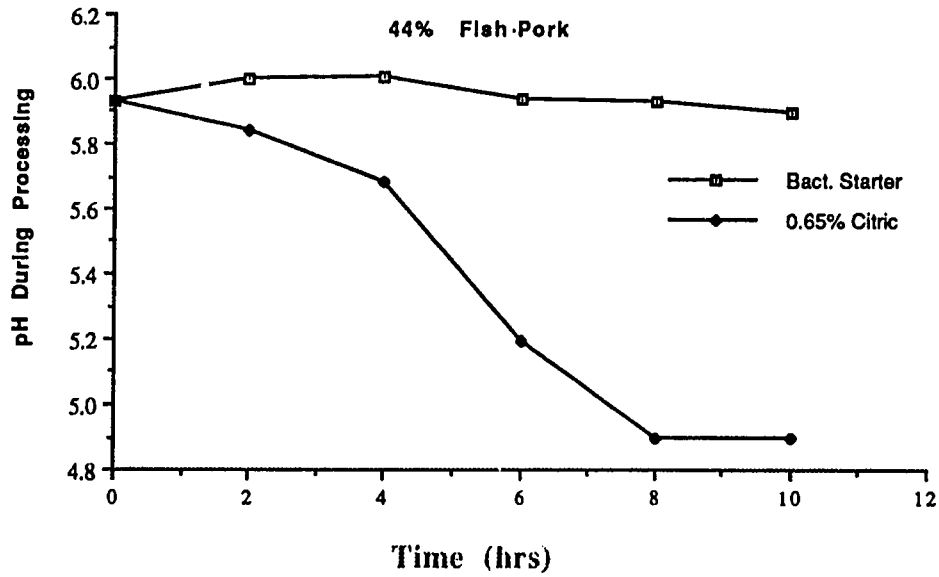


Figure 14. pH reduction in fermented and 0.65% citric acid acidulated beef-pork sausages.

Figure 14 shows the pH of the fermented sausages started out at 5.51 and started to fall after 30 hours. It fell to 5.0 after 32 hours and

then decended gradually to 4.85 by 58 hours. The pH of the citric acid treated sausages started out at 5.58 and began falling immediately.It reached 4.84 by 8 hours . The curve leveled off and the pH did not fall further throughout the rest of the processing period.



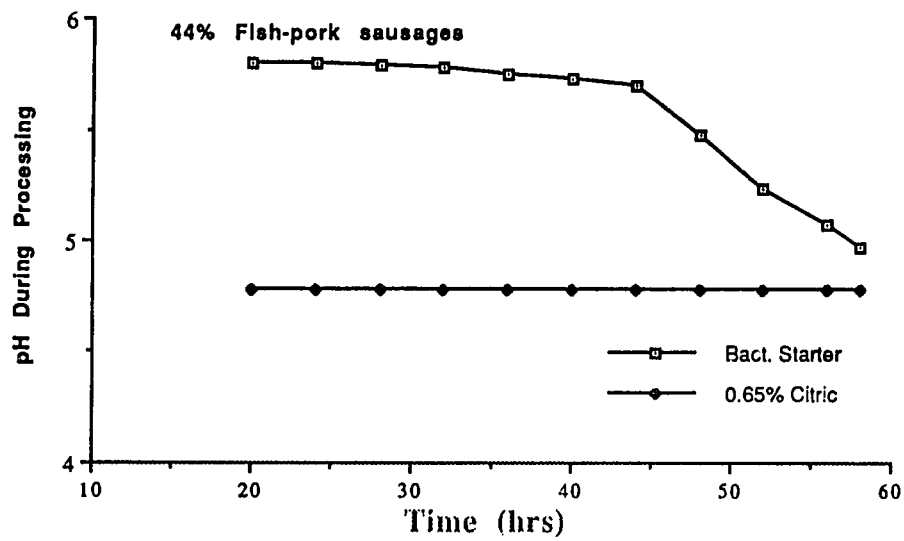
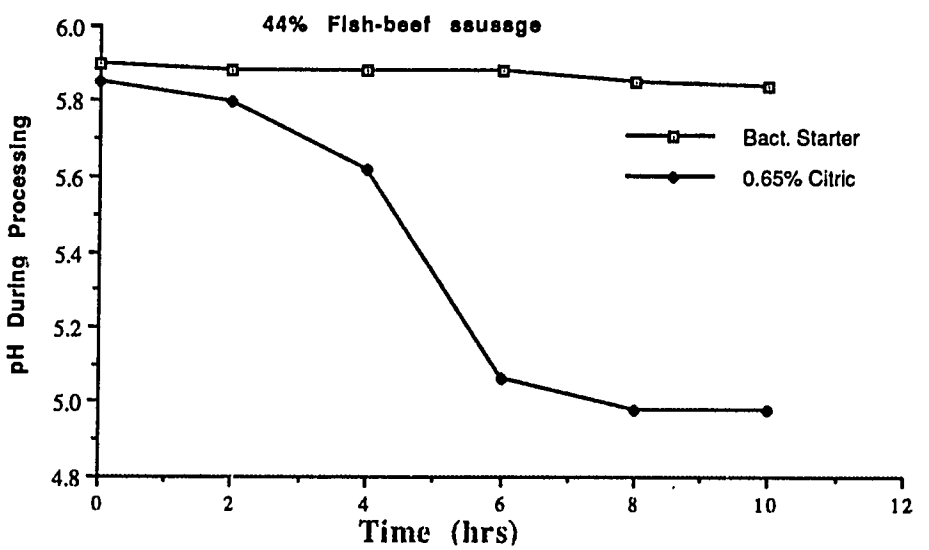


Figure 15. pH reduction of fermented and 0.65% acidulated fish-pork sausages.

Figure 15 shows the pH of both the fermented sausage and the citric acid acidulated sausage started out at 5.93. The fermented sausage remained close to its starting pH for up to 20 hours and then a slow or gradual descent in pH began. At 48 hours a steep fall began and the pH reached 5.07 by 58 hours. In the fermented sausage the pH continued to decrease. The citric acid treated sausage pH began to fall immediately reaching 5.68 by 4 hours. At that time a rapid decrease started and the pH reached 4.9 by 8 hours. The pH remained at 4.87.



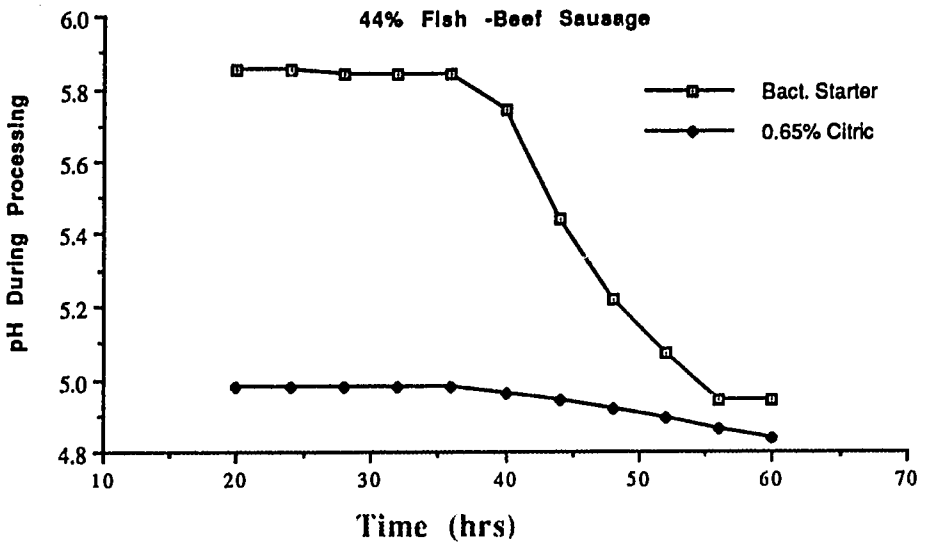
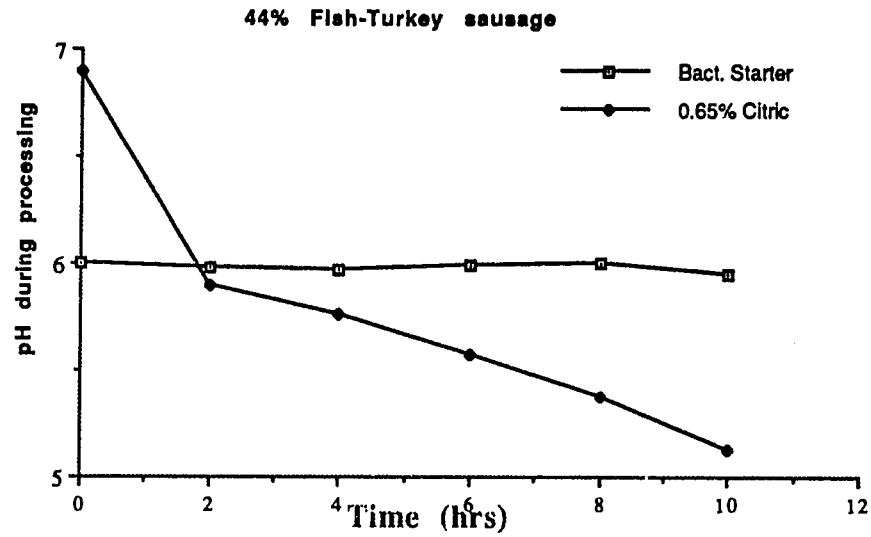


Figure 16. pH reduction in fermented and citric acid acidulated 44% silvercarp fish (Israel) -beef sausage.

Figure 16 shows the starting pH for the the bacteria fermented sausages was 5.9 while for the citric acid acidulated the starting pH was 5.85. In the bacteria starter culture fermented sausage the pH started to fall rapidly only after 35 hours of fermentation. It reached 4.94 no further change occurred.

The pH of the 0.65% citrate treated sausages started to fall immediately after the application of the acid and reached 5.06 after 6 hours when a gradual descent ensued until a pH of 4.98 was reached after 20 hours.



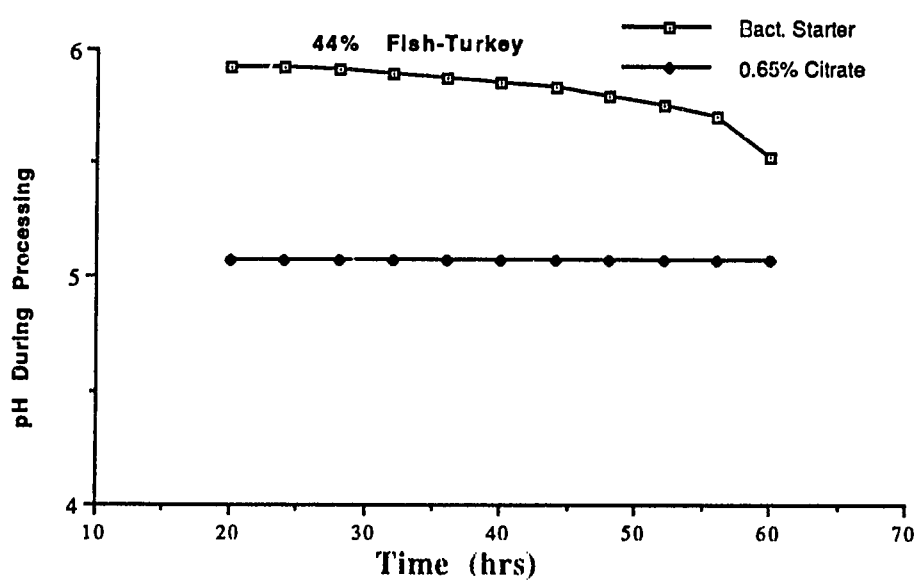


Figure 17. pH reduction in fermented and citric acid acidulated 44% silvercarp (Israel) fish-turkey sausage.

Figure 17 shows the pH of the fermented sausages started at 6.00 while pH of the citric acid treated started at6.9. The

pH of the bacteria treated descended slightly over a 20 hour period and then it began to gradually fall reaching 5.2 after 58 hours. The pH of the acidulated sauasages fell to 5.9 from a pH 6.9 within 2 hours. Following that a fairly steep fall began. The pH leveled off at 5.07 after which there was no further decrease.

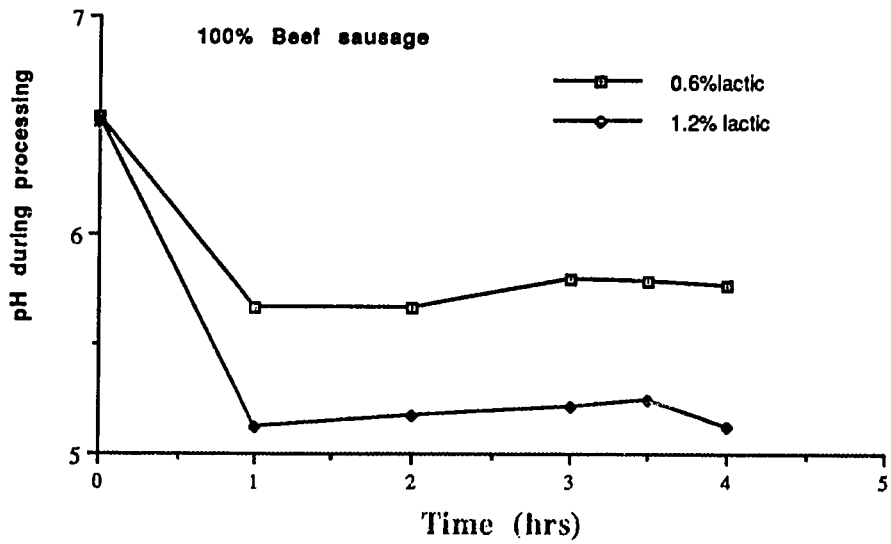


Figure 18. pH reduction in beef sausages following acidulation with 0.6 and 1.2 percent lactic acid.

Figure 18 shows the effect of lactic acid at two levels on pH reduction in a beef sausage. At 0.6% there was a reduction in pH from 6.54 to 5.66 within one hour. The pH did not fall beyond that in the four hour period monitored. With1.2% lactic acid acidulation the starting pH of 6.54 fell sharply to 5.12
within one hour.

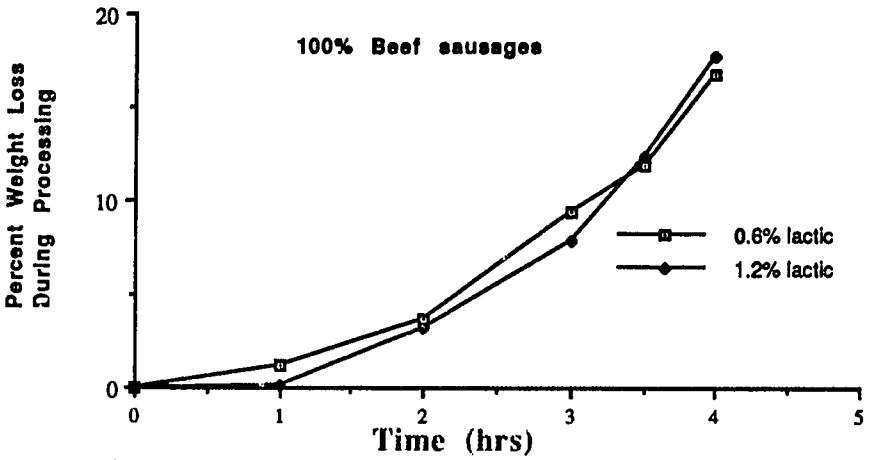


Figure 19. Weight loss in beef sausages during acidulation with 0.6 and 1.2% lactic acid.

Figure 19 shows the weight in the beef sausages treated with 1.2% lactic a was slightly higher after 4 hours of processing than in the 0.6% % lactic acid treated sausages.

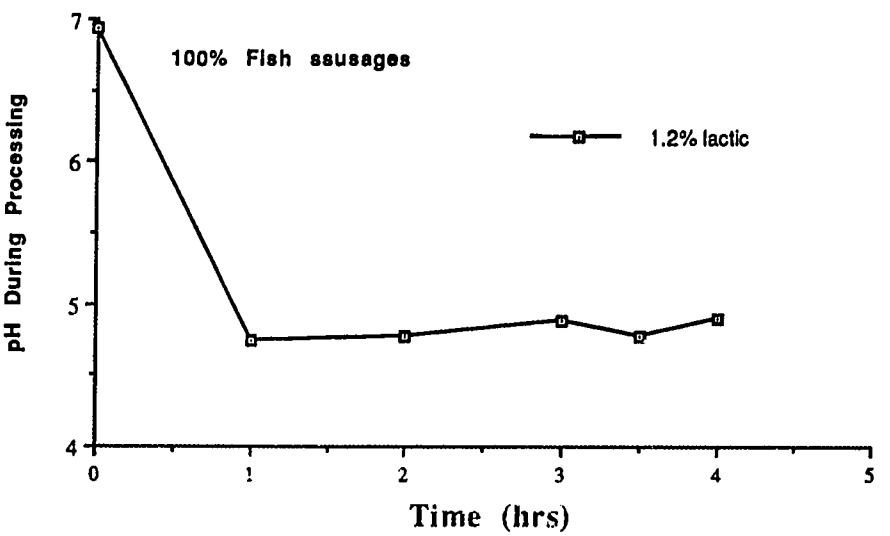


Figure 20: pH reduction in "chatarra" (Costa Rica) fish sausages acidulated with 1.2% lactic acid.

Figure 20 shows the pH was 6.9 immediately after preparing the 1.2% lactic acid acidulated sausage but it fell rapidly to 4.77 within 2 hours after processing. No further drop in pH occurred.

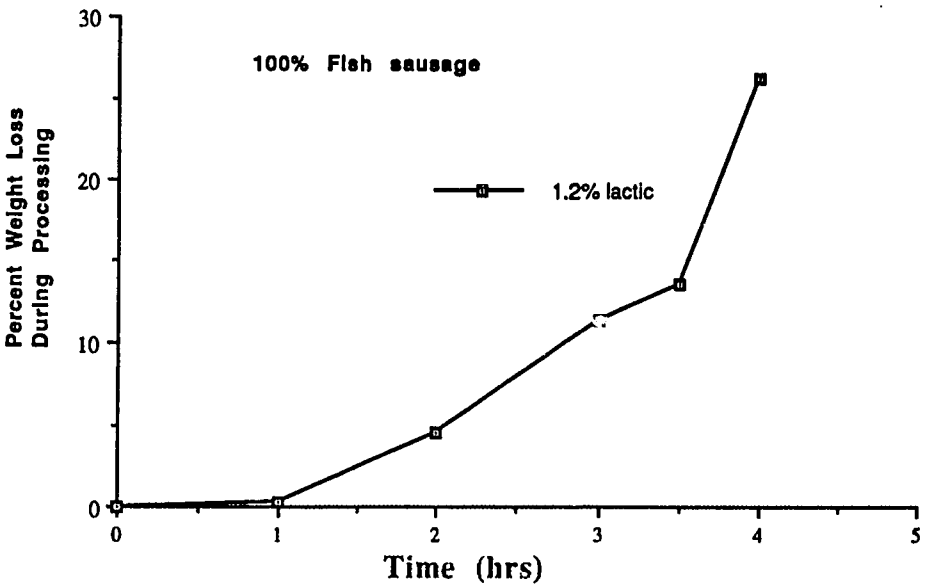


Figure 21. Weight loss in a "chatarra " fish sausage acidulated with 1.2% lactic acid.

Figure 21 shows that the all "chatarra" fish sausage acidulated with lactic acid lost 26% weight after 4 hours of processing. The loss of weight paralleled the fall in pH closely.

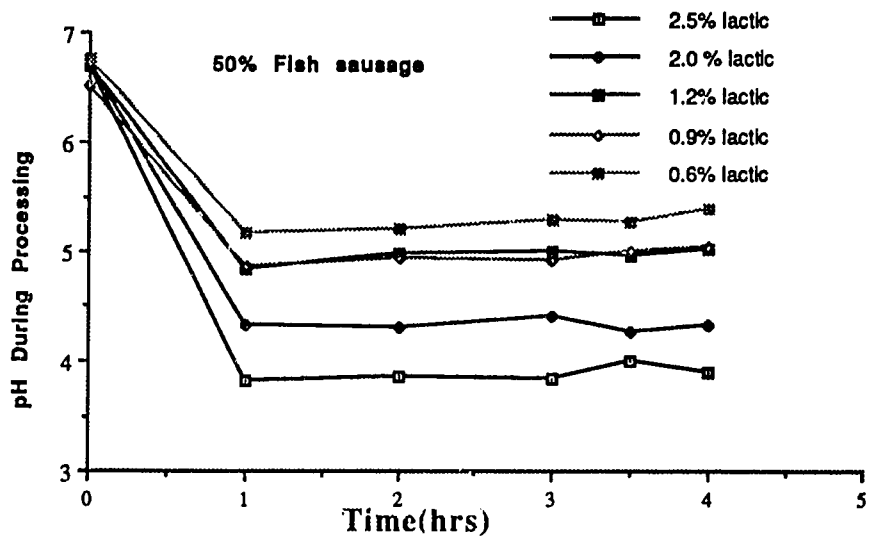


Figure 22. pH reduction in 50% "chatarra" fish (Costa Rica) sausage acidulated with 0.6, 0.9, 1.2, and 0.25% lactic acid.

Figure 22 shows the initial pH's of the sausages were similar and between 6.7 and 6.75. All the pH's dropped rapidly the first hour in the processing chamber and all the pH's did not fall after that for all practical purpose. However there were differences in the absolute pH values for the different treatments. The 0.6% lactic acid treatments resulted in pH drop to only 5.21 while the 0.9 and 1.2% concentrations of lacic acid resulted in pH drops to 4.65 and 4.97 respectuvely. The pH of the 2% lactic acid treatment dropped to 4.3 while the pH of the 2.5% lactic acid treated sausage dropped to 3.8.

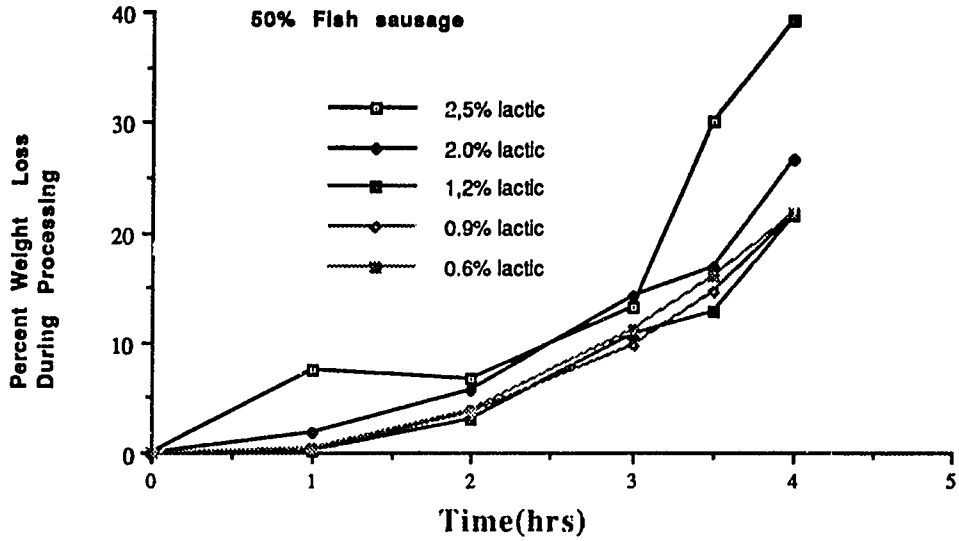


Figure 23. Percent wght loss in 50% "chatarra" fish (Costa Rica) sausages acidulated with 0.6,0.9,1.2, 2.0 and 2.5 % lactic acid.

Figure 23 shows the percent weight loss was was similar for the 0.6, 0.9 and 1.2% lactic acid treatments of the 50% "chatarra" fish sausages, reaching 19% by 4 hrs of processing, but the percent weight loss in the 2% lactic reached 25% and in the 2.5% lactic acid treated sausages the water loss reached 40% in 4 hours.

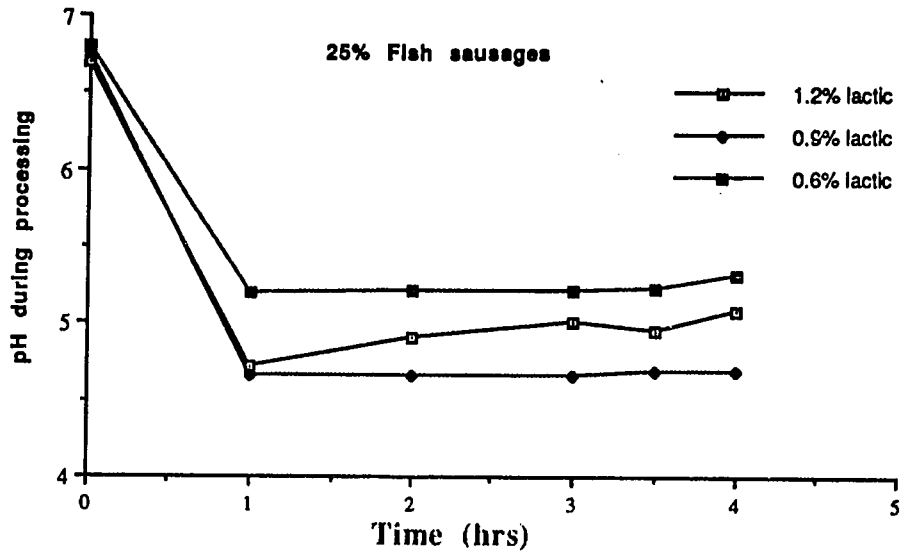


Figure 24. pH drop in 25% "chatarra" fish (Costa Rica) sausages acidulated with 0.6, 0.9 and 1.2% lactic acid.

Figure 24 shows starting pH was similar for all sausages and ranged from 6.7 to 6.8. After one hour the pH's dropped for all three treatments and remained stable. In the 0.6% treatment the pH fell to 5.2 while in the 0.9 and 1.2 concentrations of lactic acid the pH's dropped to 4.65 and 4.71 respectively.

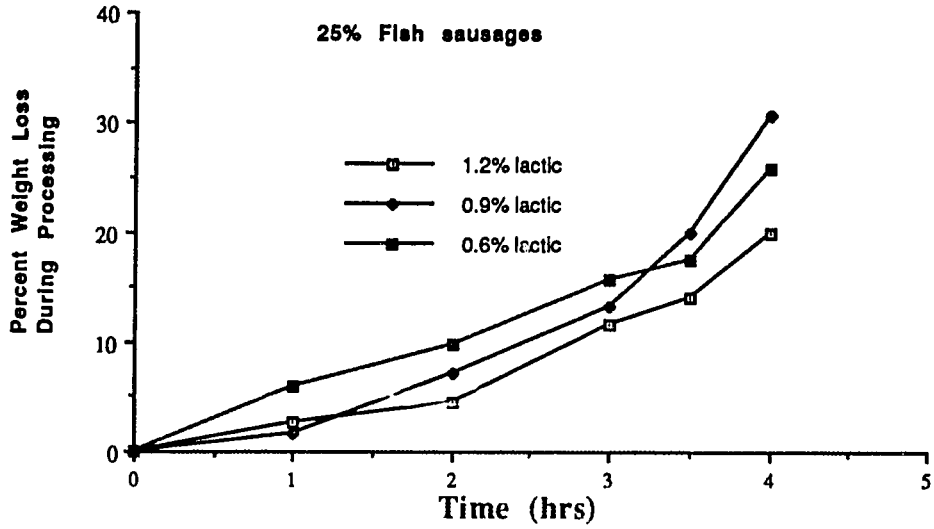


Figure 25 .Weight loss percent in 25% "chatarra" fish (Costa Rica) sausages acidulated with 0.6, 0.9, and 1.2% lactic acid.

Figure 25 shows the 0.9 % lactic acid sausages which had the lowest pH had a water loss of 25.7 percent. Surprizingly however the 0.6% lactic acid acidulated sausage had a similar percent water loss while the 1.2% lactic acid treatment had a water loss of only 19.99%. However the pH's in the latter also were higher.

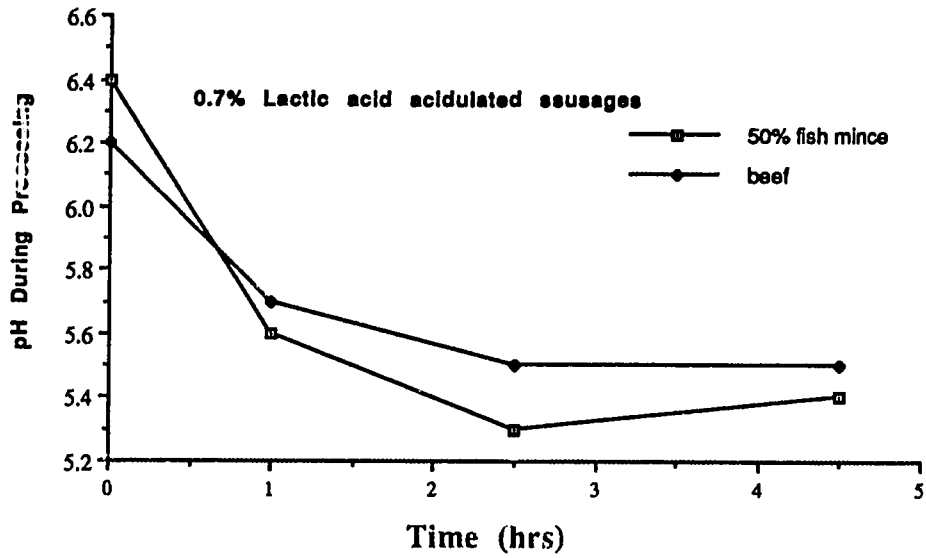


Figure 26. pH drop in 50 % sailfish (Costa Rica) and beef sausages acidulated with 0.7% lactic acid.

Figure 26 shows the pH in the 0.7% lactic acid acidulated beef sausages was initially 6.2 and in the 50% fish, 6.4. After 1 hour of processing the pH descended to 5.6 and 5.7 for the fish-beef and the beef sausages respectively. Following 2.5 hours in the processing chamber the pH of the fish fell to 5.3 and that of the beef descended to 5.5. After 4 hours of processing the fish-beef pH was 5.4 and that of the beef was 5.5.

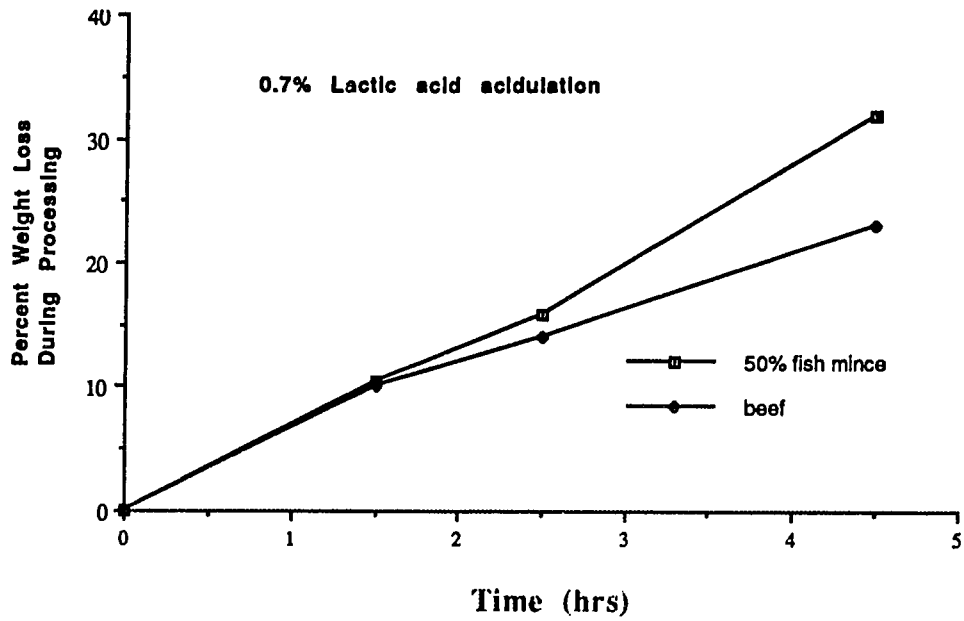


Figure 27. Percent weight loss in 50% sailfish (Costa Rica) sausages and beef sausages acidulated with 0.7% lactic acid.

Figure 27 shows that in the fish and beef sausages treated with 0.7% lactic acid, the fish which maintained a slightly lower pH than the beef lost 30% water in 4 hours of processing while the beef lost only 20%.

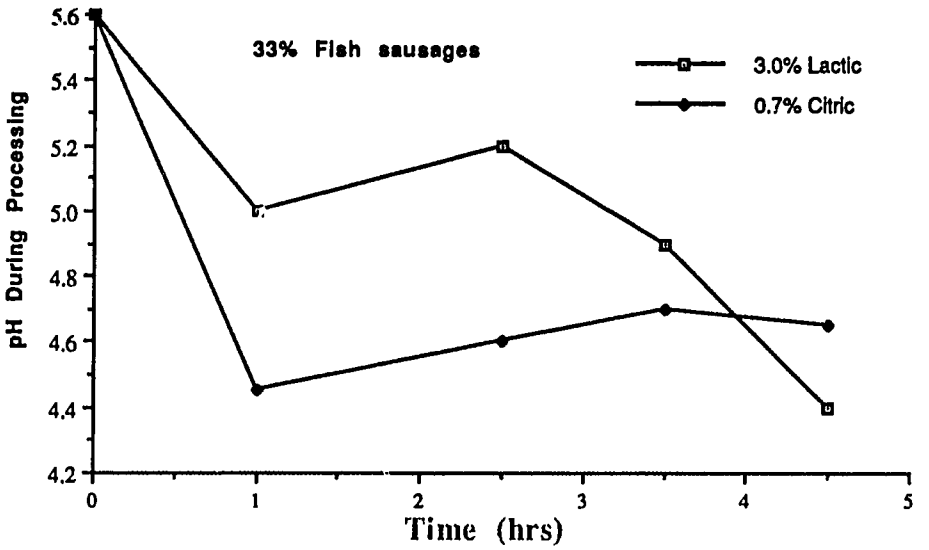


Figure 28. pH drop in 33% sailfish sausages acidulated with ,0% lactic acid and 0.7% citric acid.

Figure 28 shows for both the lactic and citric acid acidulated sausages the starting pH was 5.6. After one hour of processing the 3% lactic acid acidulated sausages had a pH of 5 and the 0.7% citric acid acidulated sausages had a pH of 4.45. The lactic acid treated sausages' pH descended to 4.45 after 4.5 hours while the citrate pH rose slightly.

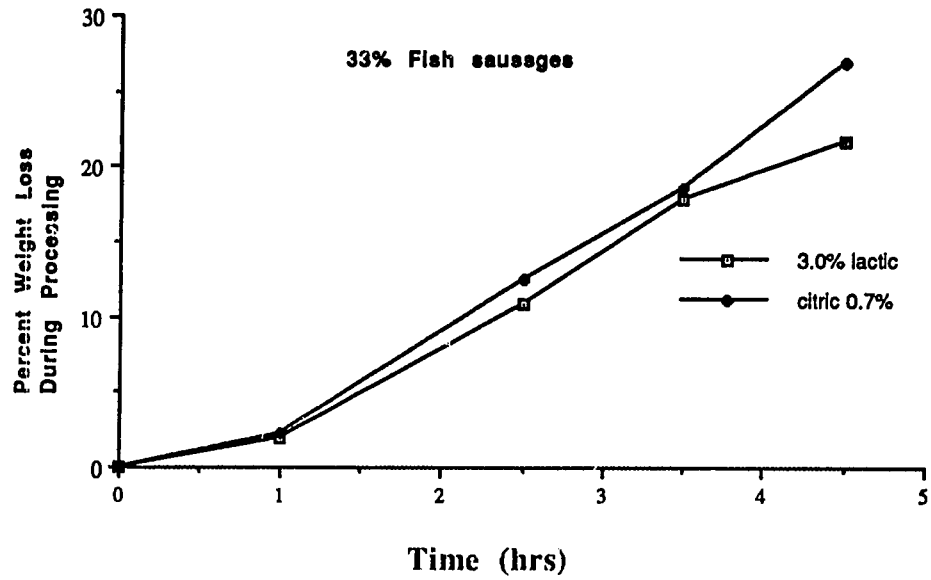


Figure 29 . Percent weight loss in sailfish sausages acidulated with 3.0% lactic and 0.7% citric acids.

The water loss reached 19% after 4 hours for both the 3.0% lactic and the 0.7% citric acids acidulated sausages. By 45 hours the lactic treated sausages reached 25% weight loss and the citric, 25%.

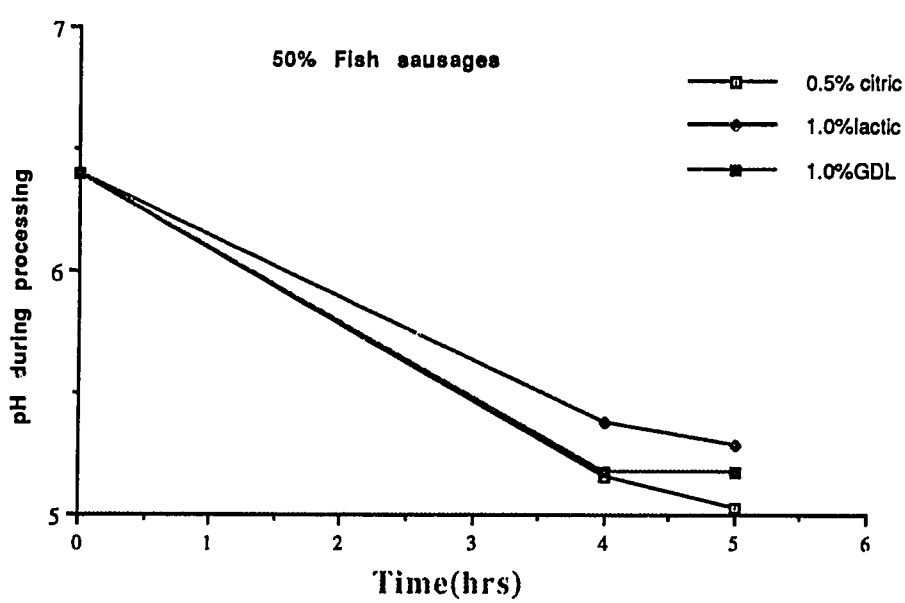


Figure 30. pH reduction in 50% sailfish sausages acidulated with 0.5% citric acid , 1.0% lactic acid and 1 percent GDL.

Figure 30 shows the starting pH's were 5.8 for all three types of acidulation. After 4 hours the citric acid acidulated sausage pH dropped to 5.16, the lactic acid acidulated to to 5.38 and the GDL acidulated to 5.18.

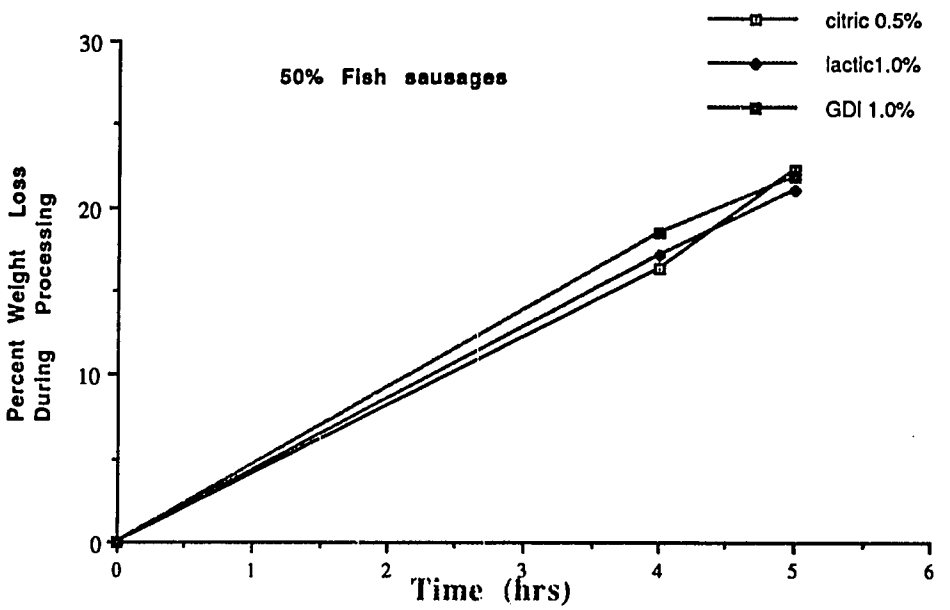


Figure 31. Percent weight loss in 50% sailfish (Costa Rica) sausages acidulated with 0.5% citric acid, 1.0% lactic acid and 1% GDL.

The graph in Figure 31 shows citric acid acidulated sausages lost 16.3% water after 4 hours processing while the lactic acid acidulated lost slighly more. The GDL acidulated sausages lost 18.5% water after 4 hours of processing. However the three kinds of acidulated sausages ended up losing practically the same amount after 5 hours of processing.

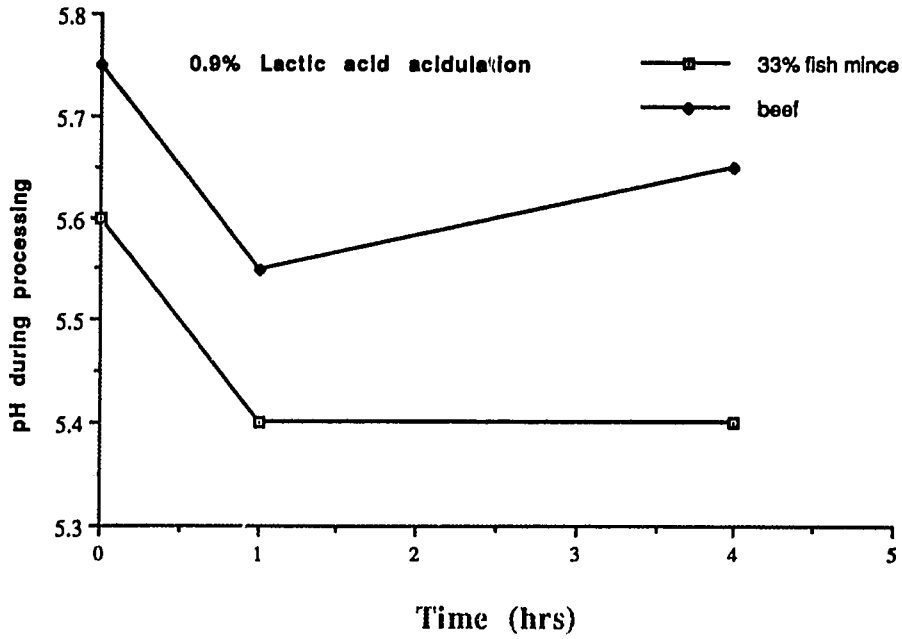


Figure 32. pH reduction in 33% fish sausages and beef sausages following acidulation with 0.9% lactic acid.

Figure 32 shows that following one hour of processing, the pH dropped
to the same relative degree in both the 33% fish and in the beef sausages with that of the 33% fish maintaining a lower pH. Little change in pH occcurred between 1 and 4 hours of processinin either of the sausages.

please go on to page 44

DISCUSSION OF pH REDUCTION DURING FERMENTATION AND ACIDULATION OF BEEF AND BEEF, FISH-BEEF, PORK AND TURKEY SAUSAGE

In the fermentation experiments the 50% sailfish-beef sausages had higher starting and final pH's than the 44% silvercarp-beef sausages. However the all-beef sausages in the experiment with the sailfish also had higher starting and final pH's than the all beef in the silvercarp beef sausage experiment.

Therefore it may be assumed that both types of fish sausages behaved similarly during the fermentation and that the differences in starting and final pH were not necessarily due to the fish species.

In the 44% silvercarp fish-beef, pork and turkey sausages fish-beef and pork pH's developed similarly and both descended below 5 while the fish-fish-turkey sausage pH started out higher than that of the fish-beef and pork sausages and ended up with a higher pH than the latter and above 5.

Acidulation with encapsulated citric acid of beef and 44% silvercarp-beef, pork or turkey combinations showed the starting and final pH's were similar as in the fermentation process although the latter was much slower taking days to attain the same pH as that obtained by encapsulated citric or lactic acids within hours.

In the acidulation of 100% silvercarp, "chatarra" or sailfish sausages, increasing concentrations of citric or lactic acids resulted in lower final pH's in the sausages. Final pH's for citric or lactic acid concentrations of 0.1 to 3.3% in the sausage ranged from 5.84 to 4.77 respectively.

In the 100% beef sausages there was no such tendency for the citric acid application but there appeared to be for the lactic.

In the 50% fish sausages, using citric acid, there was no obvious trend for decrease in pH with increasing citric acid concentration. With lactic acid there was a trend to decrease in pH with increasing encapsulated acid concentration but only in the higher concentrations of above 1.2% lactic acid.

In the fish sausages with less than 50% fish there was no tendency for reduced pH with higher citric acid concentrations. However such a trend did exist with the sausages treated with lactic acid.

There was no obvious trend in pH reduction between "chatarra", sailfish and silvercarp fish-meat sausages.

RESULTS (continued)

ORGANOLEPTIC ANALYSES:

Index to Figures showing general reactions to the new type of sausages, quality ratings, breakdown of scoring by econo-socio classes, awareness or not of fish in the product, comparison scores to other similar products, and effect of method of presentation and preparation (cooking or raw) on the scores.

Figure 33 shows the scores of the taste panel in Israel for beef and fish-beef, pork and turkey sausages following fermentation with starter cultures.

Figures 34- 42 are the results of the consumer tests carried out in 110 households in Costa Rica on fish-beef sausages.

Figure 34 shows the general reactions of the consumers to the fish-beef combination.

Figure 35 shows the score of the consumers for color, flavor, odor and overall quality of the fish-meat sausages as well as their responses to questions comparing the sausages to similar ones on the market in Costa Rica.

Figures 36-37 are a breakdown by social class or economic status of the consumer scores of organoleptic parameters and a comparison by social class to similar sausages on the market in Costa Rica.

Figures 38-39 show the organoleptic ratings of the sausages by the consumers and their comparison to other such sausages on the market when they were or wern't aware that the sausages they were tasting contained fish.

Figures 40-41 show the organoleptic ratings of the sausages by the consumers and their comparison to other such sausages on the market according to the amount of fish the sausages contained.

Figures 42-43 show the organoleptic ratings of the sausages by the consumers and their comparison to other such sausages on the market. Effect of the presentationor method of preparation of the sausages (raw, coooked or fried) on ratings are also presented in the figures.

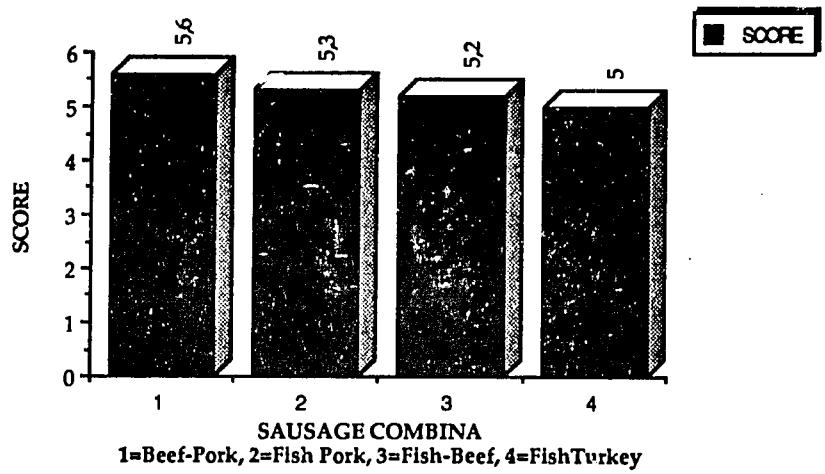


Figure 33. Scores of 28 untrained panelists for beef-pork and 33% Whiting fish- pork, beef and turkey fermeented sausages. Score of 1= dislike extremely and score of 9= like extremely. Score of 5= neither like nor dislike.

Figure 33 shows the scores for the sausages varied within the acceptable range of 5 to 5.85. The beef-pork sausages received the highest score followed by the fish-pork and the fish-beef. The fish-turkey received the lowest score equivalent to "neither like nor dislike".

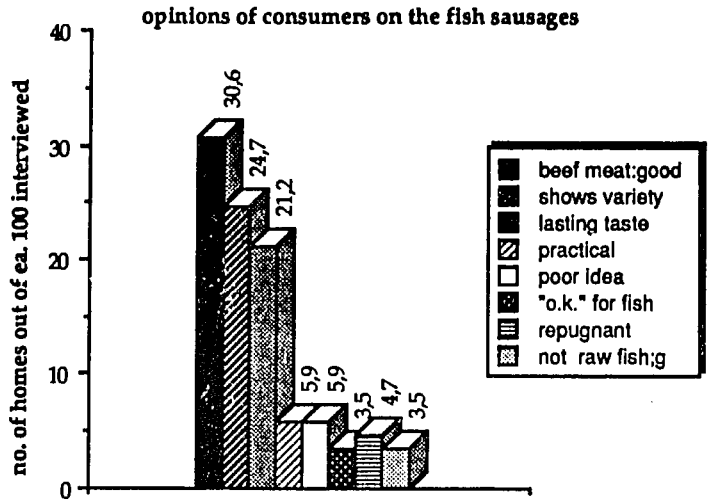


Figure 34. Reactions of consumers to fish sausage.

Figure 34 shows the opinions of the consumers on the sausages. 90.5% rated the sausage between "beef meat, good" to "practical". The 9.5% of the consumers who rejected the sausage rated it as a"poor idea" or "repugnant".

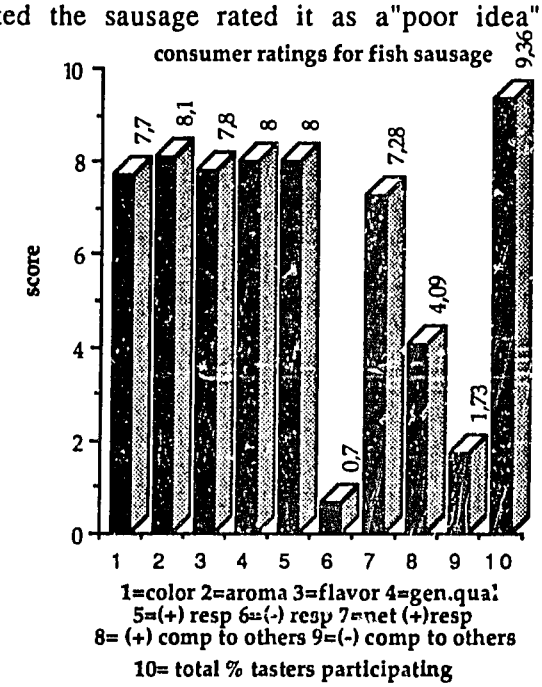


Figure 35. Consumers' organoleptic ratings, positive and negative responses for the fish sausages and comparison to other similar

sausages.

Figure 35 shows the consumers gave a score of 8.1 on a scale of 10 for odor, 7.8 for flavor and 7.7 for color and a score of 8.0 for overall quality. 80% of the responses to the sausage were positive and 7.2% were negative. 40.9% scored the sausages better than similar sausages on the market and 17.3% said the sausages were inferior to similar sausages on the market.

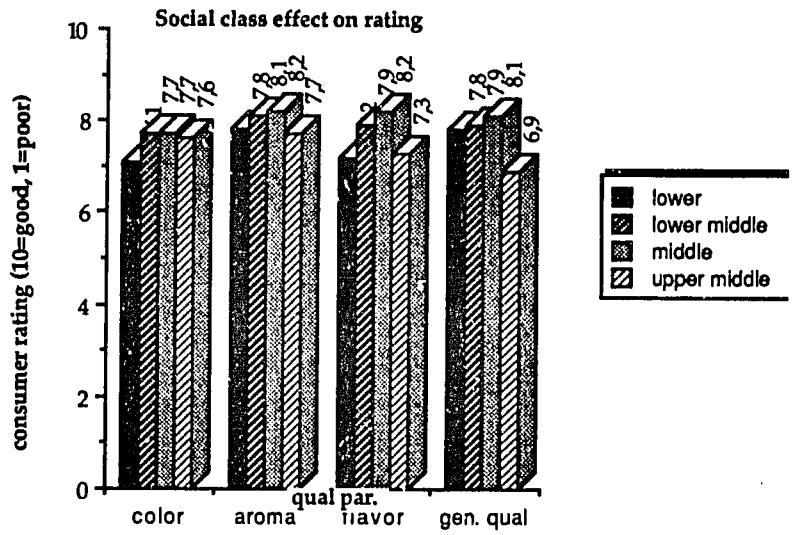


Figure 36. Social class or economic strata of consumers' rating of organoleptic parameters of the fish sausages.

Figure 36 shows the *highest* scores for odor, flavor and color: 8.1&8.2, 8.2&7.9, 7.7 respectively were given by the *lower -middle and middle class* and the *lowest* scores for odor, flavor and color: 7.8, 7.2 and 7.1 respectively were given by the *lower class*. The *highest* scores for overall quality, 8.1, 7.9 and 7.8 were given by the *middle, lower middle and lower classes* respectively while the *lowest* score, 6.9 for overall quality of the fish sausages came from the *upper class*.

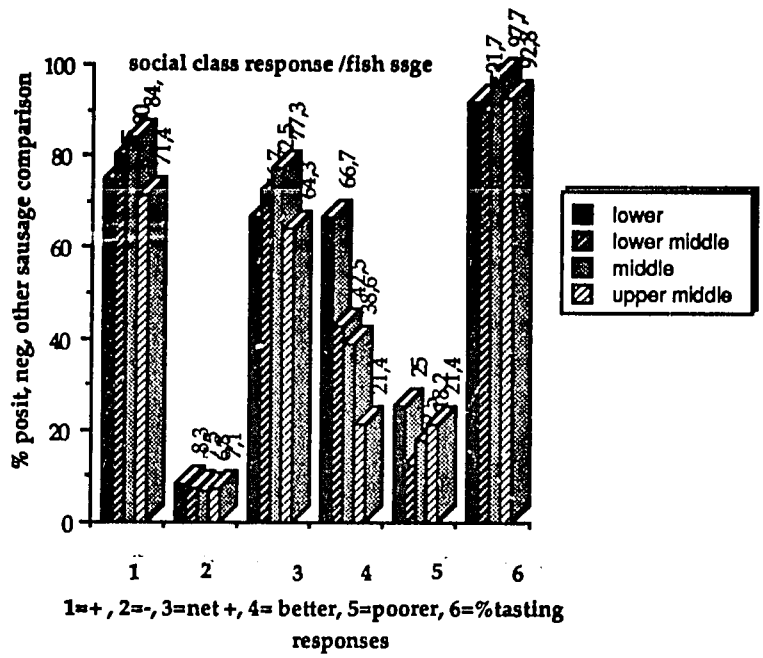


Figure 37. Social class or economic strata of consumers' rating of organoleptic parameters of the fish sausages.

Figure 37 shows there were 84.1, 80, 75 and 71.4% *positive* responses to the fish sausages by the middle, middle lower, lower and middle upper classes respectively. There were 8.3, 7.5, 7.1 and 6.8% *negative* responses by the lower, middle, middle lower and middle upper classes respectively. The *net positive responses* therefore were: 77.3, 72.5, 66.7 and 64.3% for the middle, middle lower, lower and middle upper classes respectively.

66.7, 42.5, 38.6 and 21.4% of the lower, middle lower,middle and middle upper clasess respectively considered the fish sausages *better* than similar sausages on the market. 25, 21.4, 18.2 and 12.5% of the lower, middle upper middle and middle lower classes respectively considered the fish sausages *poorer* than similar sausages on the market. Of the total tasters interviewed, 91.7% came from the lower classes, 90% came from the middle lower, 97.7% came from the middle and 92.8% came from the upper classes.

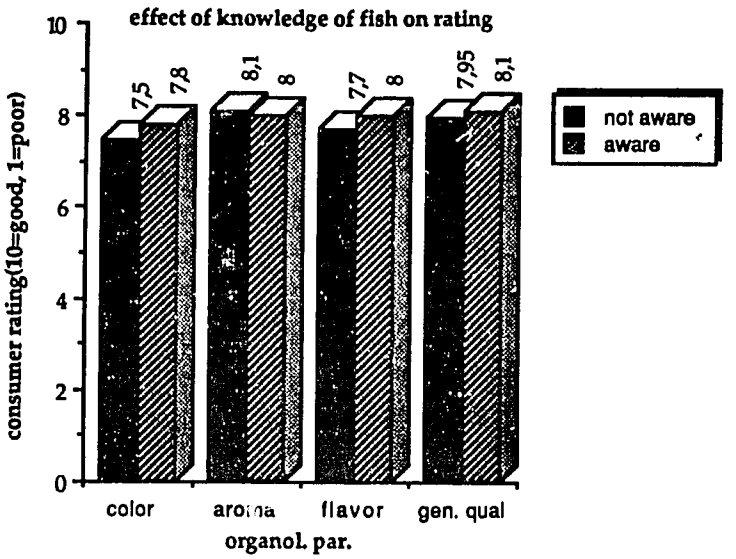


Figure 38. shows the organoleptic ratings for the sausages when the consumers were *aware* or *not aware* that they contained fish.

Figure 38 shows that for color the ratings were 7.8 and 7.5 for those aware and not aware respectively. For those aware and not aware the ratings respectfully were: aroma, 8.0 and 8.1 , 8.0 and 7.7 . For overall quality the ratings were 8.1 and 7.95 for those aware and not aware respectively.

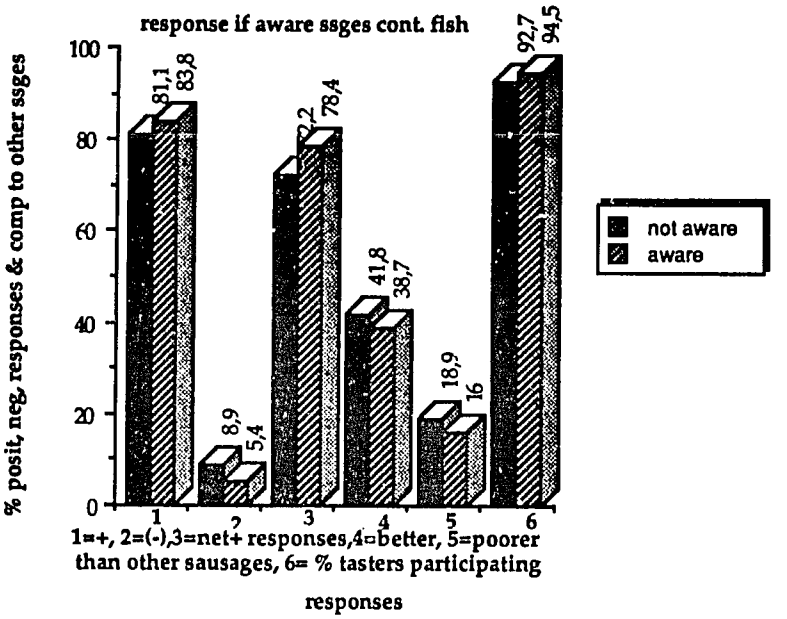


Figure 39 shows the amounts of positive and negative responses of the consumers to the sausages if they were *aware* or *not aware* that they contained fish.

Figure 39 shows that 83.8% of the responses were positive when the consumers were aware that the sausages contained fish. 81.1% of the responses were positive when the consumers were not aware that the sausages contained fish. 5.4% and 8.9% of the responses were negative when the consumers were aware and not aware respectively that the sausages contained fish.

The net positive responses were 78.4% for the aware and 72.2% for the not aware respectively. 38.7% and 41.8% of the aware and not aware respectively considered the sausages better than similar ones on the market. 16% and 18.9 respectively of the aware and not aware considered the sausages poorer than similar ones on the market. 94.% and 92.7% of the tasters were aware and not aware respectively that the sausages contained fish.

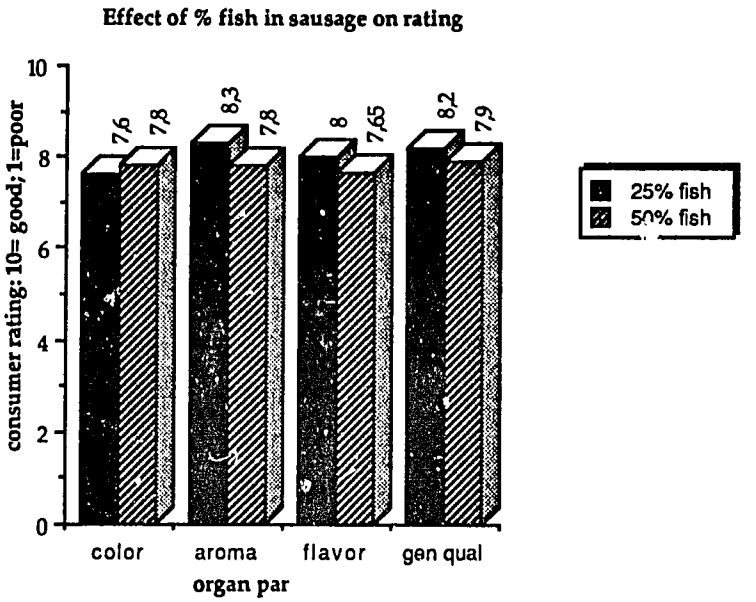


Figure 40 Consumer ratings of organoleptic properties based upon the amount of fish the sausages contained.

Figure 40 shows 50% and 25% fish sausages received ratings of 7.8 and 7.6 for color respectively. The 50 and 25% fish sausages received ratings of 7.8 and 8.3 for odor respectively. The 50 and 25% fish sausages received ratings of 7.65 and 8.0 for flavor respectively. For overall quality the 50 and 25% fish sausages received ratings of 7.9 and 8.2 respectively.

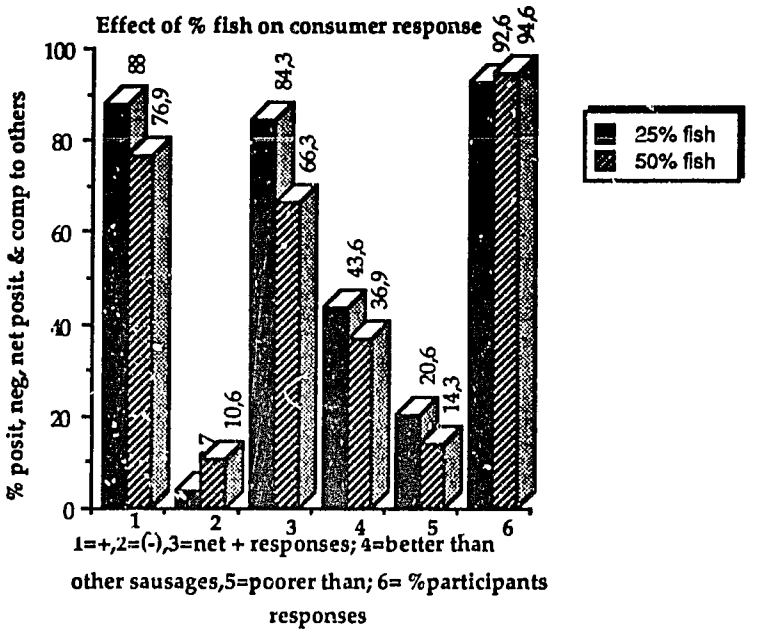


Figure 41 Consumer positive and negative response to the sausages based on the amount of fish the sausages contained.

Figure 41 shows 66.3% and 84.3% of the consumers gave positive responses respectively to 50 and 25% fish sausages. 36.9 and 43.6% of the consumers gave negative responses to the 50 and 25% fish sausages respectively.
The net positive responses were 66.3% and 84.3% for the 50 and 25% fish sausages respectively. 36.9 and 43.6 % of the consumers considered the 50 and 25% sausages respectively better than similar products on the market. 14.3 and 20.6% respectively considered the 50 and 25% sausages poorer than those on the market. The percent of consumers who tasted the 50% sausages was 94.6 and the percent which tasted the 25% fish sausages was 92.6.

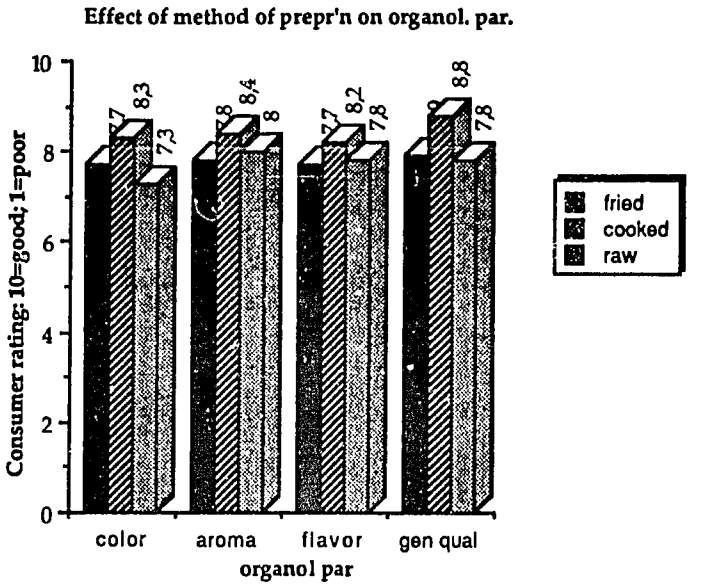


Figure 42. Consumer ratings of organoleptic properties of raw, cooked or fried fish sausages.

Figure 42 shows that color was rated 7.7, 8.3 and 7.3 for the fried, cooked and raw fish sausages respectively. Odor was rated 7.8,8.4 and 8.0 for the three methods of preparation respectively. Flavor was rated 7.7,8.2 and 7.8 for the three methods of preparation respectively. Overall quality was rated 7.9, 8.8 and 7.8 for the three methods of preparation respectively.

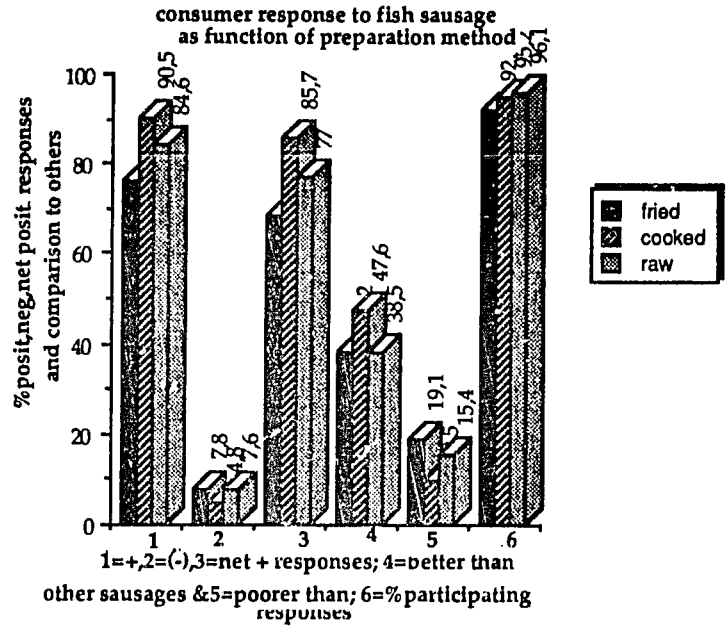


Figure 43.Positive and negative responses to the fish sausages according to the method of preparation.

Figure 43 shows the overall *positive* responses were 76.3, 90,5 and 84.6 for the fried, cooked and raw sausages respectively. The overall *negative* responses were 7.8, 4.8 and 7.6% for the three methods of preparation respectively. The net positive responses were 68.5, 85.7 and 77% for the three methods of preparation respectively.

38.2, 47.6 and 38.5% of the tasters considered the fried, cooked and raw sausages respectively *better* than similar sausages on the market. 19.1, 9.5 and 15.4% of the tasters considered the fried, cooked and raw sausages respectively *poorer* than similar sausages on the market.

92.1, 95.2 and 96.1% of the consumers tasted the fried, cooked and raw sausages respectively.

DISCUSSION OF ORGANOLEPTIC ANALYSES OF THE FERMENTED AND OR ACIDULATED SAUSAGES MADE WITH OR WITHOUT FISH

In the comparison of a dry fermented sausage of beef and pork with fermented dry sausages containing fish+ pork, beef or turkey meat it transpired that an untrained randomly picked group of 28 persons roughly the same number of males and females of various ages on a kibbutz in Israel gave a score of 5.8 out of 9 for the beef- pork sausage and 5.5 for the fish-pork and fish-beef. Fish-turkey sausages received a score of 5 which is neither like nor tasters were not too enthusiastic over such a product. The kibbutz in question produces beef-pork sausages using a higher temperatures and the starter cultures used were also different. This gave a different taste to their sausage than the beef-pork used in the experiment. Perhaps that could explain the relativly low score for the beef sausages used as a control in the experiment. Compared to the beef-pork control the fish-red meat sausage combinations received relatively *high* scores. Fish-turkey was however definitely down scored as compared to the rest.

In the Costa Rican large consumer panel 90.5% of the panelists rated the sausages containing fish as good as beef meat sausages. Color, flavor aroma and overall quality were rated 8 out of a total possible score of 10 and 80% of the panelists made positive remarks about the sausages. 41% of the panelists claimed the fish containing sausages were better al around than similar sausages on the market.

When subdividing the panel into social classes (or economic strata) the lower middle and the middle class gave the highest ratings for color, flavor, aroma and overall quality. The upper middle class gave the lowest rating (6.9 out of 10) for overall quality. The middle class gave the most net positive response (77.3% of the respondents) to the fish containg sausage while the upper middle class gave the smallest percent of net positive responses(64.3%). Interestingly the next lowest percent of net positive responses was given by the lower class(66.7%). However 66.7% of the respondents of the lower class said the fish containing sausage was better than a similar sausage on the market as against 21.4% of the upper middle class who said so.

Whether the consumer panelists were aware or not that the sausage contained fish the scores for color, aroma, flavor and overall quality all were within the 7.5 to 8.1 out of 10 range. The net positive responses were 78% of the tasters when they knew the sausages contained fish and when they were not aware 72% of the panelists gave positive responses. 41% of the tasters who were not aware the sausages contained fish said they were better than similar sausages on the market while 38.7% of those who were aware of the fact said they were better than similar sausages on the market.

The percent of fish had an effect on the scores for certain organoleptic parameters of the sausages. Color scores were hardly affected. The scores for aroma, flavor and overall quality showed the 25% fish sausages scored somewht higher. However all scores for the 25% as well as for the 50% fish sausage were within the range of 7.6-8.3 out of a total of 10. The total percent of positive responses were 88 for the 25% fish sausage and 76.9 for the 50% fish sausage. 43.6% of the panelists said the 25% fish sausage was better than a similar sausage on the market while 36.9% said the 50% fish sausage was better than a similar sausage on the market.

The method of preparation of the sausages by the consumers had a consistent influence on the organoleptic panel scores. Cooking gave the highest scores for color, flavor, aroma and overall quality. These all ranged between 8 and 8.8 out of a total possible of 10. The next highest scores were for the fried sausages. These all ranged between 7.7 and 8. The lowest scores were given to the raw state. Color suffered most resulting in a score of 7.3 out of ten. Aroma, flavor and overall quality ranged between 7.7 and 7.8 and were similar to the scores for the fried sausages. The overall net positive responses of the consumers was 85.7% for the cooked sausages, 77.0% for the raw and 68.5 for the fried. Thus the cooked again came in first but the raw and not the fried came in as a second choice. 47.6% of the consumers thought the cooked fish containing sausage was better than a similar sausage on the market while 38% said the fried and raw sausages were better than similar sausages on the market. Again here was evidence that the consumers preferred the cooked sausage over the other two methods of preparation but there was no difference between fried and raw.

CONCLUSIONS

The addition of fish to a dried sausage met with favorable responses by untrained panelists both in Israel and in Costa Rica. In fact the positive responses were recorded for over 80% of the panelists.

The population in Israel is familiar with dry sausages but generally not with raw or uncooked sausages. This affected the overall score not only of the fish containing dry raw sausage but also of the sausage control not containing fish.

In Costa Rica people generally cook or fry the sausages and are not at all familliar with a raw sausage. The raw uncooked sausage therefore was downgraded as compared to the cooked. However the scores for the raw sausage and the general acceptability was good. It will take some education to teach the population to use the sausage as is without cooking or frying.

The 25% fish was more acceptable than 50% fish as a whole by the panelists in Costa Rica but panel scores for organoleptic parameters did not show that much

difference between the two. In Israel a 33% fish content was not rejected and in fact was almost as acceptable as a pork-beef sauasage. More work needs to be done on a sausage conaining between 25 and 50% fish. The flavor also needs improving since negative comments were obtained about the saltiness of the sausage. The greasy casing also has a negative effect on consumers.

There was a tendency for the upper middle classs to give lower positive response to the fish containing sausage. However the lower class consumers gave the next lowest % net positive responses. Generally the sausages as such enjoyed good acceptability on the average among all classes. A dry sausage even by a fast process is not inexpensive to prepare. If the upper middle class as a whole is not too excited about it the price may be too high for the lower middle, middle and lower class. Therefore reformulation is necessaey to obtain a sausage whose contents are less expensive. The work with the pH observations in Israel and Costa Rica and the connection between that and weight loss showed that the lower the pH the greater the rate of weight loss.

Encapsulated lactic acid at concentrations of around 3% cause a lower pH to be obtained and a greater rate of weight loss. This reduction in time of processing plus increasing the amount of inexpensive fish in the sausage will further reduce cost. Much more work is needed especially with the last component of the sausage before a popular product can be marketed on a national scale in Costa Rica, the target population for this sausage.

SUMMARY

The most important result obtained was the positive response of the consumers especially in Costa Rica to a completely new meat product containing fish, acidified and dried. Despite the fact that the people were not accustomed to eating such a product they didn't reject it.

The dried sausages contained between 18.5-19.0% protein and would be an invaluable source of protein for children in schools especially in outlying areas. In order to assure wider acceptance and lowered cost of the product, based on the panel work during this project, a new reformulated product which will contain less sugar, 50% fish and new spicing is being produced at CITA, Centro de Investigaciones en Tecnologfa de Alimentos. The product will resemble "slim jims " salami sticks in the U.S. also popular with children, and will be presented to a panel of households in Costa Rica with instructions as to how they are to be eaten. (out of hand and not fried or cooked as many did in previous tests since that is how they were used to eating sausages in Costa Rica.

please go on to page 60

References and Bibliography

Acton, C., Williams, J.G. and Johnson, M.G. (1972) The effect of fermentation temperature on changes in meat properties and flavor of summer sausages . J. of Milk and Food Technology 35: 264.

Amlacher, E. (1961) Rigor mortis in fish, in Fish as Food by Borgstrom Georg., EditorAcademic Press, N.Y. and London, p. 403.

Association of Official Agricultural Chemists, A.O.A.C, 1980

Baird-Parker, A.C. and Freame, B. (1967) Combined effect of water activity, pH and and temperature on growth of C. botulinum from spore and vegetative cell inocula. J. Appl. Bacter. 30: 420.

Baran, W.L., Dawson, L.E. and Stevenson, K.E. (1973) Production of a dry fermented turkey sausage. Poultry Science 52: 2358.

Baumgartner, P.A., Klettner, P.G. and Rodel, W. (1980) The influence of temperature on some parameters for dry sausage ripening. Meat Science: 4:191.

Bendall, J.R. and Wismer Pederson, J. (1962) Some properties of fibrillar proteins of normal and watery pork muscle. J. of Food Science 27: 147.

Birch, G.G., Davies, R. and Parker, K.J. (1955) Intermediate Moisture Foods. Applied Science Publishers. London p. 127.

Blackwood, C.M.B. (1974) Utilisation of mechanically separated fish flesh-Canadian experience. Technology Conference on Fishery Products. Tokyo. December 4-11, 1974. pp1-5.

Branstedt, F. and Auerbach, Margaret (1961) The spoilage of fresh water fish. In Fish as Food by Borgstrom, Georg. Editor. Volume 1. Academic Press. page 613.

Collins-Thompson, D.L., Krusky B.and Usborne, W.R. (1984) The effect of nitrite on the growth of pathogens during the manufacture of dry and semi dry sausages. Can. Instit. of Food Science and Technology J. 17: 102.

Connell, J.J. (1964) Fish muscle proteins and some effects on them of processing. Symposium on Foods,Proteins and their Reactions. Chapter12: 225-294. The Avi Publishing Company, Inc., Connecticut, U.S.A.

Coretti, K. (1971) Rohwurstreifung und Fehlerzeugnisse bei der Rohwurst Herstellung. Published by Rheinhessischen Druckwerkstatte. E. Danieland Co., Alzey, Germany.

Fougere, H. (1946) L'iodate de potassium et le glucose comme agents inhibiteurs de la decomposition de poisson. J. Fish. Res. Bd. Can. 6: 441.

Gill, T.A., Dingle, J.R., Smith-Lall, B. and Stanley, D.W. (1979) Improved utilization of fish protein by quality enhancement of mechanically deboned meat. Can. Inst. Food Sci. and Technology J. 12: 200.

Graves, R. (1988) Sausage fermentation: new ways to control acidulation of meat. The National Provisioner 1988.

Jacquot, R. (1961) Organic constituents of fish and other aquatic animals, in Fish as Food by Borgstrom Georg. , Editor Vol. 1, Academic Press, p 145.

Kaoru, Tomoto (1971) The means of preventing denaturation of the ingredients of pastes. Water binding of frozen surimi. Sympsium on Characteristics of Fish Meat Muscle Proteins in the form of Frozen Surimi. New Food Industry 13: (12) Japan.

Keay, J.N. and Hardy, R. (1974) The application of extrusion techniques to the utilization of cominuted fish flesh. Second Technical Seminar; Mechanical Recovery and Utilization of Fish Flesh. Boston, Mass. June 12-13, 1974. page 105.

Keller, J.E. and Acton, J.C. (1974) Properties of fermented semi dry turkey sausage during production with lyophilized and frozen concentrates of *Pediococcus cereviciae*. J. of Food Science 39: 836.

Kitabayashi and Ishikawa (1963) Hoku sui ken 26 go. Bull. of the Hokaido Fisheries Research Institute. November 26, 1963.

Klement, J.J., Cassens, R.G. and Fennema, O.R. (1973) The association of protein solublity with physical properties in a fermented sausage. J. of Food Science 38: 1128.

Klement, J.J. and Cassens, R.G. (1974) The effect of bacterial fermentation on protein solubility in a sausage model system. J. of Food Science 39: 833.

Klettner, P.G. and Rodel, W. (1978) Uberprufung und steuerung wichtiger parameter bei der rohwurstreifung. Fleischwirtschaft 58: 57, 63 and 66.

Klettner, P.G. and Baumgartner, P.A. (1980) The technology of raw dry sausage manufacture. Food Technology in Australia 32: 380.

Koch, Herman (1966, 1989) Die Fabrikation Feiner Fleisch und Wurstwaren. Verlagshaus Sponholz. Frankfurt am Main, Germany. page 514.

Koniecho (1989) personal communication.

Kopper (1989) personal communication.

Labots, H. (1981) Aw und pH-wert konzept fur die enteilung von fleischerzengnissen in verderbliche und lagerfahige produkte. Fleischwirtschaft 61: 1

Lee, C.M. (1984) Surimi proces Technology. Food technology, November, 1984 : 69-80.

Legendre,R. (1974) Separation of flesh and bones from fish and washing of minced product. 19 th Annual Fisheries Techbological Conference, September 22-25,1974, Quebec City, Quebec, Canada: pp1-7.

Moreno, B., Calles, A., Diez, V. and Sala, F.J. (1974) Influence of pH and lactic acid on the occurrence of non specific zones of growth inhibition during antibiotibiotic-residues determination in chicken muscle. Fourth International Food Science and Technical Congress. Abstract. p. 230.

Okeda, M. and Naguchi, E. (1973) Trends in utilization of Alaska pollack in Japan, Technical Conference on Fishery Products, Tokyo. December 4-11,1973 : 2pp

Passey, Chand (1978) personal communication.

Price, J.F. and Schweigert, B.S. (1971) The Science of Meat and Meat Products. 2 nd Ed., W.H. Freeman and Co.. San Francisco. Calif., U.S.A.: page 509.

Rodel, W., Krispien, K and Leistner, L. (1979) Measuring water activity of meat and meat products. Fleischwirtschaft 59: 649.

Simidu, W. (1961) Non-protein nitrogenous compounds in fish , in Fish as Food by Georg Borgstrom, Editor, Volume 1, Academic Press ; page 353.

Sorensen, T., (1976) Effect of frozen storage on the functional properties of separated fish mince. Torrey Research Station Conference on the Production and Utilization of Mechanically Recovered Fish Flesh. Torrey Research Station, Aberdeen, Scotland. April, 1976.

Trautman, J.C. (1966) Effect of temperature and pH on the soluble proteins of ham. J. of Food Science 31: 409.

Tsatomo, Yasui (1971) The denaturation of mammal protein. Symposium on Characteristics of Fish Meat Muscle Protein in the Form of Frozen Surimi. New Food Industry 13: 57.

Wardlaw, F.B., Skelly, G.C., Johnson, M.G. and Acton, J.C. (1973) Changes in meat components during fermentation, heat processing and drying of fermented sausages. J. of Food Sci. 38: 1228.

Weiland, Georg (1980) Wir Machen Das So. Richard Pflam Verlag, KG., Munchen, Germany p.180.