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THE EFFECT OF CERTAIN PACKAGING AND STORAGE TREATMENTS ON THE ACCEPTABILITY OF FROZEN BEEF

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CONCLUSIONS

Under conditions similar to those of this experiment it may be concluded that:

Storage of frozen beef for periods up to six months at temperatures of 10°F., 0°F., and fluctuating temperatures between these ranges will not materially affect the palatability, moisture losses, or the rate of autolysis, when a good moisture vapor proof packaging material is used. Extended storage up to 12 months, or the employment of a less efficient type of packaging material will lower the acceptance of the product. A temperature of 0°F. for extended storage is desirable. This observation is in agreement with results reported by Finnegan (1939), Pennington (1943) and Sims (1947).

With defrosting temperatures ranging as high as 50°F. and where the beef is not allowed to remain defrosted more than 18 to 20 hours there is no appreciable amount of deterioration in the palatability of the cooked product even after four defrostings. The defrostings do, however, markedly impair the appearance of the uncooked ground beef, roasts and steaks.

The recommendation that once meat is thawed that it should not be refrozen appears to be an overcautious generalization. A practical guide in the handling of meat which has been thawed and refrozen should also be concerned with the length of time the product has been in the incubation zone for food poisoning organisms since this is likely to be a problem of greater importance.

There are marked differences in the protective qualities of packaging materials. Aluminum foil, cellulose film and some laminates are very efficient. Freezer waxed paper is inefficient as a protective packaging material for frozen beef.

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INTRODUCTION

The freezing of meat is an important method of food preservation. From information gathered by the department of agricultural economics of the University of Missouri it is estimated that 40 per cent, or nearly one-half million, of the farm people in Missouri are locker patrons. This does not include the thousands of families who use a home freezer unit. Seventy per cent of the lockers in the 470 plants in the state are rented to farm families. In 1947 these plants, it is estimated, processed more than 50 million pounds of meat alone. From the 1950 Farm Credit Administration frozen food locker survey it is estimated that in the United States approximately 1,300,000,000 pounds of produce are processed by locker plants each year. Of this amount 87 per cent is meat, 6 per cent fruit and vegetables, 4 per cent poultry and 3 per cent game.

In addition to the meats frozen at the locker plant and in the home freezer there is the potentially even greater commercial pack. In 1948 the commercial frozen foods pack totaled one and one-eighth billion pounds. Included in this total were but 25 million pounds of meat, 135 million pounds of poultry and 160 million pounds of sea foods.

Frozen meats are becoming increasingly well established and major developments are to be expected. The increase in the number of home units in this country from 165,000 in 1945 to approximately two million in 1951 is indicative of the change.

With increased use of low temperature refrigeration and the possible development of rapid defrosting methods it is probable that there will be an increase in the amount of retail meats prepackaged and frozen at the source of supply since packer prepackaging provides an opportunity for more economical processing and distribution. Thus, developments in the fresh prepackaged field may well serve as a forerunner for frozen prepackaged meats.

It is, therefore, highly desirable that information on the proper

handling of meats prior to freezing and during subsequent storage be obtained and made available. Improvements in the processing of this important agricultural commodity should be of real benefit in providing more adequate diet from the standpoint of nutrition and palatability as well as aiding the more orderly marketing of livestock and meats. This, in turn, should benefit the producer, processor, and consumer.

Extensive research has been carried on in frozen meats for more than a decade, and a substantial amount of work has been reported on the effect of storage temperatures and the length of storage on the keeping quality. In general, the reports indicate that the maintenance of a uniform temperature of 0°F., or lower, results in the maximum retention of the quality. Likewise, studies have shown that packaging materials showing minimum oxygen and moisture vapor transmission characteristics also result in maintenance of the highest quality. Relatively little is known, however, of the effects of various storage treatments which include marked fluctuations and defrostings. The generally accepted opinion is that these treatments are most undesirable as indicated by the recommendations, i.e., "never refreeze products which have been allowed to thaw;" "it is more desirable to store at a higher but even temperature than it is at a low but fluctuating temperature." These recommendations are rather too broad and of dubious value since they are not always consistent with the results obtained. The practicability of such recommendations is also debatable. Should, for example, meat which has inadvertently thawed in a home freezer or refrigerated car be refrozen? Is it not important to consider the magnitude of these changes as they relate to the acceptability of the product? Should not the recommendations also give consideration to the materials in which the meat is packaged? Also, should not the differences be related to the judgment of the person consuming the product? Deteriorative changes are complex and largely undefinable by means of chemical analyses now available and hence the results of such tests have not been encouraging.

The objectives of this experiment as originally conceived and designed were limited to the following:

1. A determination of the effect of temperature variation on the palatability of frozen beef.
2. An estimation of the efficiency of various types of packaging materials when used in connection with the various freezing treatments.
3. A determination of the value of free amino nitrogen as a chemical method for measuring the deterioration.

REVIEW OF THE LITERATURE

The use of selected judges as members of a panel to evaluate the quality of the product has been a practice for centuries and with certain of the beverage industries (wine and tea) has become well established. The principal reasons for using the highly trained panel is in the determination of small sensory differences. The chemical and physical tests may be used to supplement the more subjective organoleptic evaluation but, as pointed out by Lowe and Stewart (1947), the acceptability is of necessity based on subjective reactions.

The physical measurements have generally been more closely correlated with the subjective evaluation than has been the case of the purely chemical evaluation. Thus, Lowe (1937), Brady (1937), Stewart (1941), Shrewsbury (1942), Paul (1944), and Ramsbottom (1945) have all reported a high correlation between judges' scores for tenderness and the mechanical shear test.

Autolysis of proteins involves a series of complex changes and it is not surprising that in the determination of the amount of autolysis by certain chemical and organoleptic criteria no such simple or direct correlation may exist between them. Allison (1948), for example, concludes that no definite or satisfactory correlation exists between any of the following tests: bacteria count, peroxide numbers, iodine numbers, ammonia content, number of volatile amines, tyrosine and histamine present, indoles present, hydrogen sulfides given off, volatile substances oxidized by potassium permanganate, quantity of trimethyl amine present, and the number and amounts of volatile acids given off. The difficulties of relating chemical tests to organoleptic tests may also be due to some extent to the marked variability of the individual's response to a given stimulus at different times. Fox (1932) has shown that 40 per cent of the people tested were taste blind to bitter. King (1937), however, found no cases of taste blindness in a group of people tested for their ability to detect primary taste. There were, however, marked differences between the individuals since only 25 per cent had fairly acute tasting ability. Blakeslee and Fox (1932) have demonstrated that ability to distinguish taste differences varies greatly between individuals from one substance to another. There is a possibility that differences exist between those of different ages and sex. Baten (1950) has shown that young and mature people do not evaluate certain foods the same. While health, smoking, physiological factors and age have all been considered to have an important bearing on the individual's ability to distinguish differences the evidence to this effect is not clear cut. Knowles and Johnson (1941), for example, have reported that they could find no correlation between

the ability to identify the primary taste and age, experience in judging, and smoking. Likewise, Harding and Wadley (1948) have pointed out that the evidence of superiority of any age group is incomplete and contradictory. This does not, however, suggest that certain basic and standardized procedures proposed by Peret (1949) should not be rigorously followed.

Studies on the keeping quality of meats are not new. Gautier (1897), one of the earliest workers, made an extensive study of the chemical, physical and organoleptic changes which take place in beef and lamb. Richardson and Sherubel, as early as 1909, pointed out that temperatures of -9°C. (15.8°F.) were adequate for storage of beef for 554 days or longer. It will be noted here that the criteria for quality was considerably lower than would be considered satisfactory today since -9°C. (15.8°F.) is a temperature not considered effective in controlling microbial growth or enzymatic action.

In the extensive investigations of Hoagland, McBryde and Powick (1917) on aseptic autolysis of beef, aseptic samples were held at 37°C. (98.6°F.) from seven to 100 days. During this time there was an increase in protease, non-coagulable, amino and ammoniacal nitrogen and a decrease in coagulable nitrogen. The amino nitrogen content was found to increase regularly and in proportion to the length of storage. It was their opinion that the measurement of amino nitrogen was the most reliable and practical means of measuring autolysis.

Some investigations have been carried out on the value of using the increase in sulfhydryl groups as a measure of hydrolysis. Smordinstev and Tziganoua (1935) stated that sulfhydryl groups were not sufficiently defined to characterize different stages of muscle autolysis. McCarthy and King (1942), however, in a study of high temperature beef aging claimed that an increase in sulfhydryl groups was characteristic of early stages of protein denaturization. They also report the soluble nitrogen was higher with high temperature aging.

Investigations have been carried out by Tarr and Bailey (1939), Bradley and Bailey (1940), Graham (1946), and Duggan (1948) on the value of tyrosine and tryptophane production as a measure of autolysis. While most of the work was on products other than meat the results were not encouraging, although there was some indication of a relationship to the organoleptic evaluation.

Lucke and Geidel (1935) reported that in the case of fish the volatile basic nitrogen was the best test for characterizing the freshness of the fish.

A review of the literature indicates that there is no entirely satisfactory test for meat autolysis or spoilage. Furthermore, there

is little encouragement that a simple chemical test will be developed which not only will correlate closely with the organoleptic evaluation but which also will detect deterioration prior to the time at which it may be noted organoleptically. The volatile basic nitrogen and the amino nitrogen content apparently offer some encouragement in this direction.

Deterioration in frozen meats is reportedly brought about by a number of factors such as (1) prefreezing treatments including packaging; and (2) freezing and subsequent storage treatments. The recommendations on quick chilling, prompt freezing, proper sanitation and careful handling are well known and appear to be amply substantiated by both experimental and practical observations in the industry. While the advantages of quick freezing have apparently been over emphasized, a portion of the confusion can be credited to present inadequacies in defining and differentiating "quick" and "slow" freezing, especially with reference to particular sizes and kinds of products. Storage temperature recommendations have generally centered on 0°F. or lower, the factor of economy in the mechanical operation of the refrigeration being an important consideration. No small amount of attention has been given to the effects of dehydration and fluctuating temperatures, Tressler (1935), Melhart (1939), Finnegan (1939), and Gortner *et al.* (1948). Of special interest is the work of Gortner *et al* in 1946, who in a study of temperature variations between 0°F. and 20°F. report that the palatability over a 12 months storage period was apparently a function not so much of the fluctuation in temperature but rather could be attributed to the actual length of storage at each temperature. This is in contradiction to the work of Sims (1947) who reports that beef fluctuated between 0°F. and 16°F. on seven day cycles underwent changes similar to those occurring at 16°F. storage.

The value of good packaging has been increasingly recognized. The importance of an effective moisture vapor barrier has been repeatedly pointed out, Woodroof (1941), Schaffer (1944), Finnegan (1939) and Brookbank (1949). Steinberg, Winter and Hustrulid (1949) and others have more recently focused attention on the necessity of the packaging material serving as an oxygen barrier.

EXPERIMENTAL

The beef used in this experiment was selected from eight steers and eight heifers grading "high commercial" and "low good." Two days after slaughter the carcasses were broken down and 18 ribs, four loins and eight rounds set aside for this experiment. On the third and fourth days after slaughter the top rounds were each cut into nine three-quarter inch steaks and the loins into one-inch

T-bone steaks. The rib cuts were divided into four roasts each, namely: 6th, 7th and 8th, 9th and 10th, and the 11th and 12th ribs. The 6th rib, and the 7th and 8th rib roasts were used for chemical analyses while the 9th and 10th, and 11th and 12th ribs were used for the organoleptic testing. The remaining portions of the rounds and the flanks were ground twice and thoroughly mixed. The resulting ground beef was rather lean and was comparable to the best type of market ground beef. Subsequent chemical analysis (Table 8) indicates this to be a close approximation. Altogether, 90 one-pound packages were prepared. All of the meat was frozen on coils at a temperature of -10°F. and stored at 0°F.

Storage Temperature Treatments

A total of five experimental storage temperature treatments were used as indicated in Table 1. They consisted of:

1. 0°F. storage, 6, 12 months (actual temperature averaged -0.1°F.)
2. 0°-10°F.w., 6, 12 months storage at 0°F. and 10°F. on alternate weeks (actual temperatures averaged -0.1°F. and 10.8°F.)
3. 10°F., 6, 12 months (actual temperature averaged 10.8°F.)
4. 0°F.v., 6, 12 months. Wide variation temperature storage (actual average range in product temperature from -4°F. to 8.5°F., each complete refrigeration cycle being made in 24 to 30 hours).
5. 0°F. coincident with from one to six defrostings as indicated in Table 2.

TABLE 1--TREATMENT OF 258 BEEF SAMPLES

Temperature Treatment	Round Steaks	Rib Roasts	Loin Steaks	Ground Beef
0°F.	8	8	8	10
0°-10°F.w.	8	8	8	10
10°F.	8	8	8	10
0°F.v.	24	24	0	30
0°F., 1 to 6 defrostings	24	24	0	30
Total	72	72	24	90

The average load for each defrosting was 34 pounds which was approximately 12 per cent of the storage capacity of the freezer. The relatively short time intervals given in Table 2 should, therefore, not be interpreted in terms of a heavier product load. Altogether five recording potentiometer leads were used to secure the average temperature data shown in Table 2. Except for the air temperature recordings the readings were made from the center of each cut.

TABLE 2--AVERAGE TEMPERATURE CHARACTERISTICS OF BEEF DEFROSTING CYCLES

Temperature	Average Length of Time Elapsed in Hours			
	Ground Beef	Steak	Roast	Box Air Temperature
Min. to 24.8°F.	15.7	15.0	18.8	5.9
24.8° to 32.0°F.	14.3	13.9	18.2	5.4
32.0° to Max.	17.7	17.6	13.8	32.4
Max. to 32.0°F.	3.2	3.0	4.4	1.2
32.0° to 24.8°F.	6.3	7.3	11.2	0.6
24.8° to 0°F.	9.5	11.2	20.0	1.5
Av. Max. Temp. °F.	49.9°F.	50.6°F.	39.8°F.	53.3°F.
Av. Min. Temp. °F.	- 7.2°F.	- 4.0°F.	- 4.0°F.	- 6.4°F.

Packaging Treatments

All of the meat samples were packaged confectioner's style in the following materials:

1. Coated cellulose film, 300 MSAT—83 cellophane (Dupont) overwrapped with 30 pound unbleached Kraft.
2. Waxed paper consisting of 35 pound basis raw weight stock to which 18 pounds of micro-crystalline wax with additives had been applied.
3. Aluminum foil, .0015 gauge.
4. Laminate A. Wet strength Kraft laminated to plasticized glassine.
5. Laminate B. Wet strength Kraft laminated to plasticized glassine.

The ground beef samples were packaged in all five of the materials listed. The steaks were packaged in Laminate A and the roasts in cellophane overwrapped with Kraft. The 258 samples were weighed before and after packaging. The round steaks and rib roasts were paired, one being used for the organoleptic testing and one for the chemical analyses. The ground beef packages were halved at the completion of the storage period for the palatability and chemical tests while the loin steaks were used only for the palatability tests.

All of the meat samples were weighed before and after packaging at the beginning and the end of the experiment. At the end of six and 12 months storage periods weights were taken before and after the packaging material was removed and before and after the frost was brushed off. The weight loss was expressed as the percentage of frost loss, evaporation loss and total loss.

Procedure Followed in Palatability Studies

A "closed panel" consisting of four members was given the following instructions:

1. Determine the intensity and desirability of the aroma and check appropriate terms listed in Figure 1.
2. Masticate, but do not swallow, a portion of the sample to determine the intensity and desirability of the flavor and check appropriate terms listed in Figure 1.
3. Take a drink of water before and after each sample is tested.
4. Do not converse during the tasting period.

To insure greater accuracy there were no substitutions in the panel and, to minimize fatigue, the number of samples tasted at each session was limited to ten. Prior to cooking, the samples were defrosted in a domestic refrigerator at 40° to 50°F. The time required was approximately 40 to 48 hours for the rib roasts, 20 to 24 hours for the steaks and ground beef. A griddle preheated to a temperature of 375°F. was removed from the heat and a 100-gram ground beef patty, approximately one-half inch in thickness, was placed on it immediately. After five minutes the patty was turned over and the griddle then placed for 15 minutes in an oven which was pre-heated to 300°F. On removal from the oven the patty was quartered for the judges. The steaks were cooked on a griddle at approximately 375°F. for 10 minutes on each side, a total of 20 minutes. The steaks were sampled very nearly in accordance with the recommendations of the Committee on Preparation Factors, National Cooperative Meat Investigations, *Meat and Meat Cookery* (1942). The roasts were cooked (158°-162°F. internal temperature) and served in accordance with the recommendations of the Committee on Preparation Factors.

Free Amino Nitrogen Determinations

Ground beef samples identical to those used for the palatability tests were used for the free amino nitrogen determinations. The 9th and 10th, and the 11th and 12th rib roasts were used for the palatability testing while the 6th, and the 7th and 8th rib roasts were used for the free amino nitrogen determinations. The top round steaks were randomized initially without regard to size or weight. The uniformity of the ground beef is indicated by the average moisture content of 59.75± 2.6 per cent of the initial samples.

The samples were prepared and analyzed in the same chronological order as the paired sample tasted. The longissimus dorsi muscle which was the entire sample used was removed from the rib roast, defatted and ground four times. The top round steaks were similarly defatted and ground. The ground beef received a total of

Date _____

Cooking Laboratory No. _____ Sample No. _____ Kind _____

Factor	Phase	7	6	5	4	3	2	1
Aroma	Intensity	Very pronounced	Pronounced	Moderately pronounced	Slightly pronounced	Perceptible	Slightly perceptible	Imperceptible
	Desirability	Very desirable	Desirable	Moderately desirable	Slightly desirable	Neutral	Slightly undesirable	Undesirable
Flavor of Lean	Intensity	Very pronounced	Pronounced	Moderately pronounced	Slightly pronounced	Perceptible	Slightly perceptible	Imperceptible
	Desirability	Very desirable	Desirable	Moderately desirable	Slightly desirable	Neutral	Slightly undesirable	Undesirable

NOTE: Encircle the words which describe intensity; mark desirability with a check.

_____
(Signature of Judge)

FIGURE 1--GRADING CHART FOR COOKED MEAT

five grindings and was then thoroughly mixed by hand prior to taking aliquot samples.

For determination of the free amino nitrogen content a variation of the formol titration test was used.[1] Approximately five grams of the tissue were blended with 45 ml. of distilled water for one minute in a small Waring Blendor jar. The solution was then neutralized with N/10 sodium hydroxide. To this solution 15 ml. of neutralized formalin were added and blended for 15 seconds. The solution was then neutralized as before and the number of milliliters of sodium hydroxide titrated recorded. The determination for neutrality was made using the Beckmann pH meter.

RESULTS

Effects of Storage Temperature

Considerable differences were encountered in the effect that the temperatures had on the various samples of meat. In describing the storage temperatures reference is specifically made only to the air temperatures at which the meat was stored. This is of special importance in any discussion of the effect of the marked temperature fluctuations since the temperature changes in the large packages (roasts) took place at a much reduced rate as compared with the smaller packages (ground beef and steak).

No significant differences were found in any of the characteristics of the roasts stored at 0°F., 0°-10°F.w., 10°F., 0°F.v. and after from one to six defrostings. All of the roasts, irrespective of storage treatments, were scored slightly desirable or higher after both 6 and 12 months of storage. This is shown in Table 3. A partial explanation has been previously indicated in referring to Table 2 which illustrates the relationship between the air temperature surrounding the product and the actual temperature of the product. It will be noted that the rise in temperature in the defrosting was slower for the larger cuts, especially as the product went through the 24.8° to 32.0°F. zone, and that the larger cuts had a slower freezing rate. The average maximum temperature was 40°F. for the roasts. This was nearly 10 degrees lower than the average maximum temperatures reached by the steaks and the ground beef. Thus, it was to be expected that defrosting treatments would have a more deleterious effect on the steaks than the roasts. The differences, however, were not significant statistically. While the number of steaks was too limited to demonstrate differences there appeared to be an effect attributable to the size of the cut.

The correlation between the number of defrostings and the desirability of the steaks was low, amounting to -0.17. It will be noted

[1]Personal communication to authors from Dr. J. L. Hall, Kansas State College.

TABLE 3--DESIRABILITY OF AROMA (ROASTS AND STEAKS[1])

Treatment	Round Steak			Rib Roast			Loin Steak		
		Stored			Stored			Stored	
	6 mo.	12 mo.	Diff.	6 mo.	12 mo.	Diff.	6 mo.	12 mo.	Diff.
0°F.	5.5	4.9	+0.6	5.8	5.9	-0.1	5.2	5.0	+0.2
0°F.-10°F.w.	5.5	5.0	+0.5	5.8	5.9	-0.1	5.2	4.5	+0.7
10°F.	5.8	4.1	+1.7	6.0	6.2	-0.2	5.3	5.0	+0.3
0°F.-10°F. 1 mo.	6.0	4.5	+1.5	5.8	3.2	+2.6			
0°F.-10°F. 2 mo.	5.0	4.8	+0.2	6.0	5.5	+0.5			
0°F.-10°F. 3 mo.	6.0	4.5	+1.5	5.0	5.2	-0.2			
0°F.-10°F. 4 mo.	5.5	3.8	+1.7	5.8	4.8	+1.0			
0°F.-10°F. 5 mo.	5.2	4.2	+1.0	6.0	5.8	+0.2			
0°F.-10°F. 6 mo.	--	4.9	---	--	6.2	---			
1 Defrosting	5.5	5.0	+0.5	5.2	5.2	+0.0			
2 Defrostings	5.2	3.2	+2.0	5.8	4.0	+1.8			
3 Defrostings	5.0	5.0	+0.0	6.2	6.0	+0.2			
4 Defrostings	3.5	5.2	-1.7	6.0	6.0	+0.0			
5 Defrostings	4.5	4.0	+0.5	6.0	5.2	+0.8			
6 Defrostings	5.2	5.8	-0.6	5.2	5.8	-0.6			
Average Difference between the 6 and 12 month values			+0.7			+0.4			

[1] Refer to Figure 1 for scale of points of desirability.

in Table 3 and Table 4 that the steaks were more subject to the deleterious effects of the temperature than were the roasts. This was more noticeable for the desirability of flavor than the desirability of aroma.

Comparisons of the desirability of flavor and desirability of aroma respectively of ground beef for the 6 and the 12 month storage periods at 0°F., 0°-10°F.w., and 10°F. are shown in Figures 2 and 3. The length of storage period had a significant effect regardless of storage temperature and was pronounced for the higher storage temperatures. The effects of storage temperatures on the desirability of flavor and aroma were small but favored the lowest storage temperature. At the end of 12 months storage only the 0°F. sample remained moderately desirable in aroma while samples stored at the other two temperatures had dropped to a rating of slightly desirable. There was a very marked and highly significant difference in the desirability of the flavor of ground beef stored six and 12 months at 0°F., 0°-10°F.w., and 10°F. favoring the shorter storage period. It will be noted in both Figures 2 and 3 that there was little difference between the treatments at the end of six months storage but at the end of 12 months storage there is apparently a

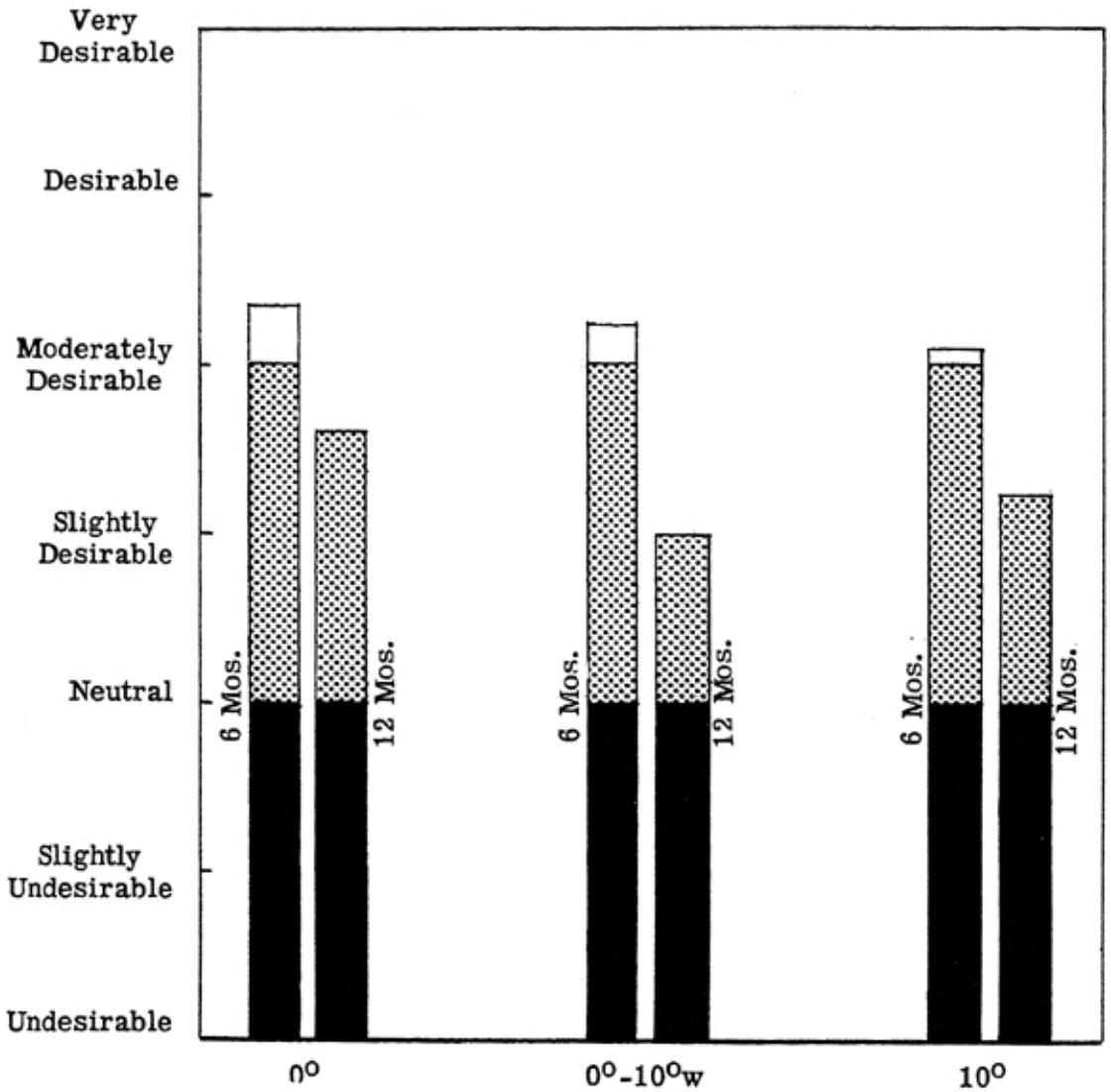

Fig. 2.—Comparison of the desirability of the flavor of ground beef stored 6 and 12 months at 0°F., 0° - 10°F.w., and 10°F. (Differences in storage period are significant at .01 level.)

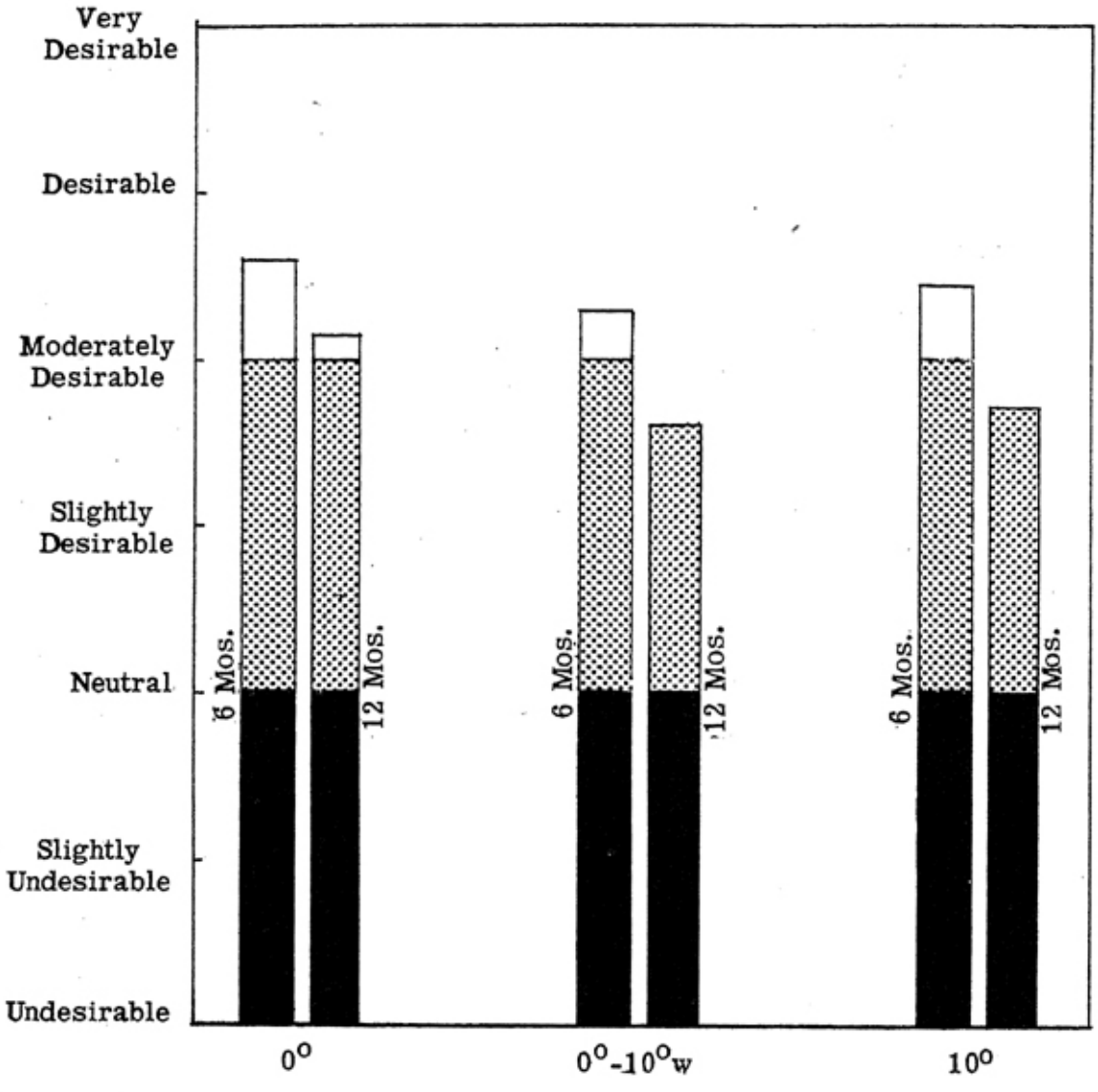

Fig. 3.—Comparison of the desirability of the aroma from ground beef stored 6 and 12 months at 0°F., 0° - 10°F.w., and 10°F. (Differences in storage period are significant at .01 level.)

TABLE 4--DESIRABILITY OF FLAVOR (ROASTS AND STEAKS[1])

Treatment	Round Steak			Rib Roast			Loin Steak		
	Stored			Stored			Stored		
	6 mo.	12 mo.	Diff.	6 mo.	12 mo.	Diff.	6 mo.	12 mo.	Diff.
0°F.	4.2	4.0	+0.2	5.8	5.6	+0.2	5.4	4.9	+0.5
0°F.-10°F.w.	5.4	4.1	+1.3	5.8	5.7	+0.1	5.3	4.9	+0.4
10°F.	5.1	3.8	+1.3	6.3	5.0	+1.3	5.1	4.8	+0.3
0°F.-10°F. 1 mo.	5.8	5.0	+0.8	5.8	4.2	+1.6			
0°F.-10°F. 2 mo.	4.5	3.8	+0.7	6.3	6.2	+0.1			
0°F.-10°F. 3 mo.	5.8	3.0	+2.8	5.2	5.8	-0.6			
0°F.-10°F. 4 mo.	5.0	3.8	+1.2	5.8	4.5	+1.3			
0°F.-10°F. 5 mo.	4.2	4.2	+0.0	5.8	5.8	+0.0			
0°F.-10°F. 6 mo.	--	3.2	---	--	6.0	---			
1 Defrosting	5.0	3.8	+1.2	4.0	5.8	-1.8			
2 Defrostings	4.5	2.8	+1.7	5.5	3.5	+2.0			
3 Defrostings	4.0	3.3	+0.7	5.5	5.8	-0.3			
4 Defrostings	2.5	3.0	-0.5	5.8	6.0	-0.2			
5 Defrostings	4.5	3.2	+1.3	6.5	5.8	+0.7			
6 Defrostings	4.0	4.5	-0.5	5.5	4.5	+1.0			
Average Difference between the 6 and 12 month values			+0.9			+0.4			

[1] Refer to Figure 1 for scale of points of desirability.

difference which favors the 0°F. temperature. The data does not support the contention that the deterioration is proportional to the length of the storage at the respective temperatures.

It will be noted that the desirability of aroma (Figure 4) is adversely affected much more quickly than the intensity of flavor (Figure 6) by the number of defrostings. After three defrostings there was a very appreciable decrease in the desirability of flavor (Figure 7). A comparison of Figures 4 and 5 indicates that the desirability of aroma was affected earlier than was the intensity of aroma. There was a significant difference between four defrostings and 0°F. storage and a highly significant difference between six defrostings and all other treatments with regard to the desirability of aroma. The correlation between the number of defrostings and the desirability of the aroma was -0.57.

Shown in Figure 5 is a comparison of the intensity of aroma for the various defrostings after six months storage. All of the samples were moderately pronounced in intensity of aroma except the samples defrosted six times. A correlation of +0.29 between the number of defrostings and the intensity of flavor indicates there is but little relationship. The sixth defrosting appeared to be dispro-

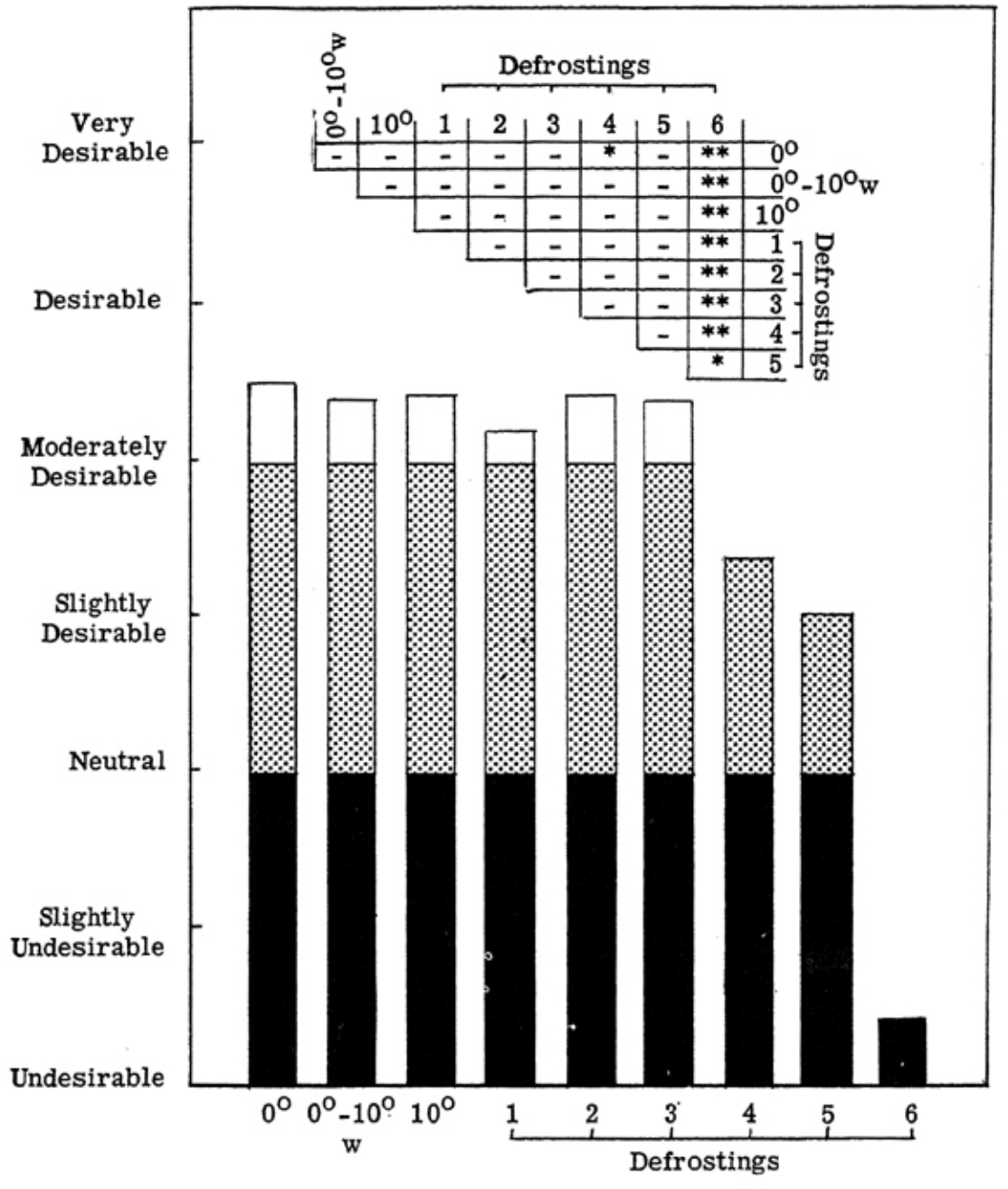

Fig. 4.—Comparison of the desirability of the aroma from ground beef stored 6 months at 0°F., 0° - 10°F.w., 10°F., and 0°F. after from one to six defrostings.

*Significant at .05 level. **Significant at .01 level.

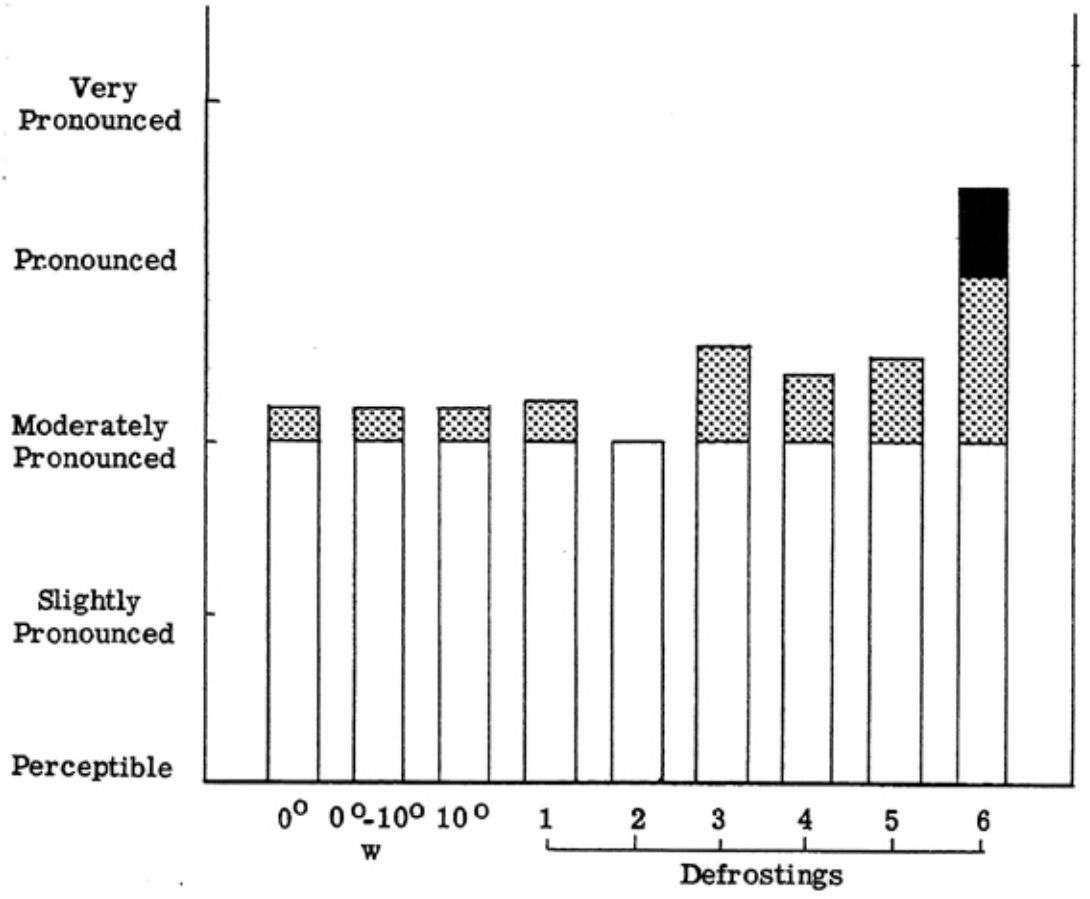

Fig. 5.—Comparison of the intensity of the aroma from ground beef stored 6 month at 0°F., 0° - 10°F.w., 10°F., and 0'F. after from one to six defrostings. (Differences between 0°F., 0° - 10°F.w., 10°F. as compared with 6 defrostings are significant at .01 level.)

portionately large in effect but may indicate the first discernible difference in the intensity of aroma.

In comparing Figures 5 and 6 it will be noted that there is a great similarity between the intensity of aroma and intensity of flavor. It is difficult to rationalize an explanation for the low values which are characteristic of the two defrostings treatment. It is apparent that after six defrostings that the samples are markedly intense in flavor and aroma which is in contrast to all other treatments. The correlation between the number of defrostings and the intensity of flavor is +0.34.

In Figure 7 is shown the marked effect of the various temperature treatments on the desirability of the flavor of ground beef. The effects of the temperature treatments on flavor are very similar to those for aroma. No significant differences were discernible in comparing 0°F., 0°-10°F.w., 10°F. and the first three defrostings. This is of considerable importance since it indicates that perhaps undue emphasis has been placed on the extent of the quality deterior-

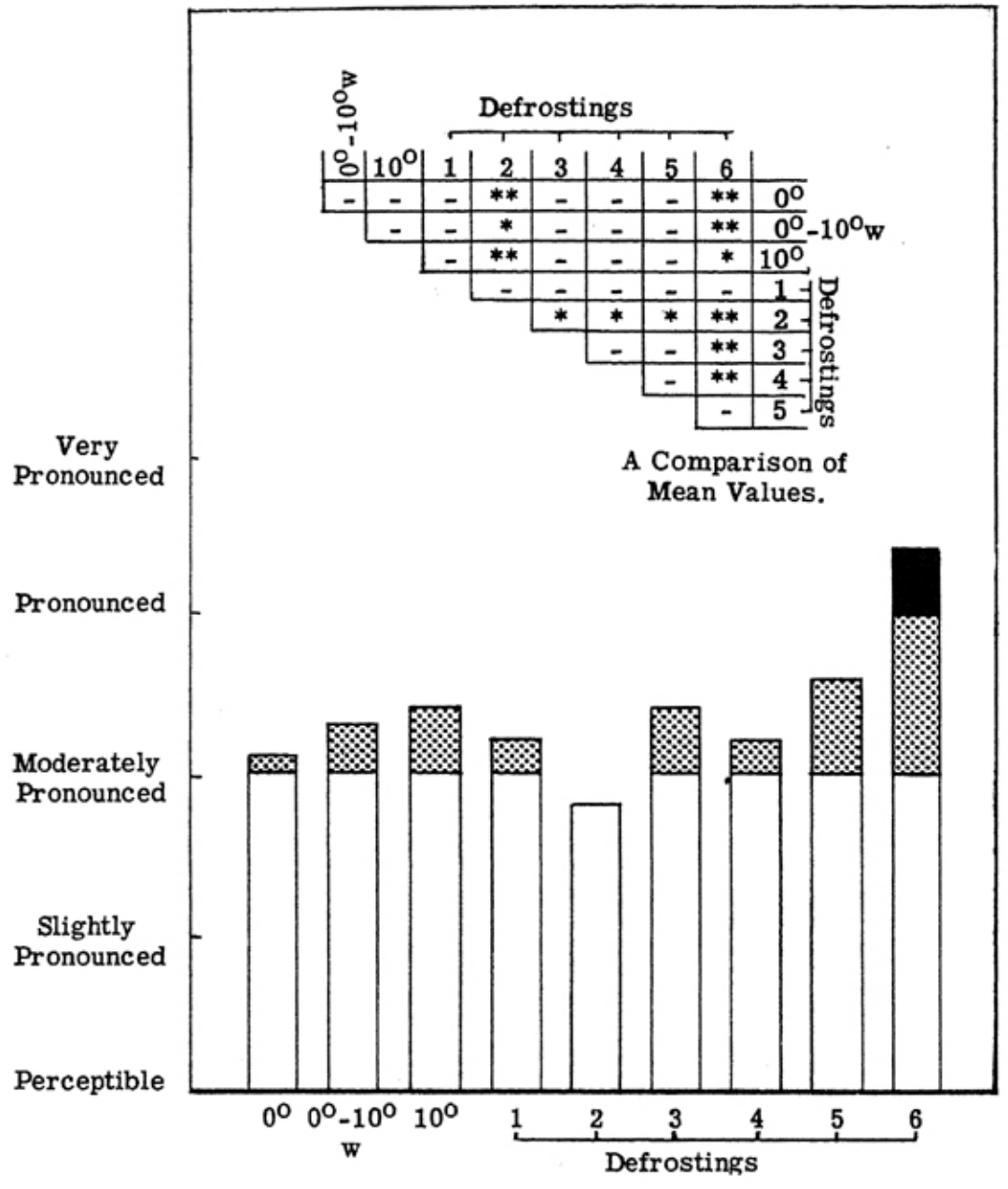

Fig. 6.—Comparison of the intensity of the flavor of ground beef stored 6 months at 0°F., 0° - 10°F., 10°F., and 0°F. after from one to six defrostings. *Significant at .05 level. **Significant at .01 level.

ation in the product where temperatures higher than 0°F. are maintained. There is an indication that the effect of the three defrostings are slightly adverse when compared with the three non-defrosting treatments. It also appears that flavor is probably more critical than aroma as a criteria for desirability. A correlation coefficient of -0.55 was found between the desirability of flavor and the number of defrostings.

Packaging

In the foregoing discussion no differentiation has been made with regard to the various packaging materials. There was reason

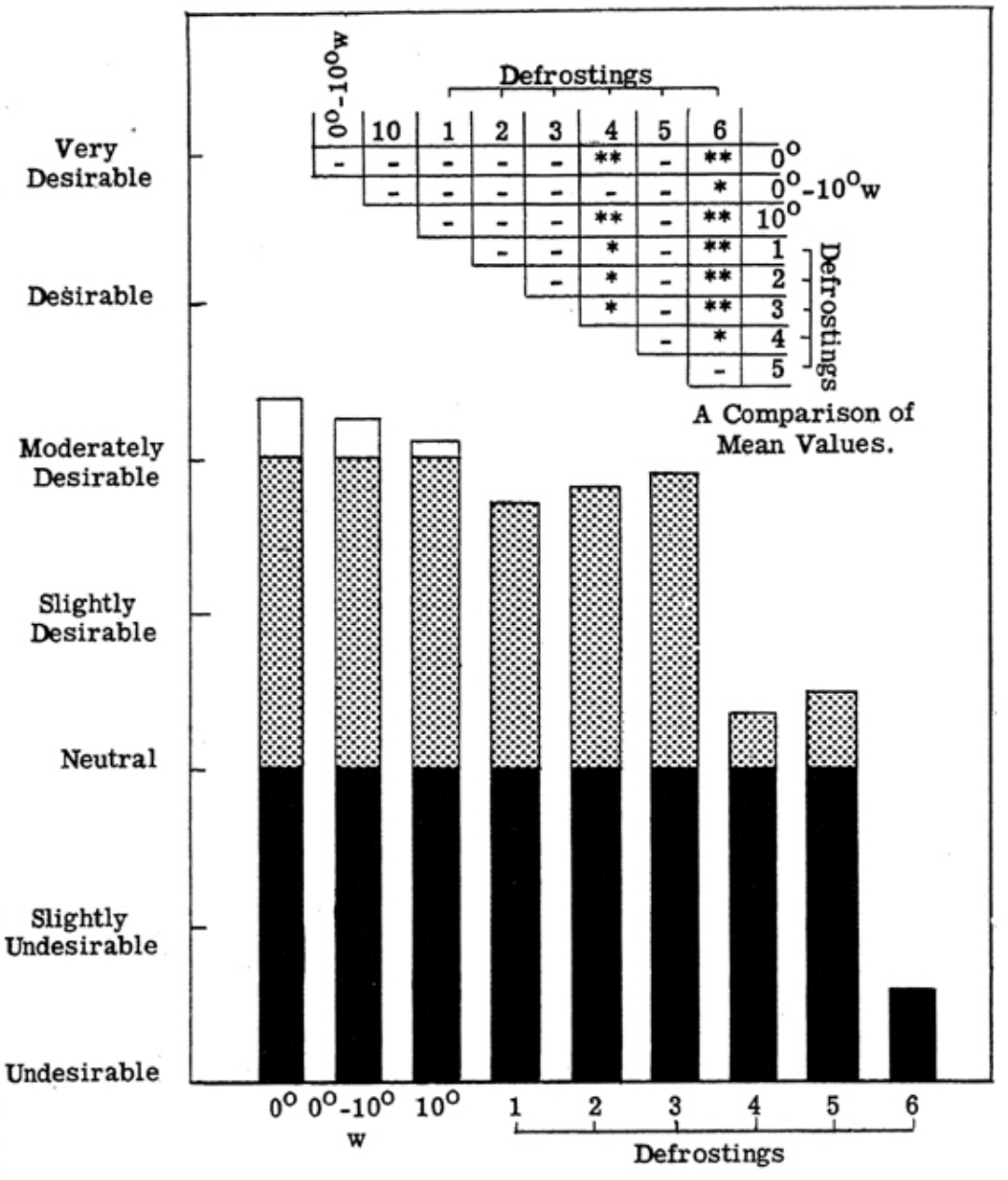

Fig. 7.—Comparison of the desirability of the flavor of ground beef stored 6 months at 0°F., 0° - 10°F.w., 10°F., and 0°F. after from one to six defrostings.
*Significant at .05 level. **Significant at .01 level.

to expect a differential response with ground beef. Figure 8 indicates the relative efficiencies of the various packaging materials with respect to moisture vapor transmission and frost loss. Frost loss is defined as the amount of moisture frozen on the outside of the cut and except in the case of the defrosted cuts is due to temperature variations as contrasted with that which is evaporated from the package. While the bar graph indicates that there is a tendency for the various packaging materials to differ in their

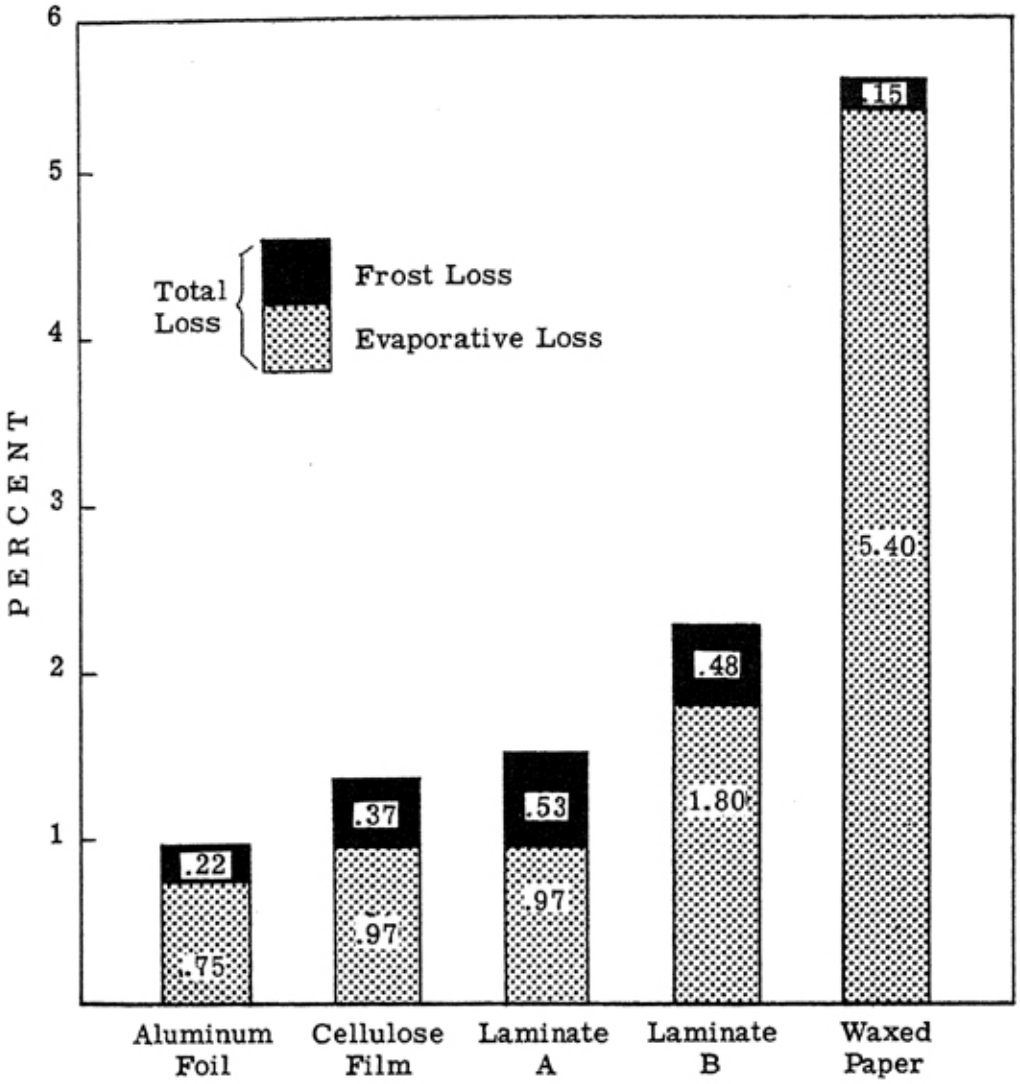

Fig. 8.—Percent weight loss of ground beef packaged in different materials and stored 6 and 12 months. Expressed as frost, evaporative, and total.* The temperature treatments were 0°F., 0° - 10°F.w., 10°F., and 0°F.v. *Differences in total loss to be significant at .05 level -2.3. **Differences in total loss to be significant at .01 level -2.6.

efficiency only in the case of the freezer waxed paper were the differences significant.

In Table 5 is shown a comparison of the moisture losses from the roasts for the various storage treatments. It will be noted that the largest losses occurred in those samples which were defrosted and hence the amount of frozen drip was especially large. The roasts stored at 0°F. showed the smallest total loss although there was but little difference when the roasts stored at 0°F., 0°-10°F.w., 10°F., and 0°F.v. were compared. Regardless of the storage treatment the moisture losses at the end of 12 months storage were not materially different than those occurring at the end of the six month storage period. This contradicts the view that has frequently been expressed

TABLE 5--THE PER CENT EVAPORATIVE, FROST, AND TOTAL WEIGHT LOSSES OF RIB ROASTS AT THE SIX AND TWELVE MONTHS PERIODS

Treatment	% Evaporative Loss		% Frost Loss		% Total Loss	
	6 mos.	12 mos.	6 mos.	12 mos.	6 mos.	12 mos.
0°F.	0.11	0.22	0.48	0.50	0.59	0.72
0°F.-10°F.w.	0.12	0.38	0.62	0.52	0.74	0.90
10°F.	0.25	0.59	0.75	0.34	1.00	0.93
1 mo. 0°F.v.	0.17	0.23	0.93	0.42	1.10	0.65
2 mo. 0°F.v.	0.47	0.44	0.52	0.38	0.99	0.82
3 mo. 0°F.v.	0.08	0.10	0.73	0.73	0.81	0.83
4 mo. 0°F.v.	0.90	0.27	0.58	0.37	0.68	0.64
5 mo. 0°F.v.	0.19	0.37	0.54	0.42	0.73	0.79
6 mo. 0°F.v.	----	0.31	----	0.45	----	0.76
1 Defrosting	0.10	0.43	1.36	0.45	1.46	0.88
2 Defrostings	1.13	1.48	1.28	1.22	2.41	2.70
3 Defrostings	0.72	0.52	1.16	1.05	1.88	1.57
4 Defrostings	0.03	0.50	1.28	1.46	1.31	1.96
5 Defrostings	0.24	0.04	0.60	1.10	0.84	1.14
6 Defrostings	2.60	1.27	1.03	0.95	3.63	2.22

to the effect that the inferior packaging materials, while not satisfactory for long term storage, could nevertheless be used satisfactorily for the short storage periods. The rib roasts had relatively high frost loss when compared to the total loss. This can be explained on the basis of the relatively high efficiency of the film as a barrier to moisture vapor transmission and the large mass to surface area of the roasts. Note Figure 13.

In Table 6 are listed the evaporation, frost and total weight losses of round steaks packaged in laminate A after 6 and 12 months storage. As in the case of the roasts, the losses were greatest for the defrosting treatments. In comparing the steaks and roasts it will be noted that the losses are several times greater for the steaks than for the roasts. For the defrosted cuts the differences were even much greater. The big increase for the defrosted cuts was due to drip or evaporation rather than frost loss. There was a loss of approximately eight per cent from one defrosting of the round steaks. The first six months, as in the case of the rib roasts, was of much greater importance than the second six months period with regard to the evaporation and total loss. The relatively high frost loss with the 0°F.v. storage treatment resulted from the marked

TABLE 6--THE PER CENT EVAPORATIVE, FROST, AND TOTAL WEIGHT LOSSES OF ROUND STEAKS AT THE SIX AND TWELVE MONTHS PERIODS

Treatment	% Evaporative Loss		% Frost Loss		% Total Loss	
	6 mos.	12 mos.	6 mos.	12 mos.	6 mos.	12 mos.
0°F.	0.45	0.68	1.21	0.65	1.66	1.33
0°F.-10°F.w.	0.59	1.57	0.63	1.30	1.22	2.87
10°F.	1.03	1.14	0.96	1.19	1.99	2.33
1 mo. 0°F.v.	0.56	0.38	2.25	0.37	2.81	0.75
2 mo. 0°F.v.	0.65	1.32	1.52	0.67	2.17	1.99
3 mo. 0°F.v.	0.00	0.47	1.16	0.94	1.16	1.41
4 mo. 0°F.v.	0.60	1.29	0.98	0.69	1.58	1.98
5 mo. 0°F.v.	0.85	1.29	1.05	0.85	1.90	2.14
6 mo. 0°F.v.	----	0.88	----	1.94	----	2.82
1 Defrosting	5.54	6.34	2.38	1.84	7.92	8.18
2 Defrostings	6.49	10.34	1.86	1.89	8.35	12.23
3 Defrostings	3.39	4.55	2.32	3.36	5.71	7.91
4 Defrostings	7.65	8.63	2.94	2.35	10.59	10.98
5 Defrostings	9.64	7.82	2.25	3.29	11.89	8.11
6 Defrostings	10.64	8.10	2.73	2.28	13.37	10.38

fluctuation in temperature which occurred in the first six months. It will be noted that a large portion of this frost evaporated during the second six months.

Dehydration proved to be a much more serious factor with the round steaks than the rib roasts. This is related in part to the high surface area relationship which characterizes the steaks. Figure 14 indicates the extent of the dehydration.

In Figure 9 is shown the average desirability of the aroma from ground beef packaged in the various materials and stored for six months. While no large differences are to be observed it is to be noted that the same general ranking of packaging materials is also to be found in a comparison of the desirability of flavor in Figure 10. The differences shown in Figure 10 are more sharply defined while in Figures 11 and 12 where the defrosting treatments were omitted the differences are much less marked. Desirability of flavor when compared with desirability of aroma appears to be a more critical measure of the relative efficiency of the various packaging materials. The smaller differences which are to be found in Figures 11 and 12 when compared with 9 and 10 and which are due to the absence of the defrosting treatments in the former indicates that good packaging provides a degree of protection with undesirable temperature treatments which is not available with the poorer packaging materials.

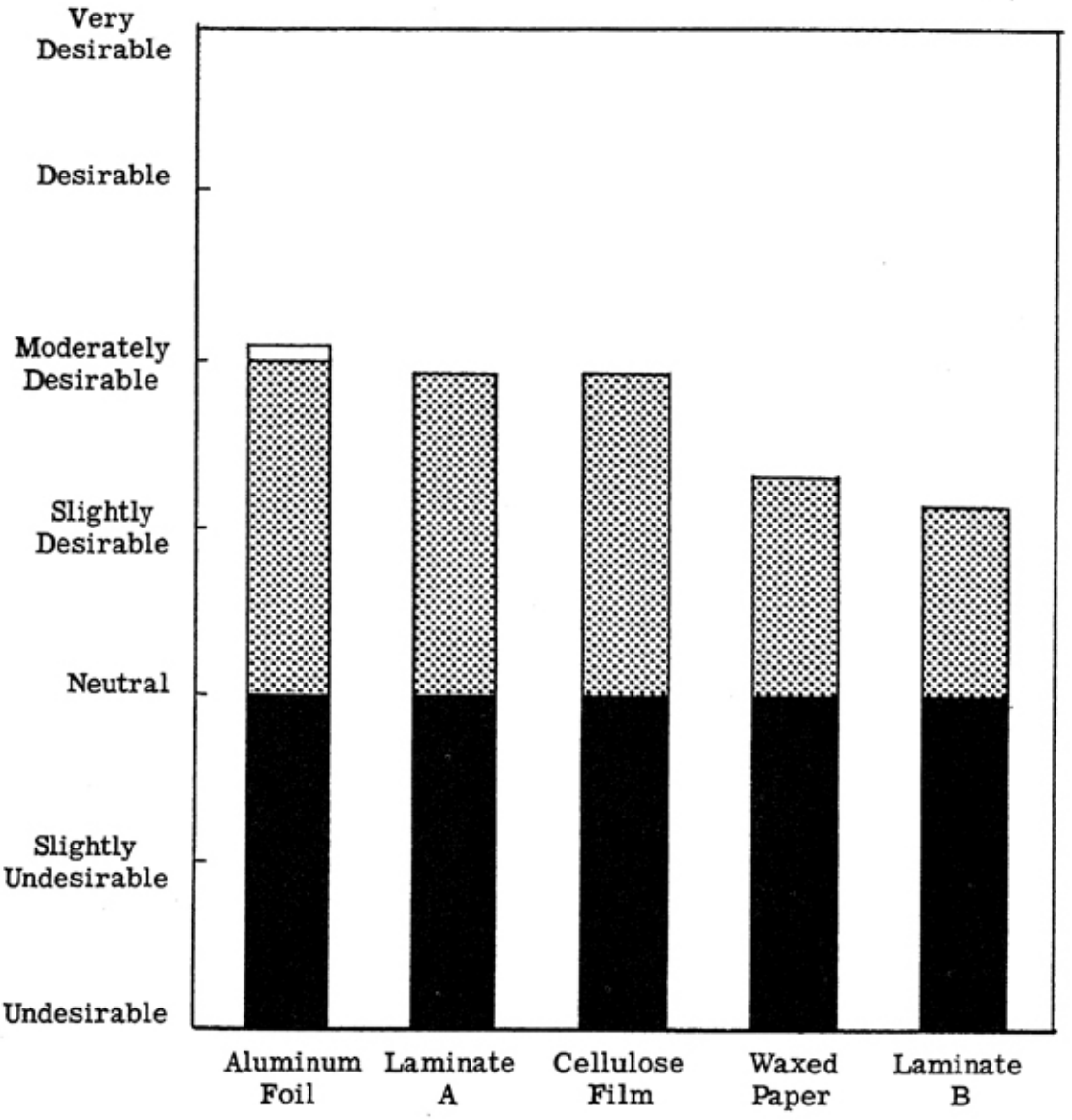

Fig. 9.—Comparison of the desirability of the aroma from ground beef packaged in different materials and stored 6 months. The temperature treatments were 0°F., 0° - 10°F.w., 10°F., and 0°F. storage after from one to six defrostings.

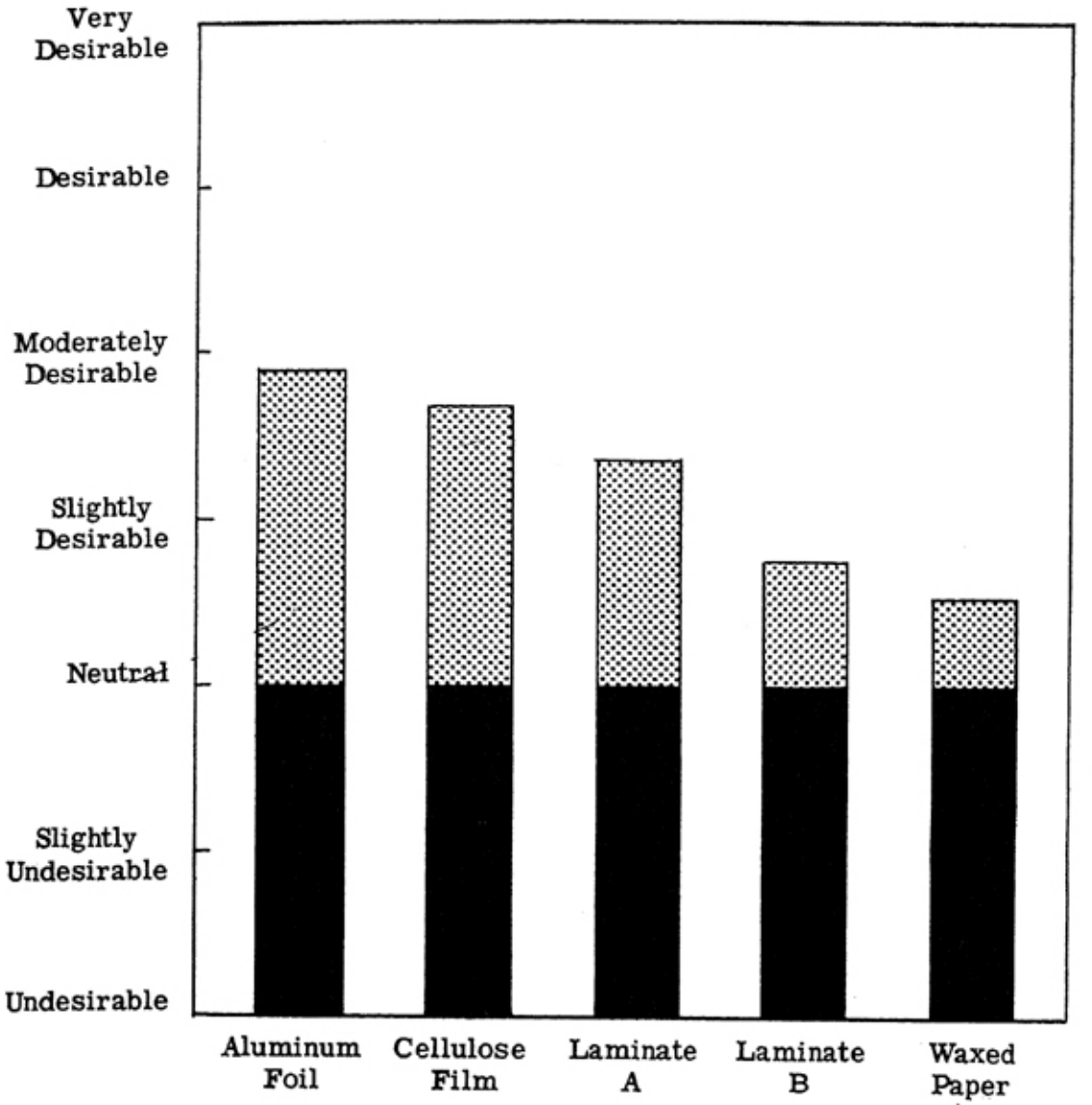

Fig. 10.—Comparison of the desirability of the flavor of ground beef packaged in different materials and stored 6 months. The temperature treatments were 0°F., 0° - 10°F.w., 10°F., and 0°F. storage after from one to six defrostings.*

*Significant difference between aluminum foil and waxed paper at .05 level.

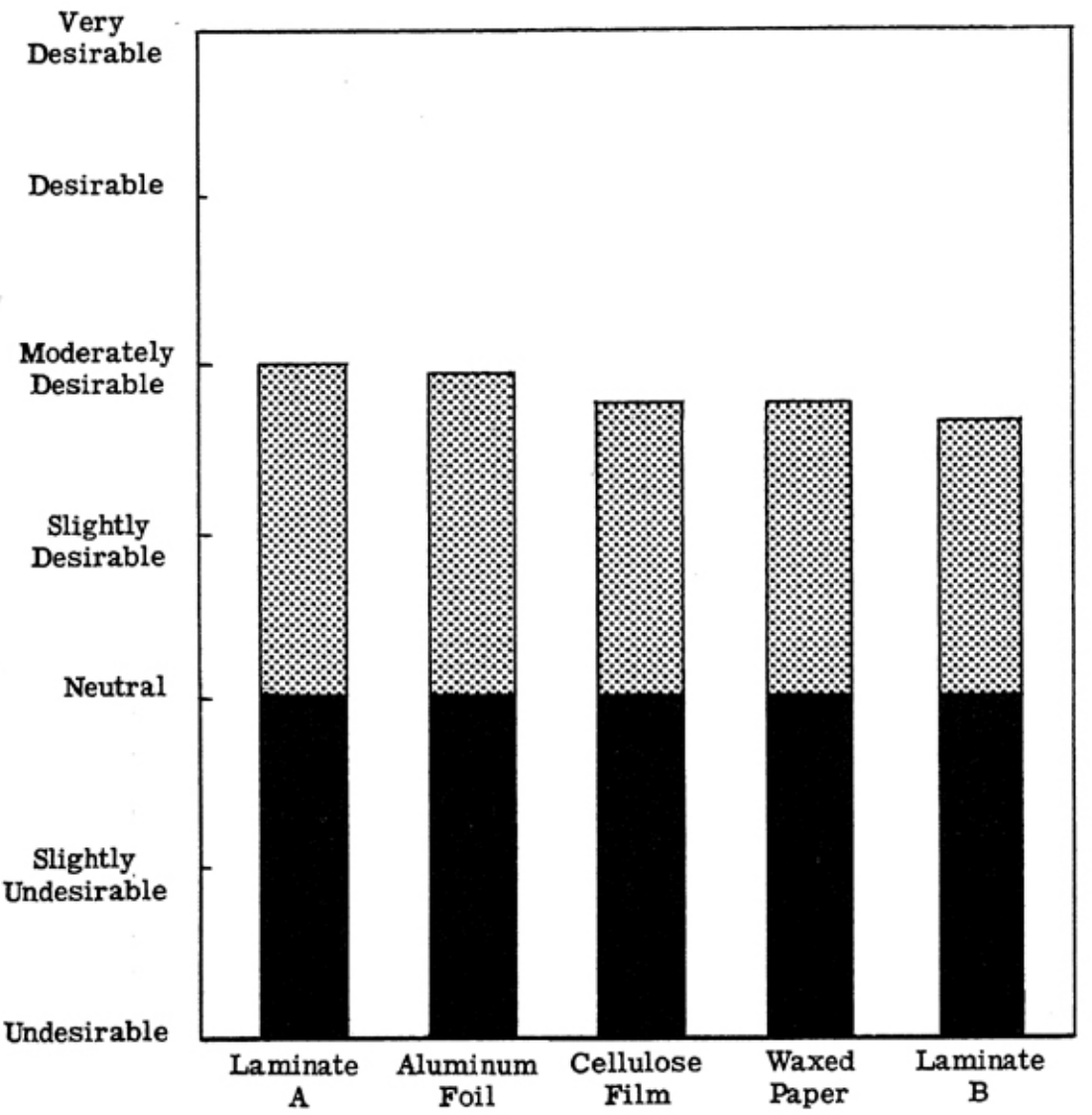

Fig. 11.—Comparison of the desirability of the aroma from ground beef packaged in different materials and stored 12 months. The temperature treatments were 0°F., 0° - 10°F.w., 10°F., and 0°F.v.

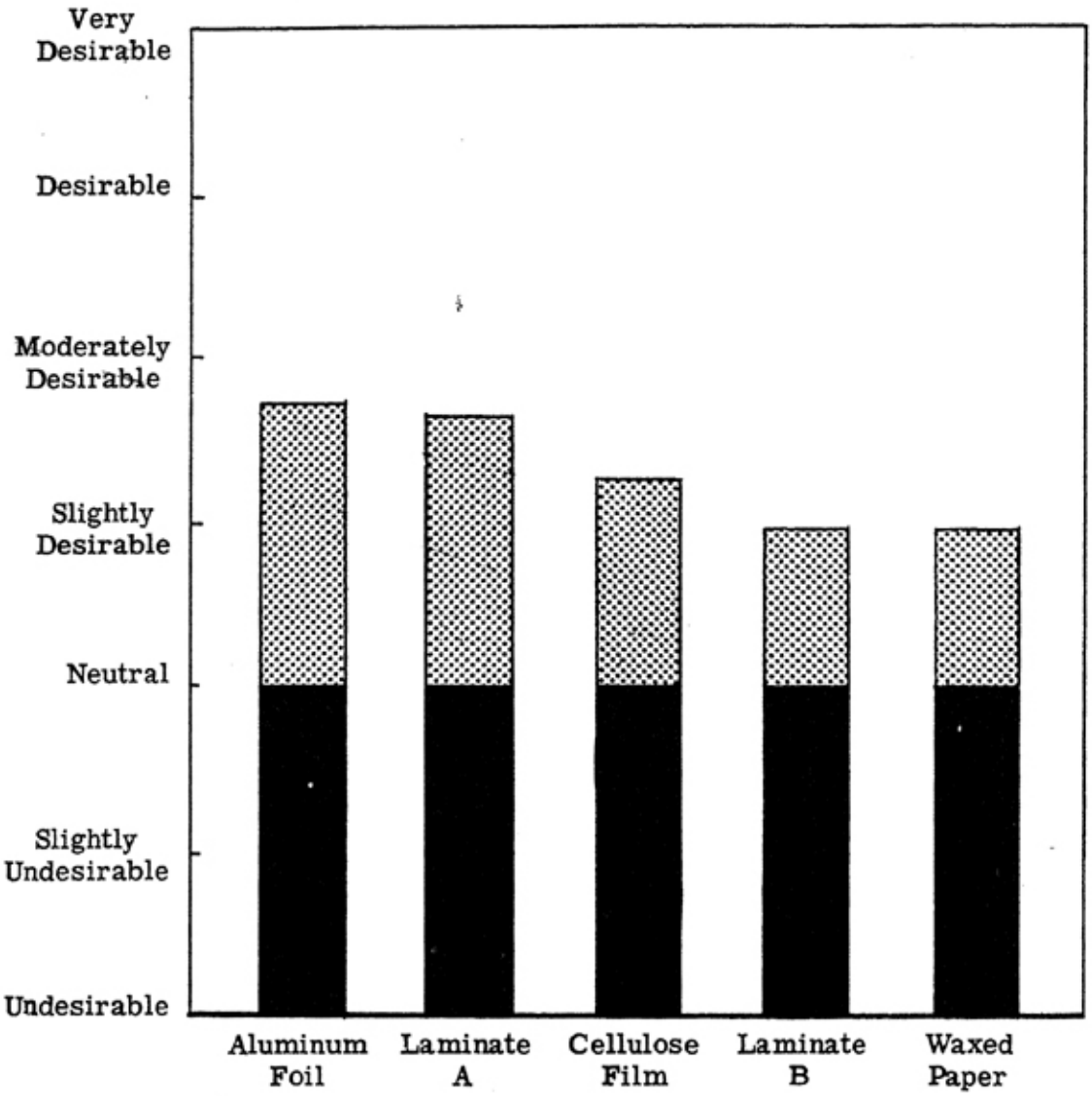

Fig. 12.—Comparison of the desirability of the flavor of ground beef packaged in different materials and stored 12 months. The temperature treatments were 0°F., 0° - 10°F.w., 10°F., and 0°F.v.

TABLE 7--THE PER CENT EVAPORATIVE, FROST, AND TOTAL WEIGHT LOSSES OF GROUND BEEF AT THE SIX AND TWELVE MONTHS PERIODS

Treatment	% Evaporative Loss		% Frost Loss		% Total Loss	
	6 mos.	12 mos.	6 mos.	12 mos.	6 mos.	12 mos.
0°F.	1.23	1.28	0.44	0.48	1.67	1.76
0°F.-10°F.w.	1.14	2.69	0.35	0.62	1.50	3.30
10°F.	2.25	2.91	0.66	0.97	2.91	3.88
1 mo. 0°F.v.	----	1.59	----	0.35	----	1.94
2 mo. 0°F.v.	----	2.11	----	0.35	----	2.47
3 mo. 0°F.v.	----	1.63	----	0.18	----	1.80
4 mo. 0°F.v.	----	1.76	----	0.31	----	2.07
5 mo. 0°F.v.	----	1.89	----	0.53	----	2.42
6 mo. 0°F.v.	----	2.91	----	0.35	----	3.26
1 Defrosting	2.38	----	1.41	----	3.79	----
2 Defrostings	1.67	----	1.81	----	3.48	----
3 Defrostings	2.47	----	1.32	----	3.79	----
4 Defrostings	3.57	----	1.89	----	5.46	----
5 Defrostings	3.35	----	1.32	----	4.67	----
6 Defrostings	3.00	----	1.67	----	4.67	----

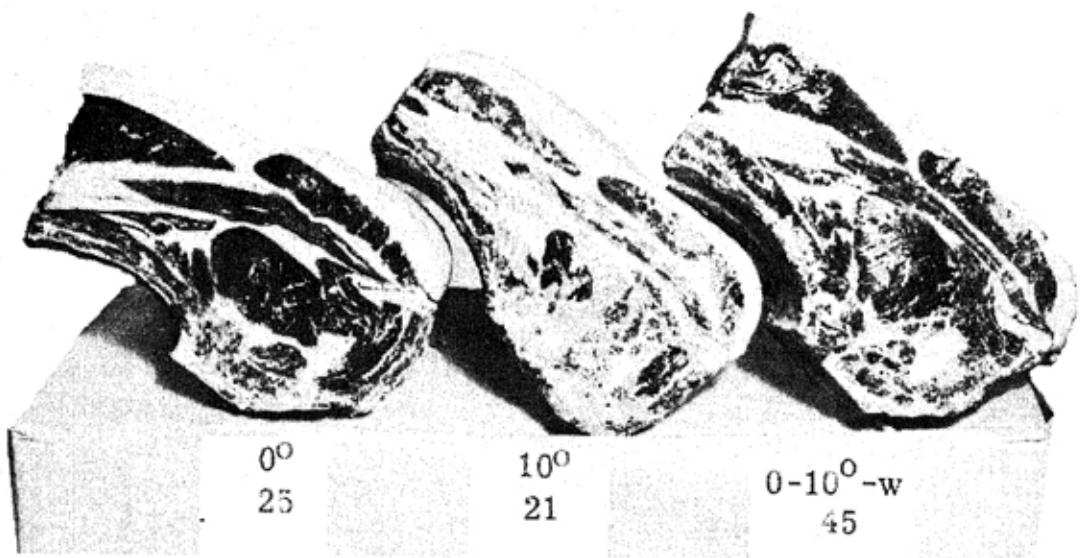

Fig. 13.—The effects of 0°F., 10°F., and 0° - 10°F.w. storage for six months on the observable frost loss and general appearances of rib roasts packaged in Cellulose film.

In Table 7 are to be found the evaporative, frost and total weight losses for ground beef stored for 6 and 12 months. While the frost loss is not greatly different for the ground beef than for the roasts, the evaporative losses are much greater for the de-

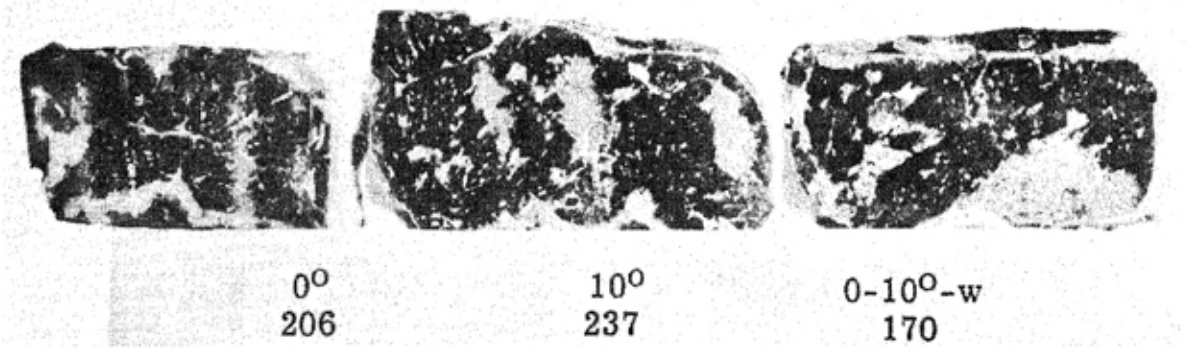

Fig. 14.—The effects of 0°F., 10°F., and 0° - 10°F.w. storage for six months on the observable dehydration of top round steaks packaged in laminate A.

Fig. 15.—The effects of different types of packaging materials on ground beef samples stored at 0° - 10°F.w. for six months. The packaging materials were aluminum foil (246), laminate A (264), laminate B (282), cellulose film (300), and waxed paper (318).

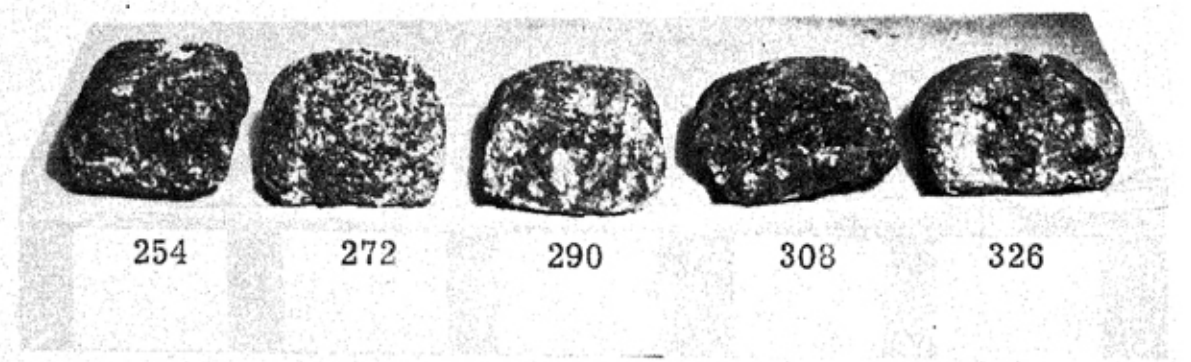

Fig. 16.—The effects of different types of packaging materials on ground beef stored at 0°F. for six months after five defrostings on the general appearance of the samples. The packaging materials were aluminum foil (254), laminate A (272), laminate B (290), cellulose film (308), and waxed paper (326).

frosted steaks than the defrosted roasts. This indicates that the adverse effects of grinding were secondary to the large surface area which characterizes the steaks.

There are also other effects attributable to the various packaging materials that are not shown in the figures just discussed. In Figures 15 and 16 may be found some indication of the effect of different packaging materials on the quality of ground beef from

different materials. These two figures also give some idea of the amount of deterioration with two different temperature treatments after a storage period of six months.

Aluminum foil and cellulose film were superior in preserving the natural color of the ground beef and thus had the most eye appeal. The ground meat packaged in the waxed paper showed marked dehydration and discoloration.

Free Amino Nitrogen

In comparing the free amino nitrogen values of the rib roasts, round steaks, and ground beef on the various treatments (Table 8), only small variations are noted. While there appears to be a slight increase in the values for the more drastic treatments this tendency is inconsistent and no reliance can be placed on this criteria. The failure to secure an increase in the free amino nitrogen indicates that free amino nitrogen values are of exceedingly limited utility as an index of deterioration. This is further substantiated by a correlation of but +0.36 between the per cent free amino nitrogen and the number of defrostings. Inability to secure a closer relation-

TABLE 8--MEAN VALUES FOR THE PER CENT MOISTURE, PER CENT NITROGEN, AND THE PER CENT FREE AMINO NITROGEN FOR RIB ROASTS, ROUND STEAKS, AND GROUND BEEF AT THE SIX MONTHS PERIODS

	Rib Roasts			Round Steaks			Ground Beef		
Treatment	Moisture	Nitrogen	Free Amino Nitrogen	Moisture	Nitrogen	Free Amino Nitrogen	Moisture	Nitrogen	Free Amino Nitrogen
	%	%	%	%	%	%	%	%	%
0°F.	69.2	3.46	2.72	73.2	3.56	2.76	58.5	2.79	4.15
0°F.-10°F.w.	71.4	3.58	2.96	72.9	3.51	3.21	58.2	3.03	3.64
10°F.	67.8	3.32	3.24	70.9	3.49	2.72	58.1	2.77	3.72
1 mo. 0°F.v.	71.7	3.52	3.19	72.5	3.65	2.90			
2 mo. 0°F.v.	64.0	3.24	3.06	72.5	3.53	3.06			
3 mo. 0°F.v.	70.2	3.39	3.45	73.6	3.51	3.13			
4 mo. 0°F.v.	70.6	3.55	2.87	73.2	3.71	3.36			
5 mo. 0°F.v.	67.0	3.22	3.08	73.4	3.50	3.53			
1 Defrosting	70.0	3.40	3.27	70.2	3.80	2.55	57.9	2.75	3.92
2 Defrostings	70.0	3.63	3.39	70.4	3.69	3.38	58.5	2.86	3.81
3 Defrostings	67.4	3.50	3.32	67.9	3.52	3.41	58.1	2.89	4.03
4 Defrostings	69.5	3.55	3.13	72.7	3.72	3.60	53.9	2.93	3.83
5 Defrostings	72.0	3.45	3.47	70.0	3.90	3.69	58.2	2.92	4.16
6 Defrostings	69.1	3.59	3.36	69.9	3.97	3.71	58.4	2.70	4.28

ship may be attributed in part to the failure of the treatments to produce beef which could be regarded as undesirable except in the case of beef defrosted six times.

SUMMARY

1. Temperature and storage treatments generally had but a slight effect on the palatability, moisture loss and increase in free amino nitrogen. The only pronounced effect was limited to ground beef defrosted four or more times. Three defrostings followed by storage at 0°F. resulted in a product at least equally as acceptable to that stored at 10°F.

2. Beef stored for 12 months was appreciably less desirable than that stored for six months regardless of storage temperature. Limitation of the length of storage period is the most important criteria in the maintenance of optimum quality.

3. Aluminum foil followed by special cellulose film and laminate A were superior in their ability to prolong the period of desirable flavor, aroma and appearance retention. The ability of the various types of packaging materials to retain moisture was directly related to their ability to protect the desired flavor of the product.

4. The average of the frost and evaporative losses at the end of the twelve month storage period was approximately equal to the average of the losses at the end of the six month storage period. These results indicate that the first six months of storage is the critical period for frost and evaporative losses and hence total moisture loss.

5. With a limited number of defrostings and where the defrosting temperatures were not allowed to go above 40° - 50°F. the only deleterious effect is apparently confined to the increased amount of drip as far as palatability is concerned although the appearance was much poorer.

6. Free amino nitrogen values were not found to be a satisfactory criteria for determining deterioration in beef.

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