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# LONG-TERM STORAGE STUDIES ON DEHYDRATED RATION ITEMS AND FOOD PACKETS

Utah State University
Department of Nutrition and Food Sciences
Logan, Utah 84322



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Studies were conducted for the effects of long-term storage at three temperatures (40°, 70°, and 100°F) on physical and chemical characteristics and quality of freeze-dehydrated ration items and food packets. Food packets from Meal, Ready-to-Eat, Individual (MREI) included ham and chicken loaf, beef steak, beef stew, frankfurter, fruitcake, pineapple, cheese spread, and chocolate brownies. Freeze-dehydrated ration items from Packet Long Range Patrol included beef hash, beef stew, chicken stew, spaghetti and meat sauce, chili con carne with beans, chicken and rice, escalloped pork with potato and beef and rice.

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At 100°F, storage life of cheese spread, pineapple, beef stew, chocolate brownies, and fruitcake was 12, 12, 30, 30, and 30 months, respectively. Ham and chicken loaf, beef steak, and frankfurters were still acceptable after 100°F storage for 30 months. Browning is usually associated with the high temperature storage of high sugar foods. Meat products except beef stew are apparently more stable than others at high temperature storage. Losses of quality of all food packets at 70°F for 30 months were observed. However, they were acceptable then. Storage at 40°F for 30 months had no or very little effect on quality of all food packets. They were highly acceptable then. High temperature storage affected color, volatile reducing substance, rancidity, titratable acidity, and some vitamins.

Freeze-dehydrated foods from Packet Long Range Patrol were much more stable in quality than food packets from MREI during storage at three temperatures. After 20 months of storage all freeze dehydrated foods were still in highly acceptable condition. Storage at 100°F for 20 months definitely decreased the quality of freeze-dehydrated foods. Storage at 70°F had little effect, while at 40°F it had no effect on quality of freeze-dehydrated foods.

## PREFACE

The period during which procesaed fooda will retain acceptable quality is important to all who manufacture, transport, store, or use them. Factora which determine the storage life of processed foods include the type of product, method of processing, manner of packaging, and the temperature and humidity of storage. This report presenta the resulta of part of the long-term storage atudy of 8 Meal, Ready-to-Eat, Individual ration items packed with flexible retortable pouches and 8 freeze-dehydrated ration itema vacuum-packed with flexible pouches. Ration items from MREI included ham and chicken loaf, beef ateak, beef atew, frankfurters, fruitcake, pineapple, and chocolate covered brownies and cheeae spread. Freeze dehydrated ration itema from Packet Long Range Patrol included beef haah, beef atew, apaghetti with meat sauce, chili con carne with beana, chicken and rice, eacalloped pork with potato, and beef and rice.

Project officera for the U. S. Army Natick Reaearch and Development Command, Food Sciences Laboratory were Dr. J. W. Giffee and Mr. A. S. Henick. The work waa conducted under Contract No. 17-73-C-0288

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## LONG-TERM STORAGE STUDIES ON DEHYDRATED RATION ITEMS AND FOOD PACKETS

### INTRODUCTION

The period during which processed foods will retain acceptable quality is important to all who manufacture, transport, store, or use them. As technology progresses, there are new and modified techniques employed in the preservation of food in order to maintain quality and extend the period of time from harvest to consumption of the products. With these advances, there is a need for re-evaluation of quality under various conditions. Factors which determine the storage life of processed foods include the type of product, method of processing, manner of packaging, and temperature and humidity of storage. Each item has a certain storage potential. Ideal storage conditions are not always feasible and may vary in temperature from freezing to high tropical conditions, and have humidity variance from 10 to 100%. Products typically are tested for quality at the time of production and over short-term storage, but there is need for scientifically controlled testing of the interrelationship between time, temperature, humidity, and their effect on consumer acceptance of the commodities. Packaging also plays a role in this interrelationship. Appropriate types of packaging are especially essential during storage of long duration. All of these factors will affect flavor, aroma, color, and texture, which in turn will affect acceptance of the product.

Increased knowledge of storage time under various conditions will facilitate the planning of purchasing, storage, and rotation of large quantities of food. In addition to the value of this knowledge to the armed services, it would be beneficial to institutions dealing with quantity foods and to consumers that are active in storage programs.

Adequately stored food is essential if a wide variety of foods is to be offered to people in all countries regardless of the growing season in any one country. It is also necessary during times of disaster, war, transportation, strikes, and inclement climate.

We know that foodstuffs, during storage, do undergo certain detrimental changes. In the absence of reliable objective measures these changes must be evaluated by sensory perception since, in the final analysis, it is human acceptance that will determine the fate of the foodstuff. The use of taste panels in a storage study serves two functions. They assist the investigators to establish expanded storage life data and help establish criteria for rejection of bad foods. They also provide valuable information when compared to the objective tests. The benefits of combining sensory tests with selected objective tests may also be divided into two categories. First, they establish techniques that can be used on the commodity in order to control the decrease in quality in a relatively inexpensive, rapid manner. Second, they serve the important function of elucidating the mechanism of storage degradation. Ideally, this increased knowledge will in turn lead to methods and techniques of improving storage life of foods.

This report covers the first phase of long-term storage study conducted from June 29, 1973, to June 28, 1976, and includes eight items of food packets from MREI and eight freeze-dehydrated items from Packet Long Range Patrol.

## REVIEW OF LITERATURE

Bailey (1944) reported that conditions for holding military rations in the Southwest Pacific averaged from 93-95°F during the daytime to 78-82°F during the night. Temperatures under tarpaulins where rations were stored ranged as high as 110°F. While most of the 7-10% spoilage, which was found each time the stacks were overhauled, was due to inadequate packaging or rough handling, high temperatures and humidities also resulted in a marked loss in quality of all of the products. Although the air temperature over large stacks of uncovered food in desert regions reached 108°-112°F daily, product temperatures ranged from 98°F to 100°F (Dunlop, 1945). Covering the stacks with tarpaulins caused the temperature of the product to rise to 111°-113°F on top, but it remained near 98°F at the bottom. The average temperature for storing military rations in desert regions was reported to be about 100°F. Porter and Greenwald (1971a) studied the temperature distribution and effects of insulation and night-time ventilation in an Army warehouse at Richmond, Virginia, during a three-year period. The greatest all-year temperature differential between ventilated and non-ventilated bays produced by both insulation and ventilation was from May, 1957, to May, 1958, for which 2.75°F was the mean of all monthly carton air temperature differential values. This is equivalent to only an 11% difference in reaction rate or increase in storage life for a $Q_{10}$ of 2. During the period April through July, 1957, the figure 4.25°F corresponds to an 18% difference in reaction rate, or an increase in storage life of 18% for the late spring and early summer months. They also found that using only two one-horsepower exhaust fans, the effect of combined night air ventilation and insulation was somewhat smaller (4.25°F difference in mean storage air temperature). They predicted that the installation of more fans would greatly increase the cooling and resultant food storage life. Increasing the horsepower without an increase in number of fans would be less effective.

In a study containing the detailed computer analysis of the frequencies, means, and standard deviations of temperature observations at 18 positions located in empty and loaded boxcars at both Yuma, Arizona, and Cameron Station, Virginia, Porter and Greenwald (1971b) found that the effect of both radiation and heat barrier insulation was a reduction of maximum temperatures by 10°-15°F and mean temperatures by 5°F in the more severe Yuma storage. Foil-faced kraft paper was as effective as more expensive types of insulation. Mean and maximum air temperatures near the roof of the empty boxcar at Yuma were only two degrees higher than those in the loaded car. However, at Cameron, maximum air temperature in the empty wooden car near the roof was 25°F below that in the loaded steel car, and the mean was 6°F lower. They also reported that the highest temperature on an exterior wall surface at Yuma was 173°F on the corrugated steel surface of the south end of the loaded car. Highest temperature on an interior surface was 159°F.

Porter and Ross (1959) and Porter and Greenwald (1971c) used daily maxima and a standardized average daily temperature distribution to estimate total temperature frequency in what was found to be the most critical carton, the Top Center Carton. In the large dumps, absolute maximum temperature observed in carton air was 128°F in the Top Center Carton of the Tight Pauline Stack. Absolute food temperature maximum was only 118°F. They also found that the Tight Pauline Stack had a pronounced gradient of temperature from surface to interior. The remaining three stacks showed little mean temperature gradient from surface to interior and little mean temperature difference from stack to stack, although the more protected stacks showed a smaller temperature range due to both lower maximum and higher minimum temperatures. The isolated Black Covered Abandon Ship Ration Carton air reached an absolute maximum temperature of 131°F, and its effective mean was 103°F.

King (1948) reported the storage life of certain basic items as estimated by the British and German armies. The British estimated that rice and corned beef were acceptable for two to three years at 37°C, with three to five years for rice and three to four years for corned beef at 20°C.* German estimates were two years and five years, respectively, for these items at 20°C. Flavor was considered good for three to six months at 37°C and 9 to 18 months at 20°C by British estimates; one year at 20°C by the Germans. Dried fruits and vegetables kept for six months to a year at 37°C and one to two years at 20°C by British evaluations; German results indicated three months at 37°C and one year at 0°C for dried fruits, with six months at 20°C and two to four years at -10°C for dehydrated vegetables. Brenner (1947, 1948), in the study of the stability of 13 representative canned foods used in army rations, reported that canned apricots stored at 70°F were highly acceptable after 18 months; those at 90°F had lower than original ratings but were acceptable after 18 months; those at 100°F were definitely unacceptable after 12 months. Army spread at 70°F remained acceptable after 18 months. Cheese spread and powdered whole milk remained acceptable for 18 months at each of the three storage temperatures as did green beans, yellow corn, peas, spinach, and limas. While carrots were practically unchanged at 70°F, those at 90° and 100°F were rated downward but were still acceptable after 18 months. Evaporated milk stored at 70°F remained acceptable for 10 months. Orange juice remained stable and acceptable at 70°F for 12 months. Tomato juice was acceptable for 18 months at 70° or 90°F, but for only 12 months at 100°F.

Evaluation of products in the Canadian ration pack, Arctic Pack RPX-1, following two years of service storage, showed that only 14 of 43 items remained acceptable to a 25-man score panel (Berryhill et al., 1955). Those acceptable were: hard candy, grape or orange beverage, beefsteak and onions, bacon, corn, fruit salad, steamed fruitcake, chocolate nut bread, plums, rolled oats, raspberry and strawberry jams, and one brand of cigarettes. Unacceptable were almonds, raisins, chewing gum, hamburgers with gravy, wieners and beans, beef and spaghetti, sausages, chipped beef, bean soup, pea soup, vegetable soup, chicken noodle soup, peas and carrots, peaches, oatmeal block ration biscuits, sweet biscuits, biscuit spread, honey,

*-10°C=15°F; 0°C=32°F; 20°C=68°F; 37°C=100°F

and two brands of cigarettes. Ballantyne and Anglin (1955) stored 35 items of the Canadian Arctic Ration Pack RPX-1B at 0°, 70°, 100°F, and cycled from 0° to 70°F at three-week intervals, for a period of two years. Products stored at 0°F were unchanged. Of the products stored at 70°F, tea was scored borderline; raisins, cocoa, salmon, vegetable soup, strawberry jam, biscuit spread, and canned peaches were unacceptable; scores for chocolate bars, beef and spaghetti, chicken soup, canned plums, cigarettes, and ration biscuits were erratic. Of the products cycled from 0° to 70°F for two years, scores for raisins, tea, beef and spaghetti, wieners and beans, salmon, hamburgers with gravy, spearmint gum, and ration biscuits were erratic. Stored at 100°F for one year, tea, chocolate nut bars, vegetable soup, biscuit spread, canned peaches were unacceptable; and scores for almonds, peppermint gum, and sandwich biscuits were erratic. Kemp (1958) and Kemp et al. (1958) found that enamel-lined aluminum cans performed quite well for long-term storage of 18 foods--meats, vegetables, fruits, cheese, and spreads--stored at 0° and 70°F for 24 months and at 100°F for 12 months. No leaking cans developed, though pinholing and etching of the enamel occurred. Deterioration of the foods was normal for storage and not attributable to failure of the aluminum cans.

Plough et al. (1958) obtained two groups of combat rations from the same procurement in 1954; one group was stored at 100°F and the other at 34°F for 20 months. Analysis showed that storage caused no changes in nutrient composition except losses of thiamine and of vitamin $B_6$ which were more marked at the high temperature. Brenner et al. (1948) investigated the effect of fortification on the stability of canned bread. Lots enriched with dried yeast retained riboflavin and niacin almost completely during fermentation, baking, and storage for one year at 72° and 100°F. Thiamine decreased by 15% during baking and 20 and 50% during six months at 72° and 100°F, respectively. A 1% level of yeast was more acceptable and preferable to 3%.

Cosler, Woodroof, and Grant (1953) and Cowan and Heaton (1954) reported that peanut candies kept fresh up to two years when properly packaged and stored at 0°F. With higher storage temperatures, the storage life was proportionally shorter--one year at 32°F, six months at 50°F, and only a few weeks at 70°F. Chocolate coated peanuts, peanut roll bars, and pan coated peanuts were most stable, due to the protection of the peanuts by the heavy chocolate coating; also, slight staleness or rancidity was masked by the chocolate flavor. Peanut brittle and peanut butter kisses were least stable.

Cosler et al. (1958, 1959) found that a 1% coating of zein and acetylated glyceride increased shelf life of nutmeats from one month for untreated to six months for treated nuts at 100°F, where coated peanuts and almonds in chocolate ration bars remained acceptable for more than six months. Shelf life for these candies with coated nuts at 70°F was more than two years. Mitchell (1955) found that coated fudge bars had a storage life of less than 18 months at 100°F, but were more stable at 70° and 40°F. Berryhill et al. (1954) stated that chocolate bars in Arctic Survival Packets failed to withstand more than one year of storage in satisfactory condition. Nine types of starch jelly candies in sealed polyethylene pouches changed little in 24 months at 0°F (Kemp et al., 1958), and were palatable though somewhat firmer after two years at 70°F. At 100°F, candies were acceptable but badly deteriorated in texture and flavor after six months, with candies sealed in cans maintaining a slightly better texture than those in pouches.

Mitchell (1955) reported that increases in saline fluorescence, free fatty acid formation, and losses in riboflavin of cheese spread were greater at 100°F than at 40° or 70°F. The product was virtually unchanged after 24 months at 40°F, but was significantly less acceptable at both 70° and 100°F. Kemp et al. (1958) found normal color, texture, and flavor in canned processed cheese after two years at 0°F. Some spoilage occurred within two years at 40°F, with severe spoilage within two years at 70°F, while severe spoilage with fading of color, gas formation, and oiling off took place within one year at 100°F.

Gardner (1948, 1949) reported that most of 31 canned meat items of types used in Army rations were acceptable after storage for one year at room temperature and at 100°F. Ham with raisin sauce became unacceptable, and dehydrated meat with rice, dehydrated corned beef hash, sausage links, and ham with sweet potatoes were considerably reduced in quality. Use of interior-enameled cans resulted in better appearance and flavor in all products. Canned beef and gravy was found by Mitchell (1955) to be in good condition after two years at 100°F, but cans were badly swollen after three years.

Rice et al. (1944) reported significant losses were improved by mixing the meat with various cereals, but not by packing in vacuum, carbon dioxide, or nitrogen. Rice and Robinson (1946) found no loss of niacin, riboflavin, or pantothenic acid after eight months at temperatures up to 100°F, but canned pork lost 48% and dehydrated pork or beef lost about 70% of original thiamine contents at 80°F, and there was complete loss of thiamin at 100°F. Ballantyne et al. (1958) found that beef freeze-dried to 1.0% moisture content and stored in sealed cans at 100°F remained acceptable after 12 months of storage. Hot-air-dried meat of 3.9% moisture content developed typical signs of deterioration after the same period. With a moisture content of 5.6%, meat had a slightly burnt flavor and dry texture after six months of storage. Both air-dried and freeze-dried meat with 3.9% moisture showed little deterioration after six months in storage at 100°F. Whitmore et al. (1948) found that dehydrated beef and pork remained edible for six months at 135°F, and one year at 100°F or lower, when sealed in cans with air, nitrogen, or vacuum. In foil-cellophane laminated bags, storage life was about two years at room temperature. Furgal (1954) reported that dehydrated hamburger in vacuum cans was acceptable though somewhat woody in texture after two years at 70°F. Dried steaks remained essentially unchanged in flavor and texture for ten months, dried pork chops for six months, with less alteration of fresh meat characteristics than those which resulted from routine canning.

Moschette et al. (1947) found no significant loss of ascorbic acid in tomatoes held one year at 50°F, with minor losses at 65°F and definite losses at 80°F. All samples had decreased in niacin. Patron (1955) reported loss of about 70% of vitamin C after five years at room temperature.

Moyes (1958) noted the bright attractive color of tomatoes in fruit-enamel cans after one year at 40°, 70°, and 85°F, with slight decrease in flavor and etching of can interiors at 85°F. Storage at 100°F reaulted in decreases of product and can quality within five months, and both were borderline in acceptability in 12 months. Czyhrinciw (1954) stated that canned tomatoes had a storage life of two years in tropical conditions at 85° to 90°F. Skibbe (1955) reported a shelf life of 20 months at 98°F, noting that retention of a good vacuum was more important with canned tomatoes than with many other canned fruits. Canned whole grain corn in enameled cans remained acceptable after three years at 60°F (Rice et al., 1944). McConnell et al. (1945) found no decrease in carotene content of corn stored nine months at 70°-80°F, but Guerrant et al. (1945) reported marked losses of ascorbic acid and thiamin at 110° and 85°F, and recommended storage at 42°F or lower for best retention of vitamins.

Studying the stability of vitamins in canned apricots, orange juice, tomato juice, carrots, corn (yellow, whole kernel), green beans, lima beans, peas, spinach, processed Army spread, cheese spread, dried whole milk and evaporated milk stored for 18 months at 70°, 90°, and 100°F, it was found that thiamin and ascorbic acid decreased by an average of 60-65% within six months at 100°F. Riboflavin was stable in canned foods at all three temperatures, but had declined 10 and 30% in evaporated milk and Army spread at the end of 18 months at 90° and 100°F. Carotene, vitamin A, and niacin retention was 85 to 100% at all storage temperatures, except that carotene in yellow corn, green beans, and orange juice dropped 15 to 30% below these levels (Brenner et al., 1948).

Cecil and Woodroof (1963) studied the potential life of 35 types of canned products for long-term storage as civilian or military food supplies in four and seven-year tests at temperatures from 100° to -20°F. They determined the relationships of temperature to fading or browning of colors, softening or graining of texture, development of caramelized, stale, or rancid flavor, loss of vitamins and damage to containers of various types of various canned foods.

Fishwick and Zmarlicki (1970) observed the changes in proteins and lipids during the storage of freeze-dried turkey breast muscle in air and in nitrogen. Oxidation of sulphydryl groups accounted for part of the oxygen uptake of air stored samples, and was accompanied by a decrease in soluble nitrogen greater than in control stored in nitrogen. The major deterioration process at low moisture content was a type of lipid browning reaction which was dependent on oxygen and caused discoloration and objectionable odors. Autoxidation of lipids catalyzed by haem pigments and resulting in rancid flavors was not a major deterioration process in freeze-dried turkey muscle. Fishwick (1970) also found that during storage in the freeze-dried state the iron complexes do not catalyze the autoxidation of unsaturated lipids.

Freeze-dried foods can be kept in excess of two years without any change in acceptable quality, and can remain acceptable for up to five years or more when they are stored under 65°F in the absence of oxygen and in moisture-proof containers (Gooding, 1962).

## MATERIALS AND METHODS

Seven items--ham and chicken loaf, beef steak, beef stew, frankfurters, fruitcake, pineapple, and chocolate covered brownies--were received on September 24, 1973. Another item, cheese spread, was received on October 18, 1973. All items were from MREI. They were packed in flexible retortable pouches. Another eight freeze-dehydrated items from Packet Long Range Patrol were received on July 3, 1974. These included beef hash, beef stew, chicken stew, spaghetti with meat sauce, chili con carne with beans, chicken and rice, escalloped pork with potato, and beef and rice. Freeze-dehydrated items were vacuum packed in double flexible pouches with the inside bag opened. These are all items for long-term storage study. Zero time samples were taken. The rest were put into 40°, 70°, and 100°F storage rooms. The relative humidity for the 40°F room was 75 ± 5%, 35 ± 5% for the 70 F room, and 25 ± 5% for the 100°F room.

Subjective and objective evaluations of zero time samples were made as soon as we received these items.

After 4, 8, 12, 18, 24, and 30 months of storage for items from MREI and 4, 10, 16, and 20 months of storage for freeze-dehydrated items, they were sampled for subjective and objective evaluations.

For sensory evaluation of stored food, a panel of 20 judges (minimum number) scored the color, flavor, odor, and texture of individual items and assigned an overall quality score. The sample was rated on a nine-point Hedonic scale: like extremely, 9; like very much, 8; like moderately, 7; like slightly, 6; neither like nor dislike, 5; dislike slightly, 4; dislike moderately, 3; dislike very much, 2; dislike extremely, 1. Coded samples, arranged in a randomized block design, were presented to the scorers. A maximum of six samples was scored per sitting.

### Objective Evaluation

#### Color

"L," "a," and "b" values were determined with a Hunter Color and Color Difference Meter (Model D25D2, Hunter Associates Laboratory, Inc., Fairfax, Virginia), adjusting the instrument with a atandard color reference plate for each product.

Volatila reducing aubstances (VRS)

The amount of volatile reducing subatancea of food waa determined according to the method of Luh (1961). Fifty grams of aamples were blended with 50 ml of diatilled water. The mixture was then steam distilled until 200 ml of distillate wera collected. The distillate waa diluted with distilled water to 250 ml. Duplicate aamples of 50 ml portions were treated for 30 minutes with 20 ml of 0.1 N $KMnO_4$ in 1 N NaOH. Ten ml of 5 N sulfuric acid and 10 ml of 30% potasaium iodide were then added to the flask. The iodine liberated was titrated with 0.1 N aodium thiosulfate using a 1% aoluble atarch solution as indicator. Results were reported aa milliequivalent of $KMnO_4$ per 100 g aample.

Total and reducing augara

Total and reducing sugara were datermined by the method of Shaffer-Somogyi (AOAC, 1965).

Titratable acidity

Fifty-gram sanples were homogenized with 100 ml distilled water in a Sorvall mixer. Samples were titrated to pH 8.1 with 0.05 N aodium hydroxide. Calculations were baaed on percent citric acid for pineapplea and milliequivalent acid per 100 g for other itema.

Rancidity

Free fatty acids of aamplea were extracted and meaaured according to the method described by Rockwood et al. (1947). Calculation was based on percent oleic acid.

Hydrolyaia of protein

Free amino acida were extracted with 80% ethanol and meaaured by the method of Moore and Stein (1954). The amount of free amino acida waa calculated from a atandard curve for leucine.

Thiamine

The fluorometric method (thiochrome reaction) was uaed for the determination of thiamine (AOAC, 1965).

### Riboflavin

The fluorometric method was used for the determination of riboflavin (AOAC, 1965).

### Niacin

The AOAC (1965) method was used for the determination of total nicotinic scid (nicotinic acid, its amide, snd other combined form). The sample waa hydrolyzed with 1 N sulfuric acid. The pyridine ring of the nicotinic scid liberated by hydrolysis was opened up with cyanogen bromide. The fission product wss coupled with sulfanilic acid to give a yellow polymethine dye, whose extinction waa measured at its maximum at 436 nm.

### Ascorbic acid

The AOAC (1965) method was used for the determination of ascorbic acid in pineappla. Sample extracta were titrated with 2,6-dichlorophenolindophenol solution.

The valuea presented in the tsbles, figures, and discussion sre the sverages of determinations on replicste ssmples. Analysis of vsrisnce was made and means were compared according to Tukey's ω-procedure (Steel and Torrie, 1960). HSD (honestly significant difference) at 1% level is used to judge the significance of all differencea.

## RESULTS AND DISCUSSION

### Items from MREI

### Ham and chicken loaf

The ham and chicken loaf was packed in s flexible retortable pouch. The code for this item is 08.

Effects of temperatures and duration of atorage on physical and chemicsl chsngea and quality of ham and chicken losf are ahown in Table 1 and Figure 1. As shown by Hunter Color Vslues, lightness (L) decreased gradually and redness increased in all durations of storage at 100°F. Slight and significant changes in lightness and redness occurred at 70°F storage. Storage at 40°F for 30 months did not aignificantly change the Hunter Color Values of ham and chicken loaf. Volatile reducing substances decreaaed at 70°F and 100°F storsge. Storage at 40°F for 30 months did not significantly affect the amount of volatile reducing substancea of ham and chicken loaf. Rancidity increased at 40°F storage and greatly increased at 70°F and 100°F storage in all durations. Titratable acidity remained unchanged at 40°F storage and increased at 70°F and 100°F storage in all durations. Vitamin analyses indicated that the high storage temperature accelerated the degradation of vitamina. This is especially prominent for thiamine and riboflavin. Niacin is apparently more stable during storage than thiamine and riboflavin. Storage at 40°F for 30 months has not significantly changed the contents of these vitamins. Storage at 70°F significantly decreased vitamin contents. Storage at 100°F greatly decreased contents of vitamins--especially thiamine and riboflavin. The loss of these vitamins at 70° and 100°F occurred mostly in the first year of storage.

For sensory evaluation, ham and chicken loaf was heated for serving to the judges. As shown in Fig. 1, storage for 30 months decreased individual and overall quality of ham and chicken loaf. Ham and chicken loaf decreased in quality faster at 100°F than at 70° and 40°F. Decreases in quality due to storage are more prominent in color and odor. HSD at 0.01 for color, flavor, odor, texture, and overall quality scores are 0.80, 0.84, 0.81, 0.91 and 0.79, respectively. All items were still quite acceptable after 30 months of storage at all three temperatures.

<u>Frankfurters</u>

Frankfurters were packed in flexible retortable pouches with four in each pouch. The code for this item is 09.

Changes of quality of frankfurters after 30 months of storage at three temperatures are shown in Table 2 and Fig. 2. Storage at 40°F and 100°F severely darkened frankfurters as shown by decreases in lightness and increases in redness. Storage at 100°F increased the volatile reducing substances. Storage at 40° and 70°F for 30 months has not significantly affected the volatile reducing substances of frankfurters. Slight increases in rancidity occurred in frankfurters stored at 70°F but not at 40°F for 30 months. Storage at 100°F greatly increased rancidity in all periods. After storage at 100°F for 30 months, rancidity increased almost three times that of the original. Slight increases in titratable acidity occurred after 12, 18, 24, and 30 months of storage at 70°F, while increases in titratable acidity occurred in all periods of storage at 100°F. Storage at 40°F has not had significant effect on titratable acidity for 30 months. For retention of vitamins, storage at 40°F for 30 months had no significant effect on contents of thiamine, riboflavin, and niacin. Storage at 70°F gradually decreased vitamin contents. Percent loss of thiamine was more than that of riboflavin and niacin. Storage at 100°F caused considerable decreases in these vitamins. Loss of thiamine occurred mostly in the 12 months of storage at 100°F.

For sensory evaluation, frankfurters were heated and cut into small pieces for serving to the judges. Fig. 2 shows the changes of quality scores of frankfurters at three temperatures for 30 months. Slight but significant decreases in color scores of frankfurter occurred after 30 months of storage at 40° and 70°F. Storage at 100°F for 30 months drastically decreased color and other individual and overall quality scores of frankfurter. HSD at 0.01 for color, flavor, odor, texture, and overall quality scores are 0.81, 0.80, 0.83, 0.82 and 0.76, respectively. Frankfurters stored at 40° and 70°F for 30 months were still in very good condition. Those atored at 100°F were still acceptable then.

Beef steak

Beef steak was packed in flexible retortable pouches with one piece and juice in each pouch. The code of this item is 03.

The effects of temperatures and duration of storage on quality of beef steak are ahown in Table 3 and Fig. 3. Storage at 100°F decreased the lightness and increaaed the redness of beef steak. Storage at 70°F had but little significant effect and storage at 40°F for 30 months had no effect on color of beef steak. Volatile reducing substancea decreased in beef steak at 70°F and 100°F storaga in most periods. Storage at 100°F also significantly decraasad titratable acidity. Storage at 100°F greatly increased rancidity in all perioda. Rancidity of those beef steaks stored at 70°F significantly increaaed in the later part of storage. Storage at 40°F for 30 months had no effect on vitamin contents. Storage at 70°F caused some loss of thiamine. High temperature storage caused conaiderable losses of all three vitamins. Storage at 100°F for 30 montha reaulted in 53% loss of thiamine and 18% loss of riboflavin. Niacin and riboflavin are more stable than thiamine during storage.

For senaory evaluation, beef steak was heated and cut into small cubes for serving to the judges of the panel. As ahown in Fig. 3, storage at 70° and 100°F for 30 months decreased individual and overall quality acores of beef ateak. HSD at 0.01 for color, flavor, odor, texture and overall quality score are 0.82, 0.81, 0.78, 0.81, and 0.82, respectively. Storage at 40°F for 30 months has not significantly affected the quality scores. Individual scores mostly affected were flavor and odor. All items, however, were still quite acceptable after 30 months of storage at three temperaturea.

Beef atew

Beef stew was packed in flexible retortable pouches. The code of this item is 04.

Effects of temperatures and duration of storage on quality of beef stew are shown in Table 4 and Fig. 4. Storage at 100° and 70°F darkened meat and juice, but not very severely. Storage at 40°F for 30 months has not changed the color and appearance of beef stew. Volatile reducing subatancea of beef stew significantly decreased at 70° and 100°F atorage, but not at 40°F storage. Rancidity increased in all periods of storage at 70°F and 100°F. After 30 months of storage at 100°F, rancidity increased 2.6 times that of the original. Significant increases in free amino acids occurred at 70°F and 100°F storage. Storage at 70° and 100°F also increased titratable acidity. After 30 montha of atorage at 100°F, beef stew contained 38% more titratable acidity than that of the original samples. Vitamin analyses indicated that considerable losses of thiamine, riboflavin, and niacin occurred at 100°F storage. Storage at 70°F resulted in some loss of these vitamins. Loss of vitamins occurred mostly in the first 12 months of storage. Storage at 40 F° for 30 months has not significantly affected the vitamin content.

For sensory evaluation, beef stew was heated and the components were evenly distributed for serving to the judges. The changes in quality after storage at three temperatures are shown in Fig. 4. HSD at 0.01 for color, flavor, odor, texture, and overall quality scores are 0.78, 0.79, 0.79, 0.83, and 0.76, respectively. Storage at 40°F for 30 months did not significantly affect quality score. Storage at 70°F for 30 months slightly and significantly decreased the color, odor, and overall quality scores. Storage at 100°F drastically decreased the quality score, especially odor and flavor. It tasted very sour and was unacceptable, with overall quality scores of 4.4 to 4.1. Its storage was, therefore, terminated at that time. Beef stew stored at 40° and 70°F was still quite acceptable after 30 months of storage.

Cheese spread

Cheese spread was packed in flexible retortable pouches. There is no code for cheese spread. This item was not sterilized in the processing.

Effects of temperatures and duration of storage on some physical and chemical characteristics and quality of cheese spread are shown in Table 5 and Fig. 5. Storage at 100°F severely darkened the cheese spread. Storage at 70°F significantly darkened the cheese spread. Storage at 40°F for 30 months had little but significant effect on color and appearance of cheese spread. Storage at 70°F caused increases in volatile reducing substances, rancidity, titratable acidity, and free amino acids. Slight but significant increases in rancidity occurred in cheese spread after 24 months of storage at 40°F. Thiamine and riboflavin contents of cheese spread stored at 40°F for 30 months remained unchanged. Storage at 70°F for 30 months caused some loss of thiamine and riboflavin which also occurred when cheese spread was stored at 100°F.

For sensory evaluation, cheese spreads were brought to room temperature and kneaded for serving to the judges. Fig. 5 shows the effect of temperatures and duration of storage on quality of cheese spread. HSD at 0.01 for color, flavor, odor, texture, and overall quality scores of cheese spread are 0.78, 0.80, 0.81, 0.83, and 0.86, respectively. Storage at 40°F for 30 months significantly decreased the flavor score but not other quality scores. Storage at 70°F for 30 months decreased all individual and quality scores. Sensory evaluation of cheese spread stored at 100°F was terminated after 12 months because it was bitter and unacceptable with overall quality score of 4.4. Cheese spreads stored at 40° and 70°F for 30 months were still in acceptable condition.

## Pineapple

Pineapple was packed in flexible retortable pouches. The code of this item is Z1.

Effects of temperatures and duration of storage on physical and chemical characteristics and quality of pineapple are shown in Table 6 and Fig. 6. Subjective evaluation of pineapple stored at 100°F for 12 months was terminated while objective evaluation was terminated at the 18th month. Storage at 40°F slightly darkened pineapple and at 70°F moderately darkened it as shown by decreases in lightness and increases in redness. Storage at 100°F severely darkened pineapple. This is caused by non-enzymatic browning and caramelization of high sugar items, especially at high temperature. Storage at 40°F for 30 months significantly increased the volatile reducing substances. The higher the storage temperature the more the volatile reducing substances produced. Titratable acidity of pineapple stored at 100°F increased for 8 months and then decreased. After 12 months of storage at 70°F, pineapple had higher titratable acidity than that stored at 100°F. After storage at 40° and 70°F, some sucrose in pineapple turned into reducing sugars. This is apparently due to acid catalyzed hydrolysis of sucrose. Significant decreases in vitamin C of pineapple resulted from storage at 40° and 70°F for 30 months. Storage at 100°F for 12 months resulted in 50% loss of ascorbic acid in pineapple.

For sensory evaluation, pineapple with syrup was brought to room temperature for serving to the judges. Changes of quality scores during storage at three temperatures are shown in Fig. 6. Storage at 100°F drastically decreased the individual and overall quality of pineapple. HSD at 0.01 for color, flavor, odor, texture, and overall quality scores are 0.79, 0.81, 0.87, 0.77, and 0.85, respectively. Storage at 40°F for 30 months significantly decreased the color scores. Storage at 70°F significantly decreased the color, flavor, odor, and overall scores. Texture was not significantly affected. After storage at 100°F for 12 months, pineapple became brown, sour, bitter, off-flavor, and unacceptable as judged by the taste panel (overall score 4.3 to 3.4). Sensory evaluation was, therefore, terminated then. Pineapple stored at 40° and 70°F for 30 months was still acceptable.

## Fruit cake

Fruit cakes were packed in flexible retortable pouches. The code of this item is 13.

Table 7 and Fig. 7 show effects of temperatures and duration of storage on some physical and chemical changes and quality of fruit cakes. Storage at 100°F for 30 months severely darkened fruit cake, especially on and around the fruit chips. This was shown by sharp decreases in lightness. Significant darkening of fruit cake occurred at 40° and 70°F storage for 30 months. Volatile reducing substances decreased after storage at 70° and 100°F. Storage at 100°F increased titratable acidity and rancidity in all periods, while storage at

70°F increased titratable acidity only in the late periods. Slight increases in reducing augars rasulted from atorage at 40° and 70°F and large increaaes in reducing sugars resulted from 100°F storage. Storage at 100°F resulted in considerabla loss of thiamine in all periods. After 30 montha of storage at 100°F, fruit cake loat 53% of thiamina, 23% riboflavin, and 13% niacin. Storage at 70°F for 24 months causad 22% losa of thiamine, 14% of rihoflavin, and 4% of niacin. Storage at 40°F for 30 months had no aignificant effect on vitamins.

For aensory evaluation, fruit cakaa were brought to room temperature and cut into eight piecea for serving to the judges. Fig. 7 shows the changea in quality of fruit cakes stored at three different temperaturea and varioua durationa. HSD at 0.01 for color, flavor, odor, texture, and overall quality scores were 0.90, 0.84, 0.82, 0.80, and 0.79, reapectivaly. Storage at 40°F for 30 months haa not significantly changed the quality scores of fruit cake. Storage at 70°F for 30 months haa aignificantly decreaaed the color, flavor, texture, and overall quality acores. Fruit cake from storage at 100°F had the aroma of atale raiaina and burnt augar, a somewhat bitter taste, and a dry surface. It was unacceptable with an overall score of 4.5. Ita storage was, therefore, terminated then. Fruit cakea atored at 40° and 70°F ware atill in acceptable condition.

Chocolate brownies

Chocolate browniea were vacuum packed in flexible retortable pouches with two bars in each pouch and a piece of paper placed between the two bars. There ia no code for chocolate brownies.

Table 8 and Fig. 8 show the effects of temperatures and duration of storage on some phyaical and chemical characteristics and quality of chocolate brownies. Chocolate brownies stored at 100°F had a slightly darker color than those stored at 40° and 70°F. The surface of the chocolate bars stored at 100°F looked dry and the paper used to separate the bars became oily. Drying of the chocolate bar and oiling of the paper also occurred at 70°F storage, but to a lesser extent. Significant decreasea in lightness resulted from all periods of storage at 100°F. Storage at 70°F also decreased lightness. Storage at 40°F for 30 months had not significantly affected the color of the chocolate brownies. Volatile reducing aubstances increaaed during storage. Chocolate brownies contained more volatile reducing aubstances at high than at low temperatures. Storage at 100°F also increased titratable acidity and rancidity in all periods of storage. After 30 months of storage at 100°F, chocolate brownies contained 225% more free fatty acid than the original samples. Storage at 70° and 100°F for 30 months produced more reducing sugar than in the original samples. As to vitamin retention, storage at 40°F for 30 months had no aignificant effect on all three vitamins. Storage at 70°F for 30 months caused a 28% loas of thiamine and no significant loss of riboflavin and niacin. Storage at 100°F caused a 64% loss of thiamine, a 27% loaa of riboflavin, and a 14% loss of niacin of chocolate browniea.

For sensory evaluation, chocolate bara were brought to room temperature and each bar was cut into aix piecea for aerving to the judges. Fig. 8 shows the effects of storage temperatures and duration of storage on quality of chocolate brownies. HSD at 0.01 for color, flavor, odor, texture, and overall quality acores are 0.87, 0.79, 0.81, 0.79, and 0.83, respectively. Storage at 40°F for 30 months has not significantly affected the individual and overall quality of chocolate browniea. Storage at 70°F for 30 months significantly decreased color, flavor, texture, and overall quality acorea. Chocolate browniea atored at 100°F developed an off-flavor and were dry and rancid. They were unacceptable aa judged by the taste panel. The storage study of chocolate brownies at 100°F wsa, therefore, terminated.

## Freeze-Dehydrated Items from Packet Long Range Patrol

### Chicken stew

Effects of temperatures and durstion of storage on some physical and chemical characteristics and quality of freeze dehydrated chicken atew are shown in Table 9 and Fig. 9. Storage at 100°F for 20 montha significantly discolored the chicken stew, especially carotene pigmenta of carrot cubes and chlorophyll of peas. This was shown on the increaaes in lightneaa. Storage at 70°F for 20 months alightly but aignificantly increased the lightness of chicken stew. Storage at 40°F had no effect on color of the sample for 20 months. Storage at 100°F for 30 months alao significantly decreased the volatile reducing aubatances and increased rancidity and titratable acidity. Chicken stew stored at 70°F for 20 months contained significantly higher rancidity snd titratable acidity than the original. Storage at 40°F had no effect on rancidity and titrstsble acidity. For vitamin retention, storage at three temperatures for 20 montha did not significantly affect the thiamine, riboflavin, and niacin content of chicken stew.

For sensory evaluation, chicken stew was rehydrated with hot water for serving to the judgea. HSD at 0.01 for color, odor, and overall quality scores are 0.71, 0.80, and 0.79. Storage at three temperaturea did not significantly affect the flavor and odor acorea of chicken stew. Color, odor, and overall quality acores were aignificantly decreased at 100°F storage. Storage st 40° and 70°F did not affect the quality scores of chicken stew. All aamples were quite acceptable then.

### Chicken and rice

Effects of temperatures and duration of storage on some physical and chemical chsracteristics and quality of freeze dehydrated chicken and rice are shown in Table 9 and Fig. 10. Storage at 70° and 100°F for 20 months discolored the freeze dehydrated chicken and rice as shown by increases in lightness and decreases in redness. Volatile reducing substances were not significantly affected by storage. Storage at 100°F significantly increased rancidity and titratable acidity. Thiamine, riboflavin, and niacin contents of chicken and rice were not significantly affected by storage.

For sensory evaluation, chicken and rice was rehydrated with hot water for serving to the judges. HSD at 0.01 level for color and overall quality scores was 0.77 and 0.78, respectively. Storage for 20 months did not significantly affect the flavor, odor, and texture quality scores of chicken and rice. Storage at 100°F for 20 months did significantly decrease the color and overall quality scores. All samples were still acceptable then.

Beef hash

The effects of temperatures and duration of storage on some physical and chemical characteristics and quality of freeze dehydrated beef hash are shown on Table 10 and Fig. 11. Storage at 70° and 100°F significantly affected the color values of beef hash. Low temperature storage did not affect the color and appearance of beef hash. Volatile reducing substances of beef hash were not affected by storage at different temperatures for 20 months. Storage at 70° and 100°F significantly increased the rancidity and titratable acidity of beef hash. Thiamine, riboflavin, and niacin contents of beef hash were not significantly affected by storage so far.

For sensory evaluation, freeze dehydrated beef hash was rehydrated with hot water for serving to the judges. HSD at 0.01 for color, and overall quality scores are 0.82 and 0.77, respectively. Storage at three temperatures for 20 months has not significantly decreased the quality scores of flavor, odor, and texture. Color and overall quality scores were significantly decreased by storage at 100°F for 20 months. All samples were quite acceptable then.

Pork with escalloped potatoes

Table 10 and Fig. 12 show the effects of temperatures and duration of storage on physical and chemical characteristics and quality of freeze dehydrated pork with escalloped potato. Storage at 100°F as well as at 70°F darkened pork with escalloped potato. This was reflected by a decrease in lightness values. Storage at 40°F has not significantly affected the color. Volatile reducing substances were significantly reduced at high temperature storage. Storage at 70° and 100°F for 20 months significantly increased both rancidity and titratable acidity. Thiamine, riboflavin, and niacin of pork with escalloped potato were not significantly reduced by storage at the three temperatures.

For sensory evaluation, pork with escalloped potato was rehydrated with hot water for serving to the judges. HSD at 0.01 for color, flavor, and overall quality scores are 0.76, 0.83, and 0.87, respectively. Storage at 100°F significantly decreased color, flavor, and overall quality scores but all samples were still acceptable at 20 months.

Chili con carne with beans

Effects of temperature and duration of storage on physical and chemical characteristics and quality of freeze dehydrated chili con carne with beans are shown on Table 11 and Fig. 13. Storage at 70° and 100°F significantly affected the lightness of the samples. Storage at 40°F has had no effect on color so far. Volatile reducing substances have not been affected by the storage. Storage at 70° and 100°F also increased rancidity and titratable acidity. Storage at 40°F for 20 months has not significantly affected the rancidity and titratable acidity. Thiamine, riboflavin, and niacin contents of chili con carne with beans have not been significantly reduced during the 20 months of storage.

For sensory evaluation chili con carne with beans was rehydrated with hot water for serving to the judges. HSD at 0.01 for color, odor, and overall quality scores are 0.86, 0.87, and 0.79, respectively. Storage at 40° and 70°F did not change the quality. Storage at 100°F for 20 months significantly decreased color, odor, and overall quality scores. Flavor and texture were not affected by the storage so far. All samples were still acceptable then.

Beef stew

Effects of temperature and duration of storage on some physical and chemical characteristics and quality of freeze dehydrated beef stew are shown on Table 11 and Fig. 14. Storage at 70° and 100°F significantly changed the lightness and redness values. Discoloration of carrot cubes and peas in beef stew occurred. Volatile reducing substances of beef stew increased after high temperature storage. Storage at 70° and 100°F also increased the rancidity and titratable acidity. Storage at 40°F for 20 months did not change the volatile reducing substances, rancidity, and titratable acidity. Thiamine, riboflavin, and niacin contents of beef stew have not been affected by storage at three temperatures for 20 months.

For sensory evaluation, freeze dehydrated beef stew was rehydrated with hot water for serving to the judges. Storage at 100°F for 20 months significantly decreased the color, odor, texture, and overall quality scores of beef stew. HSD at 0.01 for color, odor, texture, and overall quality scores are 0.83, 0.80, 0.75, and 0.85, respectively. Flavor was not affected by the storage so far. All samples were still acceptable then.

## Beef and rice

Table 12 and Fig. 15 show the effects of temperatures and duration of storage on physical and chemical characteristics and quality of freeze dehydrated beef and rice. Storage at 70° and 100°F changed the Hunter color values. Volatile reducing substances, rancidity, and titratable acidity were significantly increased after storage at 70° and 100°F. Storage at 40°F for 20 months has not significantly changed these characteristics. Thiamine, riboflavin, and niacin contents of beef stew stored for 20 months have not been significantly affected.

For sensory evaluation, beef and rice was rehydrated with hot water for serving to the judges. HSD at 0.01 for color, flavor, odor, and overall quality scores are 0.75, 0.83, 0.82, and 0.84, respectively. Storage at 100°F for 20 months significantly decreased the color, flavor, odor, and overall quality scores, but not the texture. All samples were still quite acceptable then.

## Spaghetti with meat sauce

Tabla 12 and Fig. 16 show the effects of temperatures and duration of storage on physical and chemical characteristics and quality of freeze dehydrated spaghetti with meat sauce. Storage at 70° and 100°F significantly changed the Hunter color values of spaghetti with meat sauce. Volatile reducing substances were not significantly affected by the storage. Low temperature storage did not significantly change the rancidity and titratable acidity. Storage at 70° and 100°F did increase the rancidity and titratable acidity of spaghetti with meat sauce. Storage at three temperatures so far has not significantly affected the vitamins studied.

For sensory evaluation, spaghetti with meat sauce was rehydrated with hot water for serving to the judges of the panel. HSD at 0.01 for color, odor, and overall quality scores are 0.77, 0.79, and 0.84, respectively. Storage at 100°F decreased color, odor, and overall quality scores, but not those of flavor and texture. All samples were still in good acceptable condition.

# Conclusion

In conclusion, food from MREI stored at 40° and 70°F for 30 months was still in good and acceptable condition. Storage at 100° F degraded the quality of food. Storage life for cheese spread at 100°F was 12 months; pineapple, 12 months; beef stew, 30 months; chocolate brownies 30 months; and fruit cake, 30 months. Browning was usually associated with high temperature storage of high sugar foods. Meat products except beef stew were apparently more stable than others under high temperature storage. Freeze dehydrated foods from Packet Long Range Patrol are much more stable in quality than wet food items from MREI during storage at three temperatures. This is due to lower water activity of freeze dehydrated products. After 20 months of storage all freeze dehydrated items were still in very good condition. Storage at 100°F definitely degraded the quality of freeze dehydrated food. Clumping of food particles was a problem of high temperature storage of freeze dehydrated foods.

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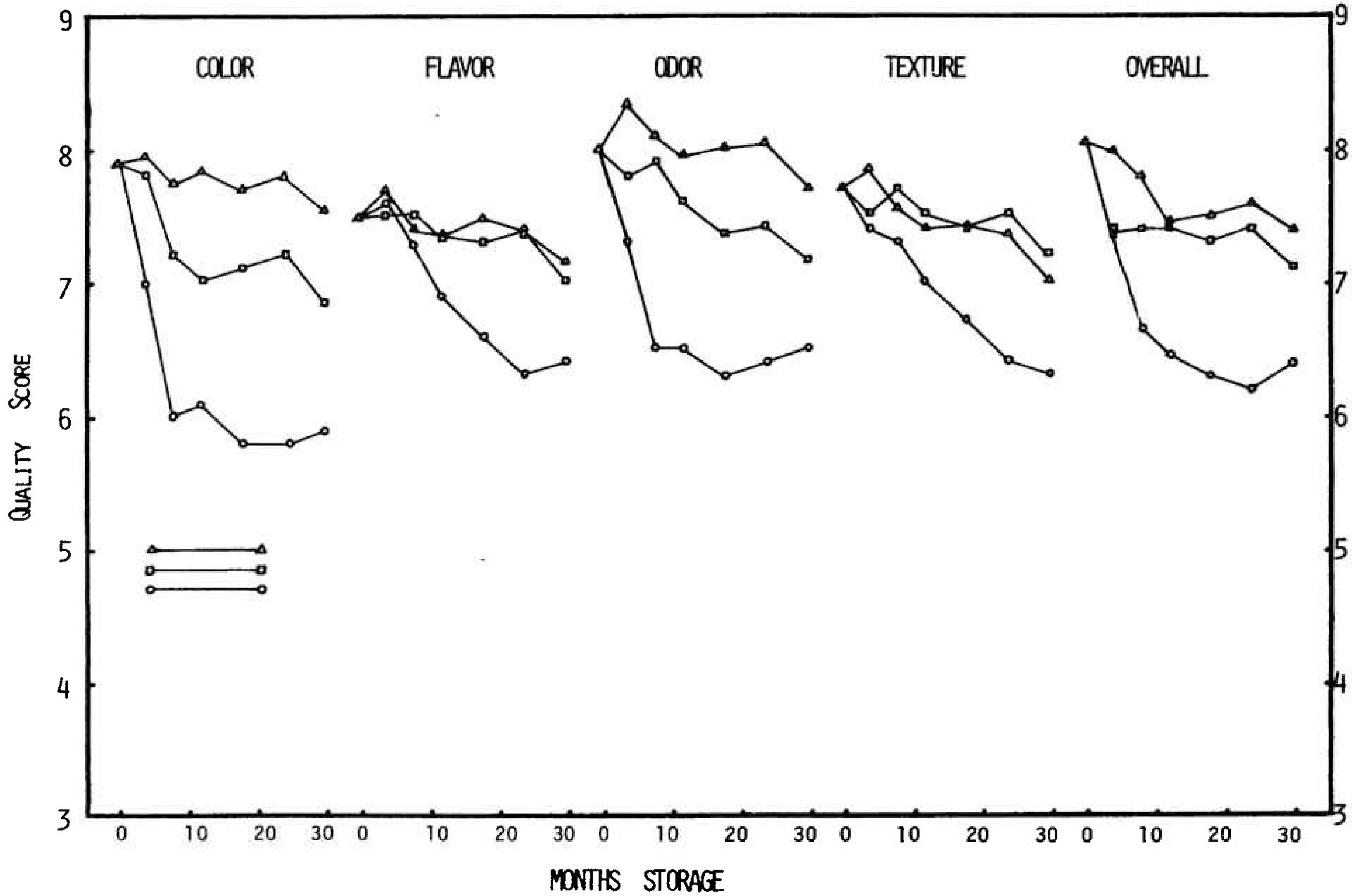


Fig. 1. Effects of temperature and duration of storage on quality of ham and chicken loaf.

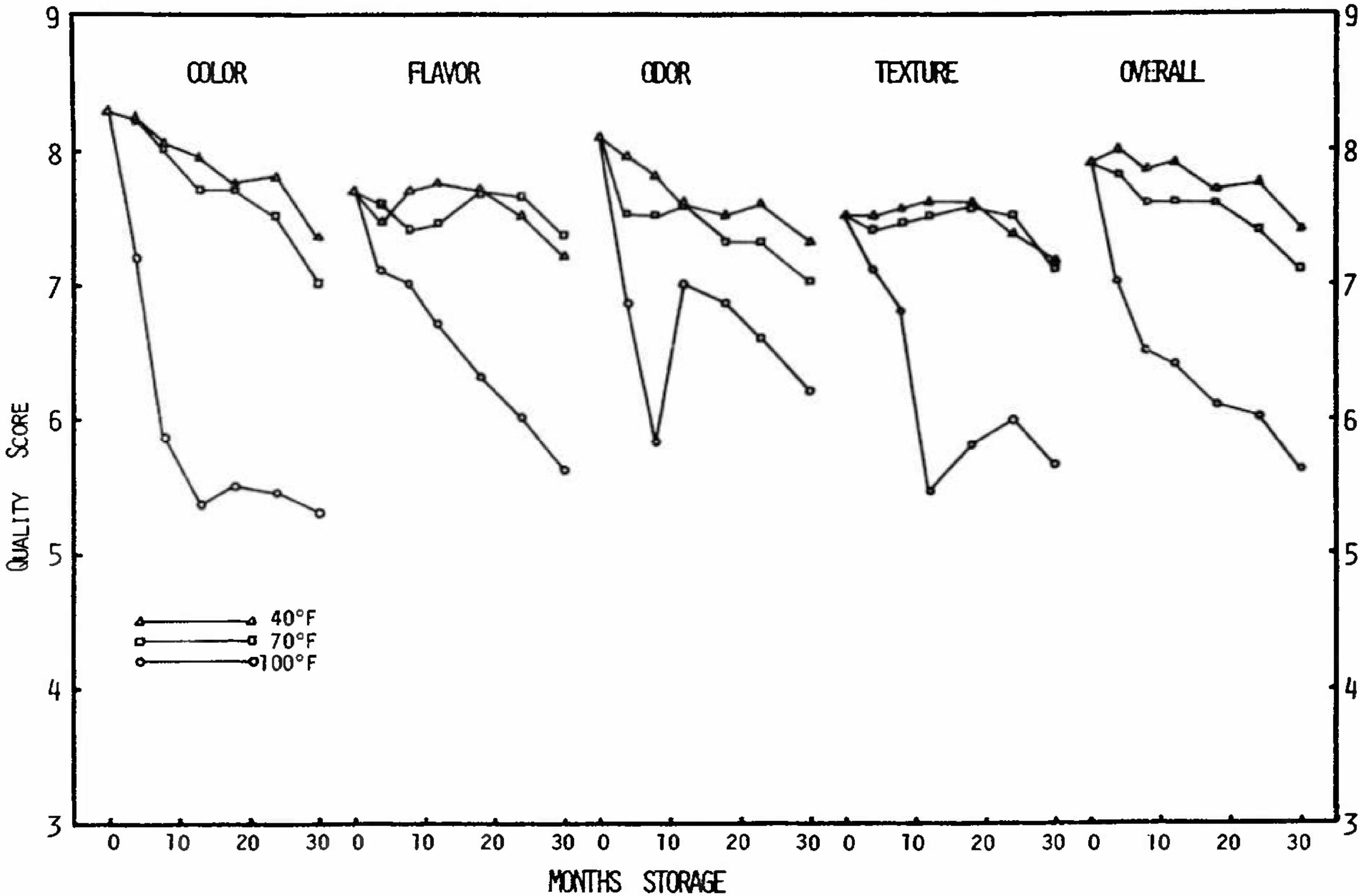


Fig. 2. Effects of temperature and duration of storage on quality of frankfurter.

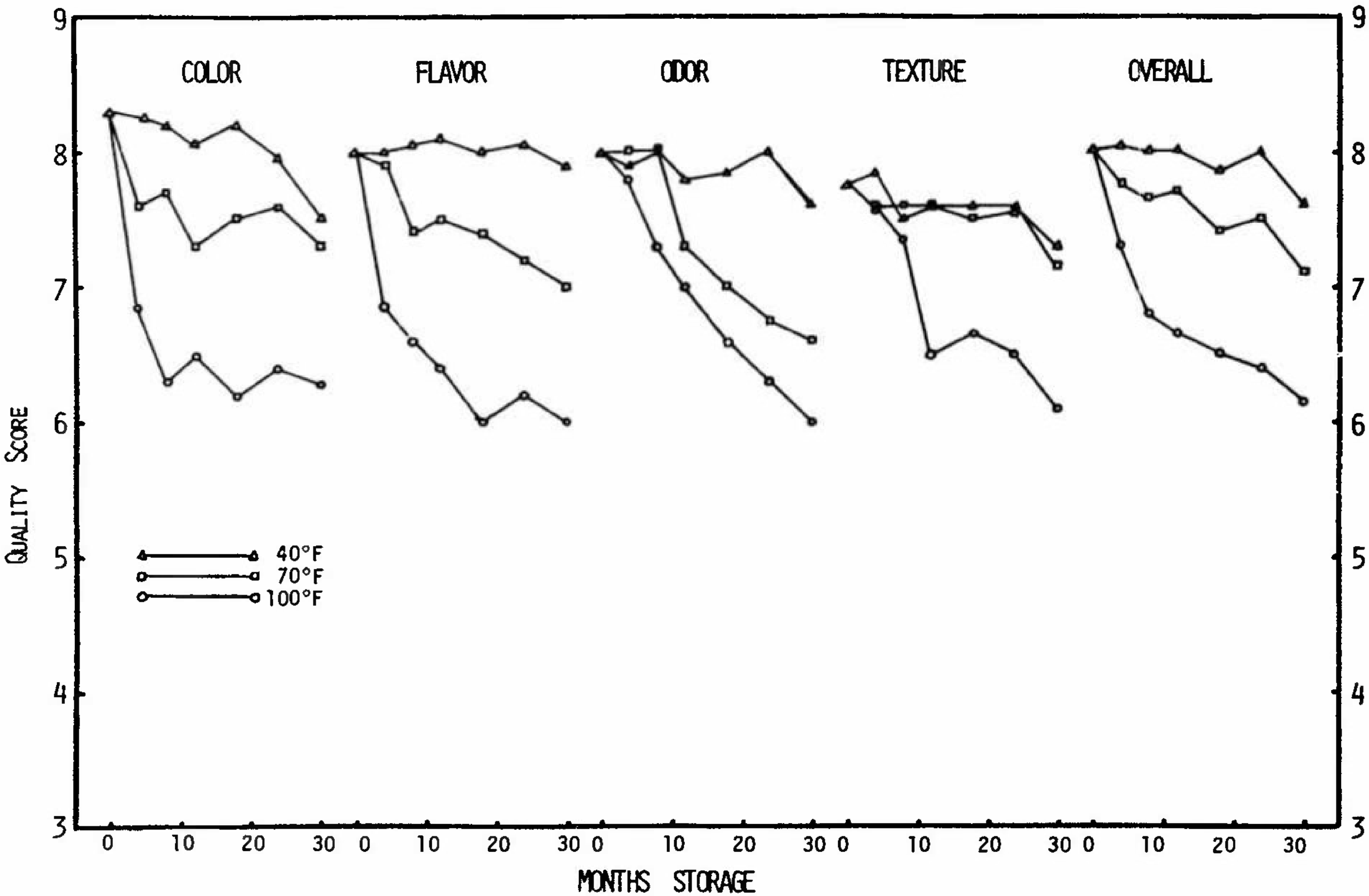


Fig. 3. Effects of temperature and duration of storage on quality of beef steak.

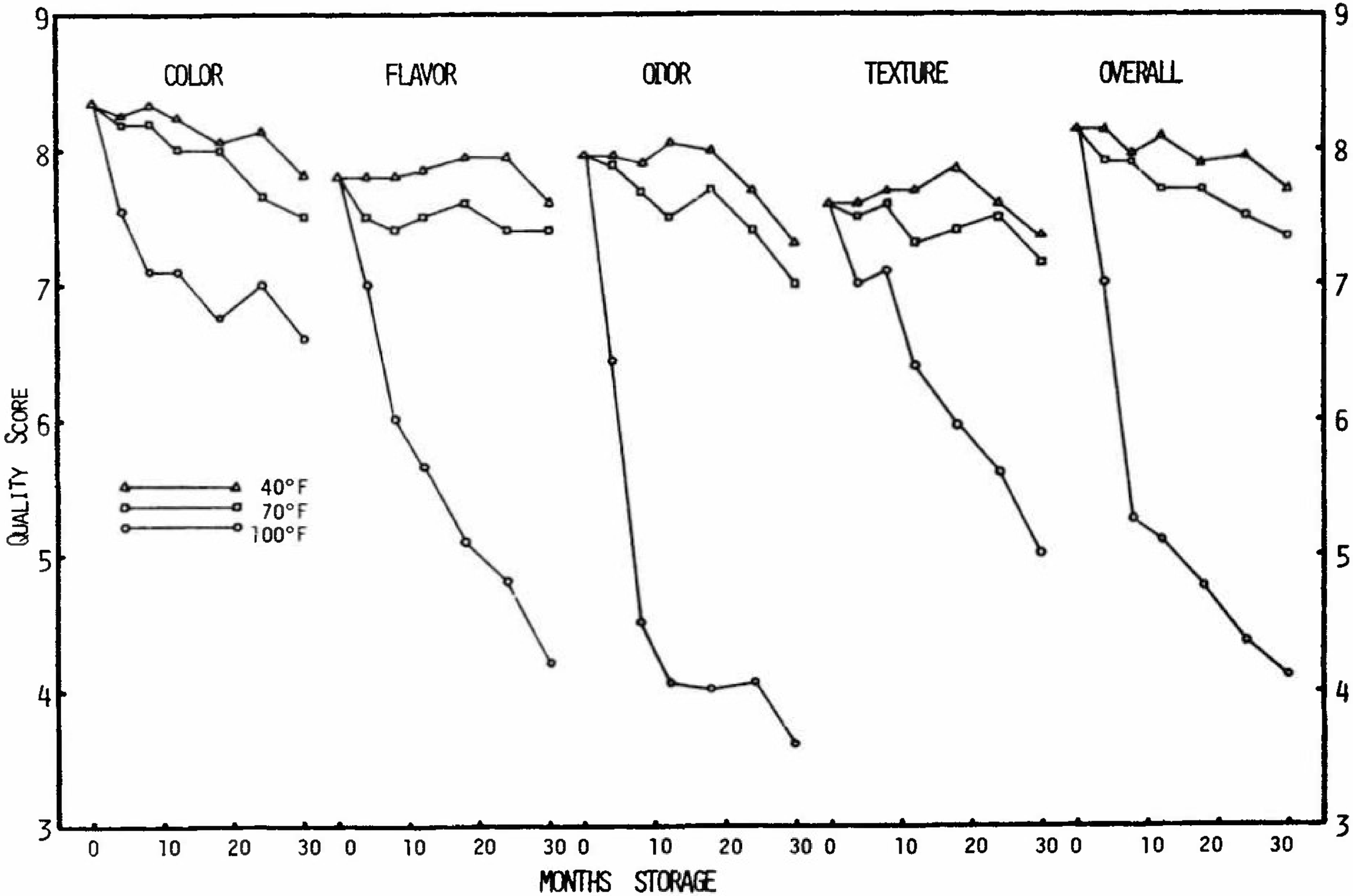


Fig. 4. Effects of temperature and duration of storage on quality of beef stew.

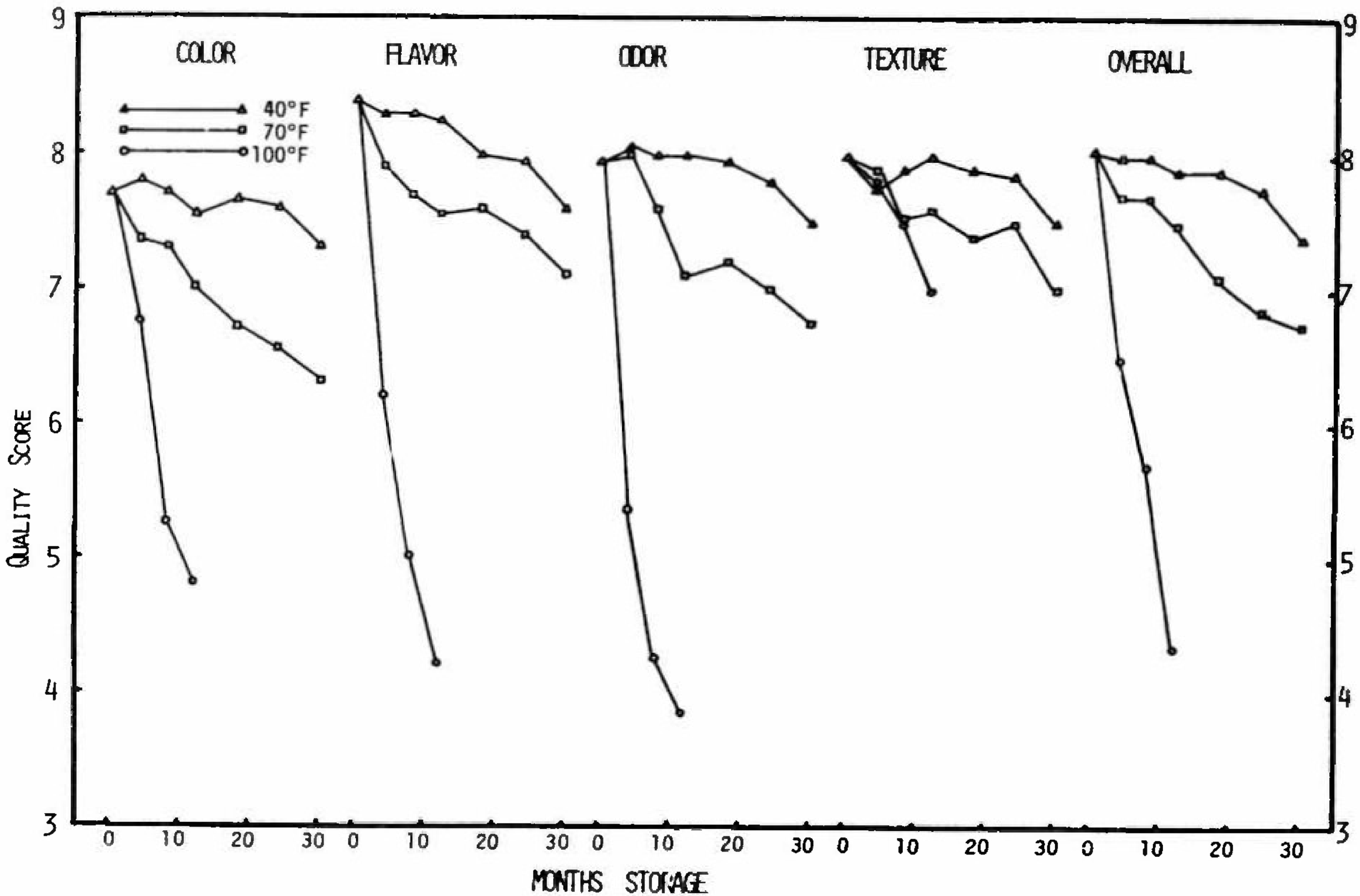


Fig. 5. Effects of temperature and duration of storage on quality of cheese spread.

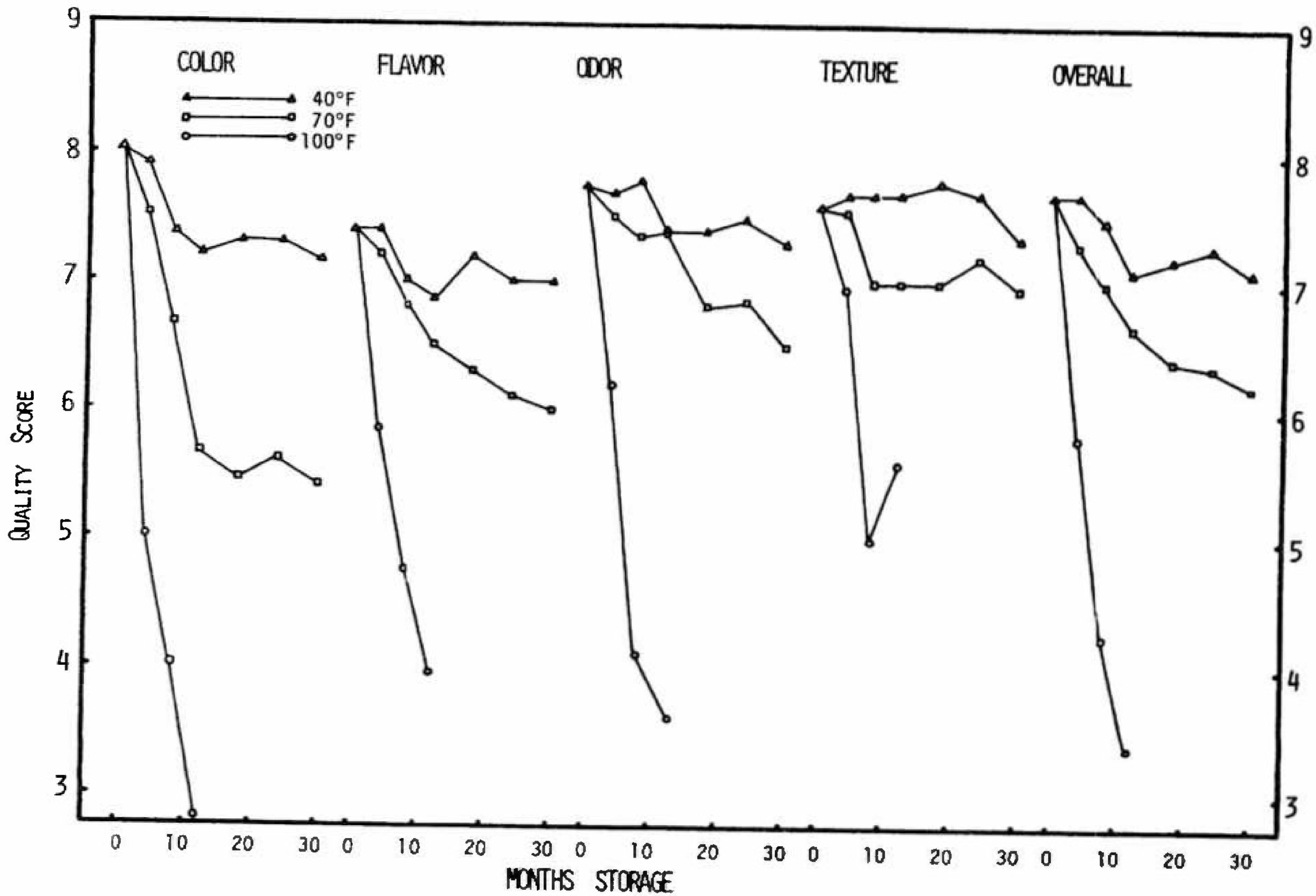


Fig. 6. Effects of temperature and duration of storage on quality of pineapple.

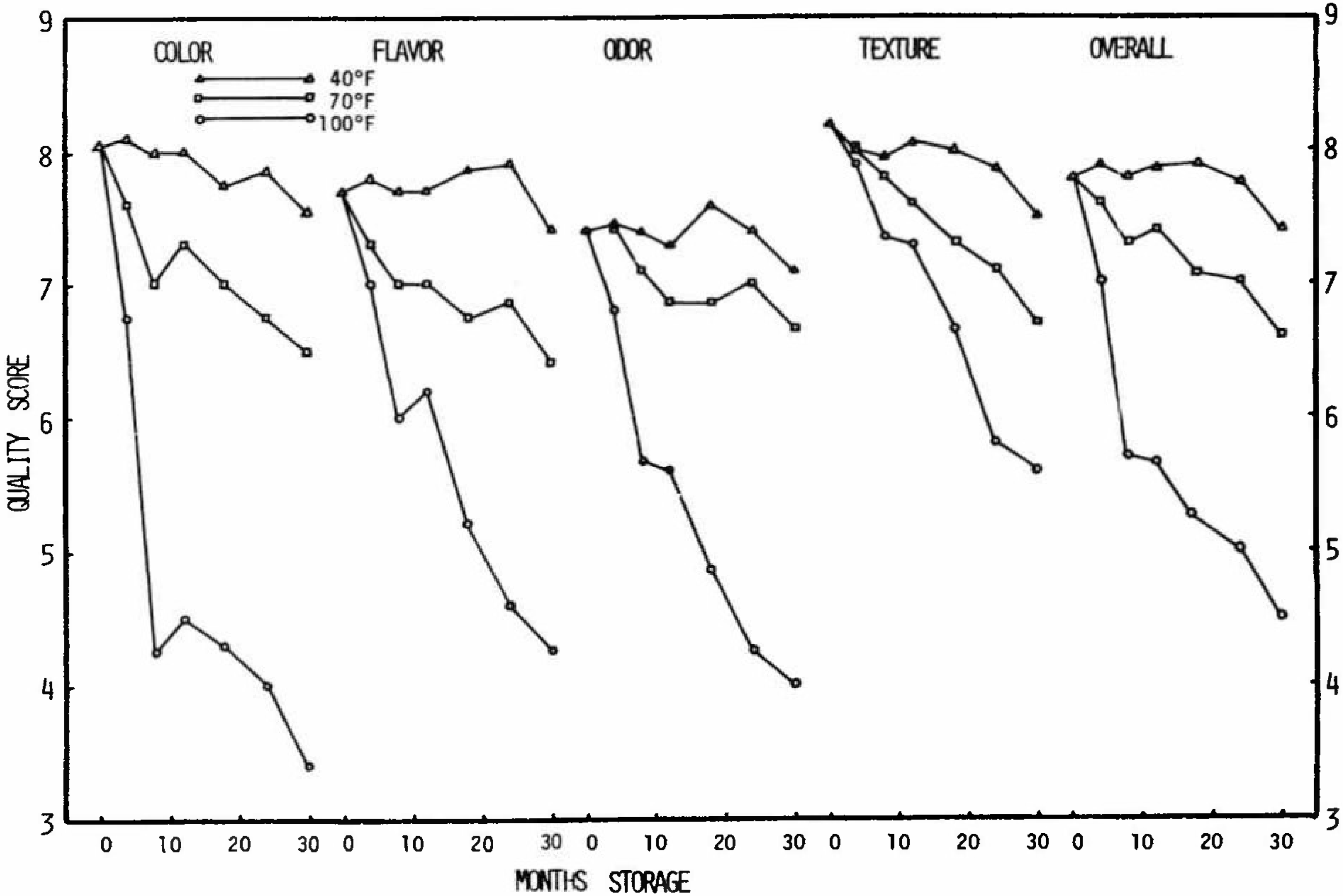


Fig. 7. Effects of temperature and duration of storage on quality of fruit cake.

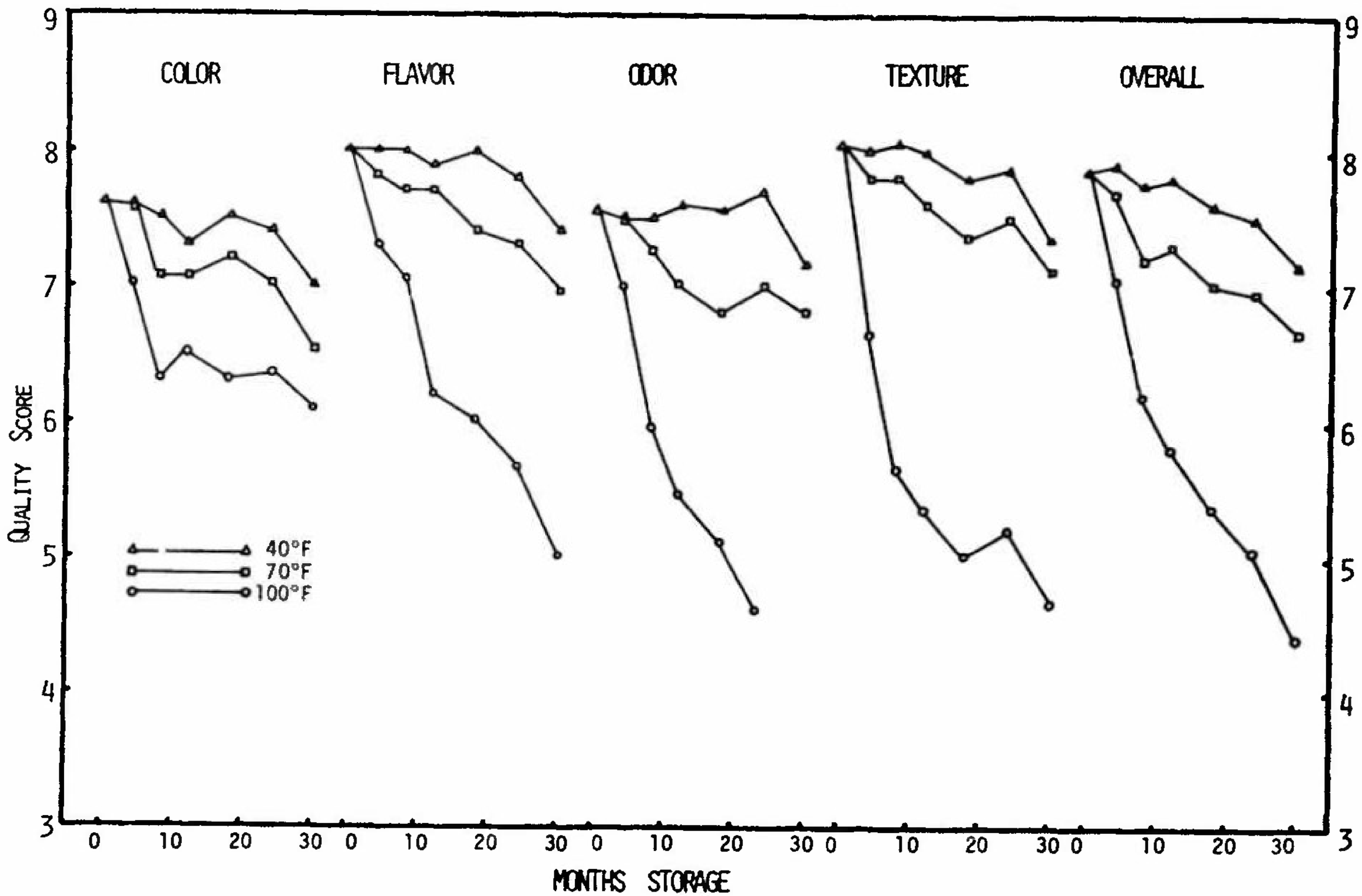


Fig. 8. Effects of temperature and duration of storage on quality of chocolate brownies.

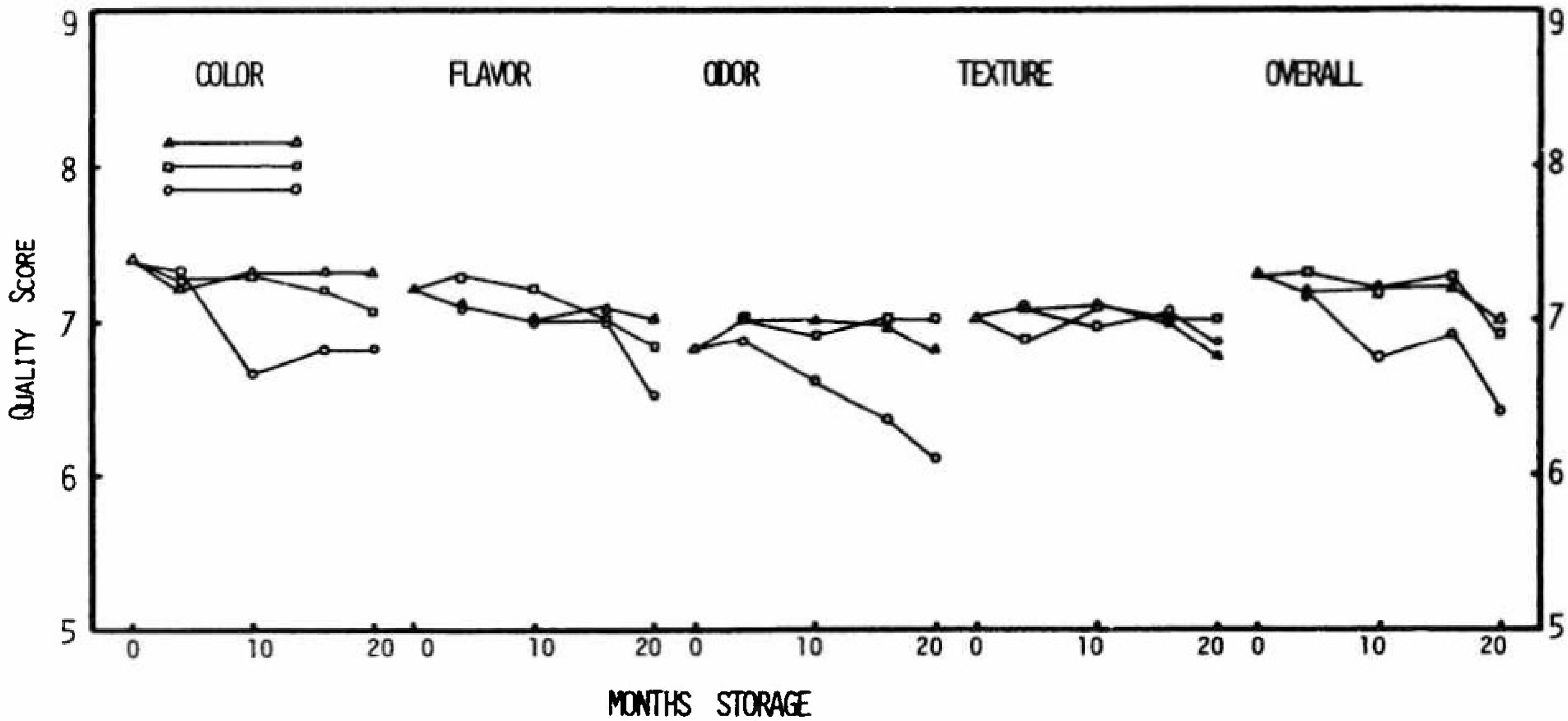


Fig. 9. Effects of temperature and duration of storage on quality of freeze dehydrated chicken stew.

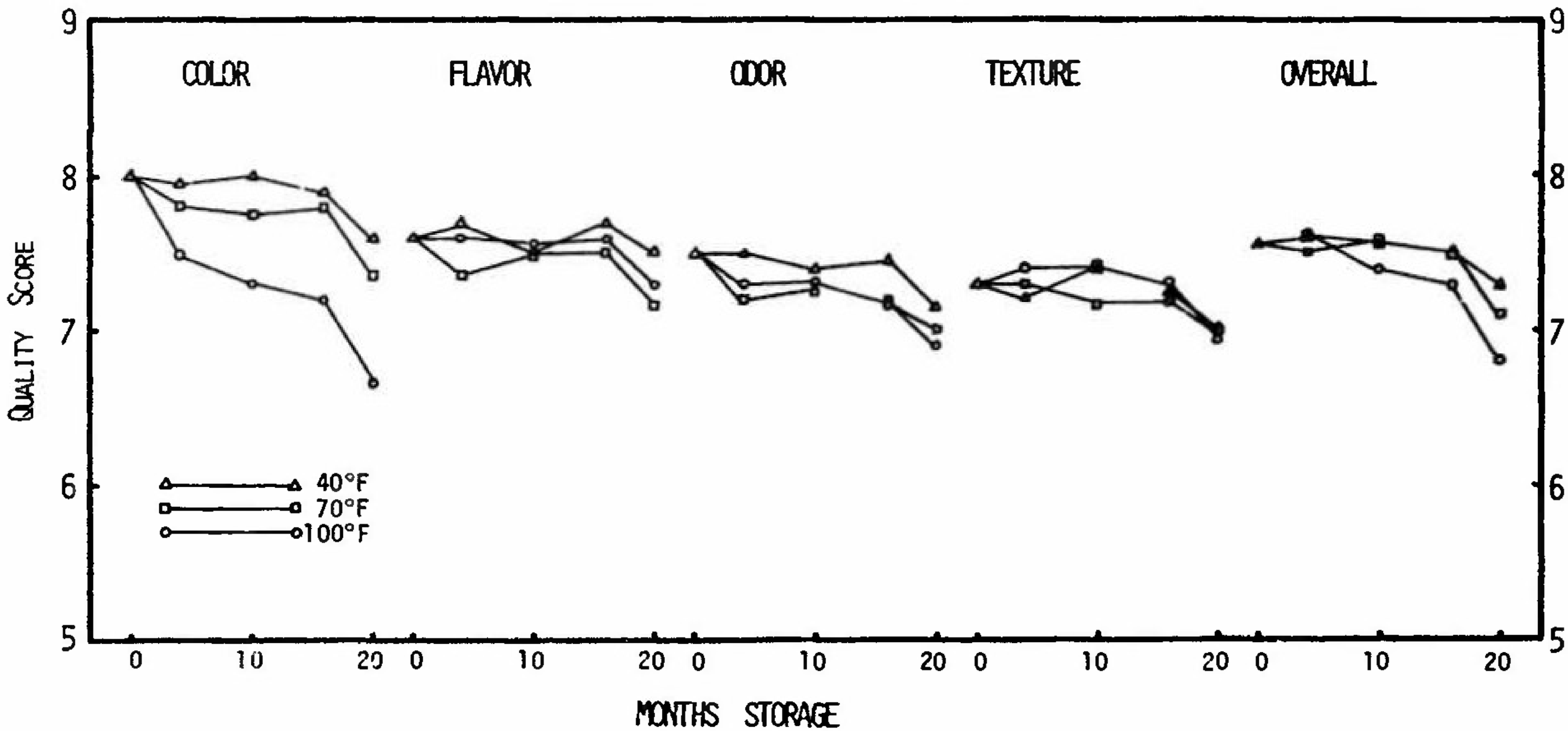


Fig. 10. Effects of temperature and duration of storage on quality of freeze dehydrated chicken and rice.

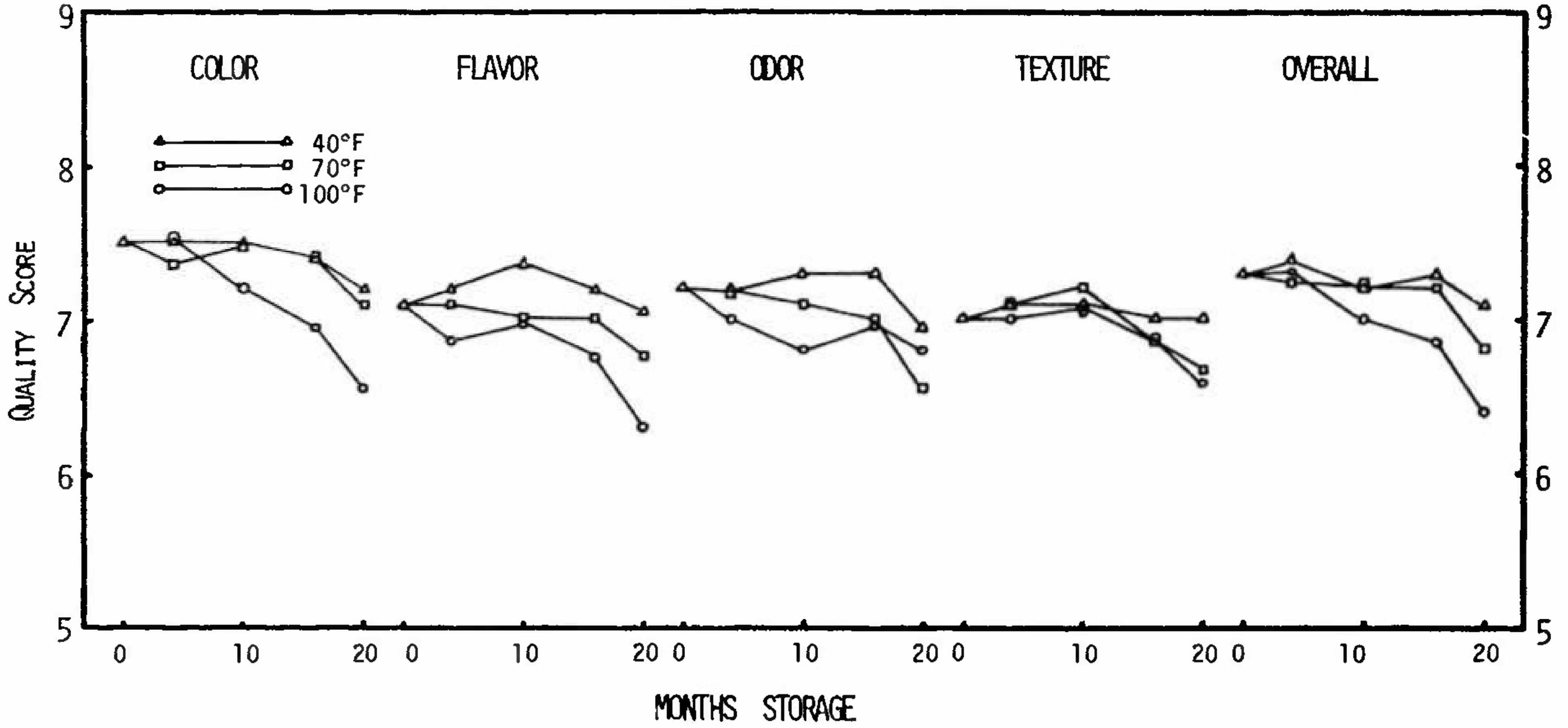


Fig. 11. Effects of temperature and duration of storage on quality of freeze dehydrated beef hash.

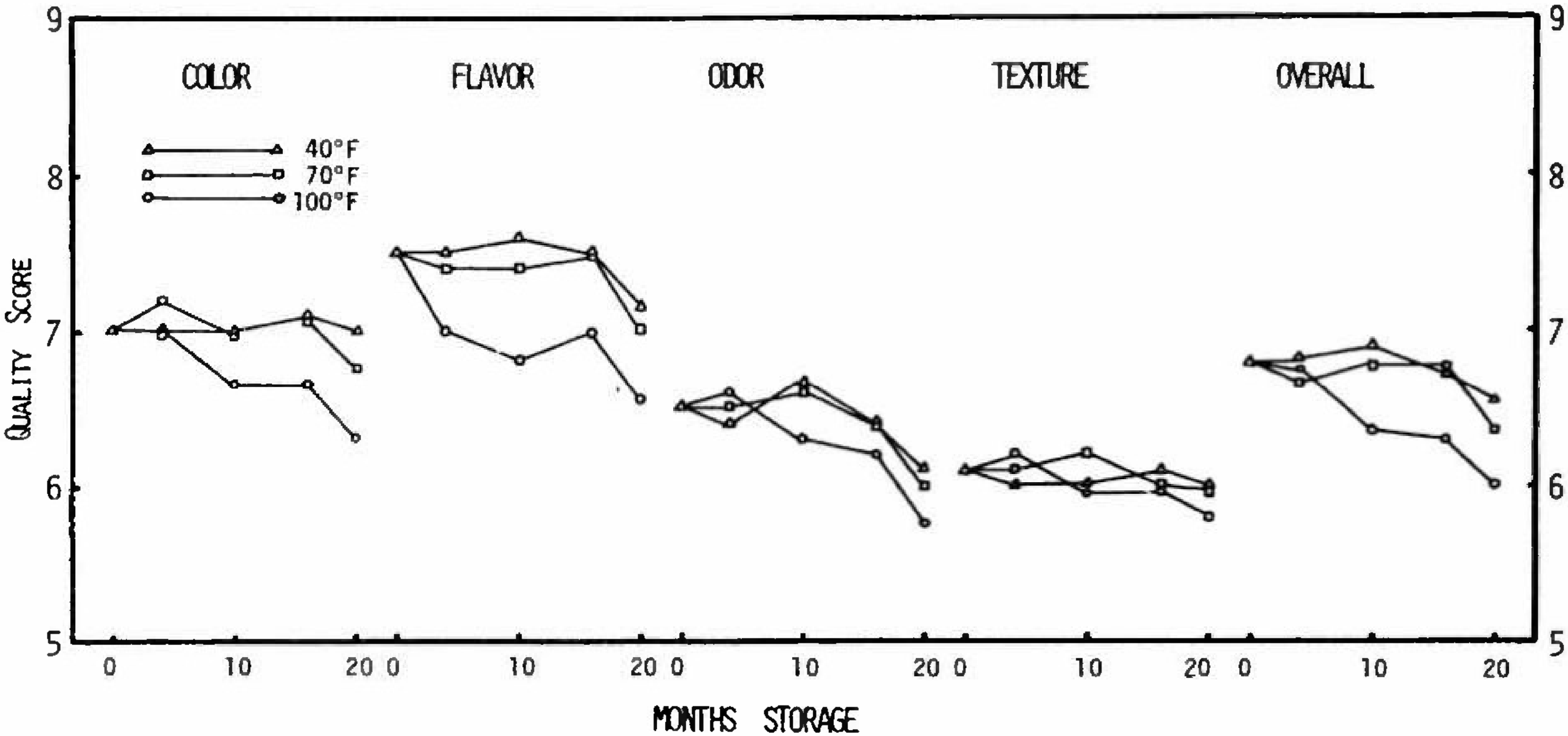


Fig. 12. Effects of temperature and duration of storage on quality of freeze dehydrated escalloped pork and potato.

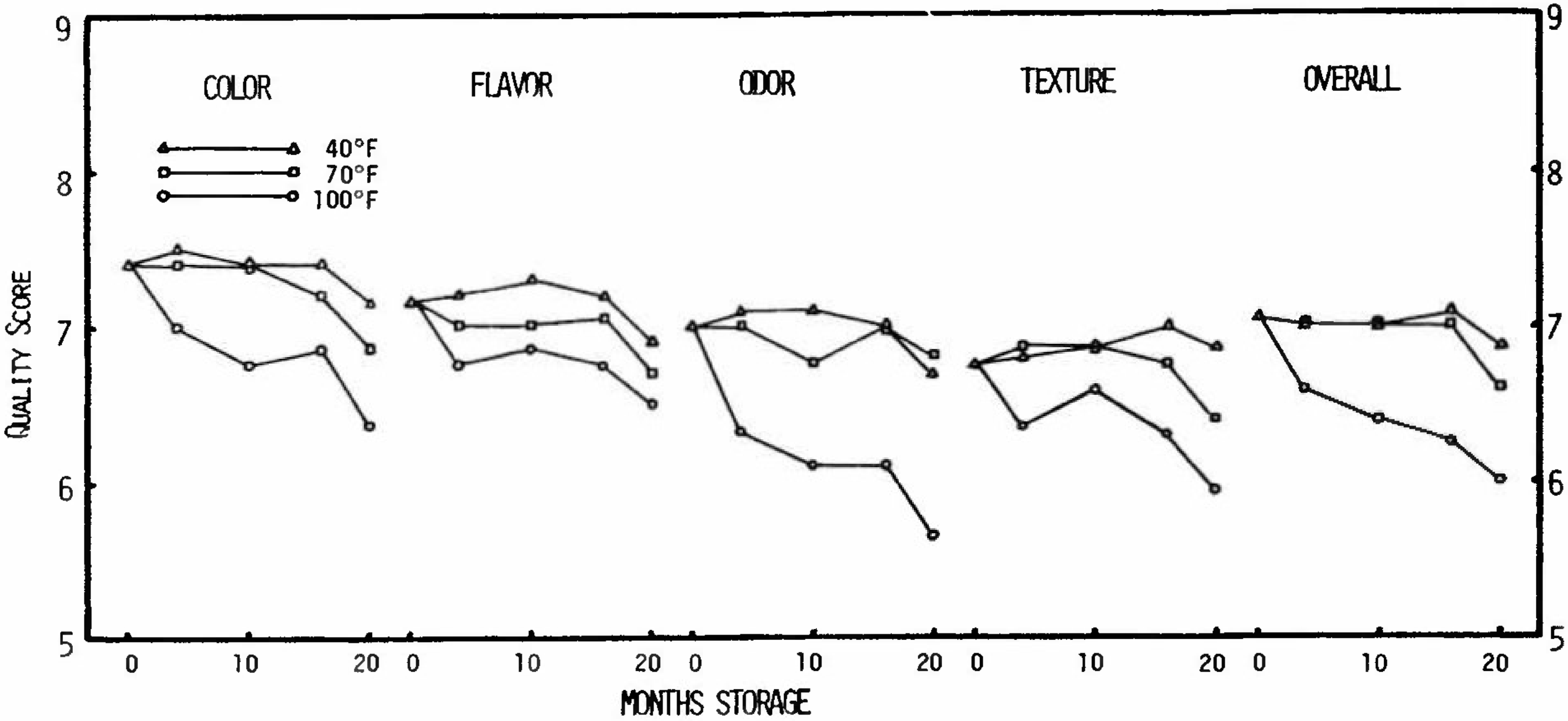


Fig. 13. Effects of temperature and duration of storage on quality of freeze dehydrated chili con carne with beans.

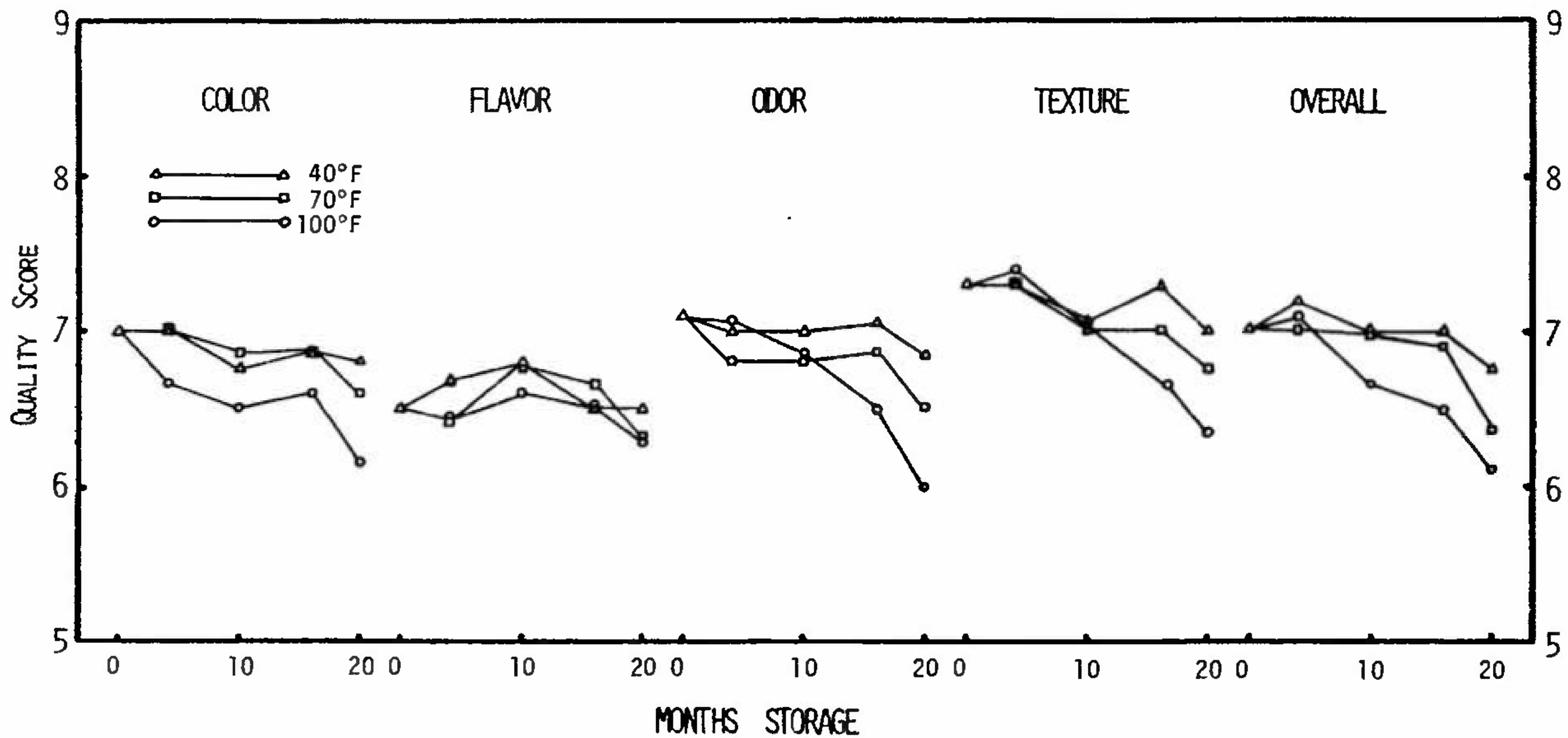


Fig. 14. Effects of temperature and duration of storage on quality of freeze dehydrated beef stew.

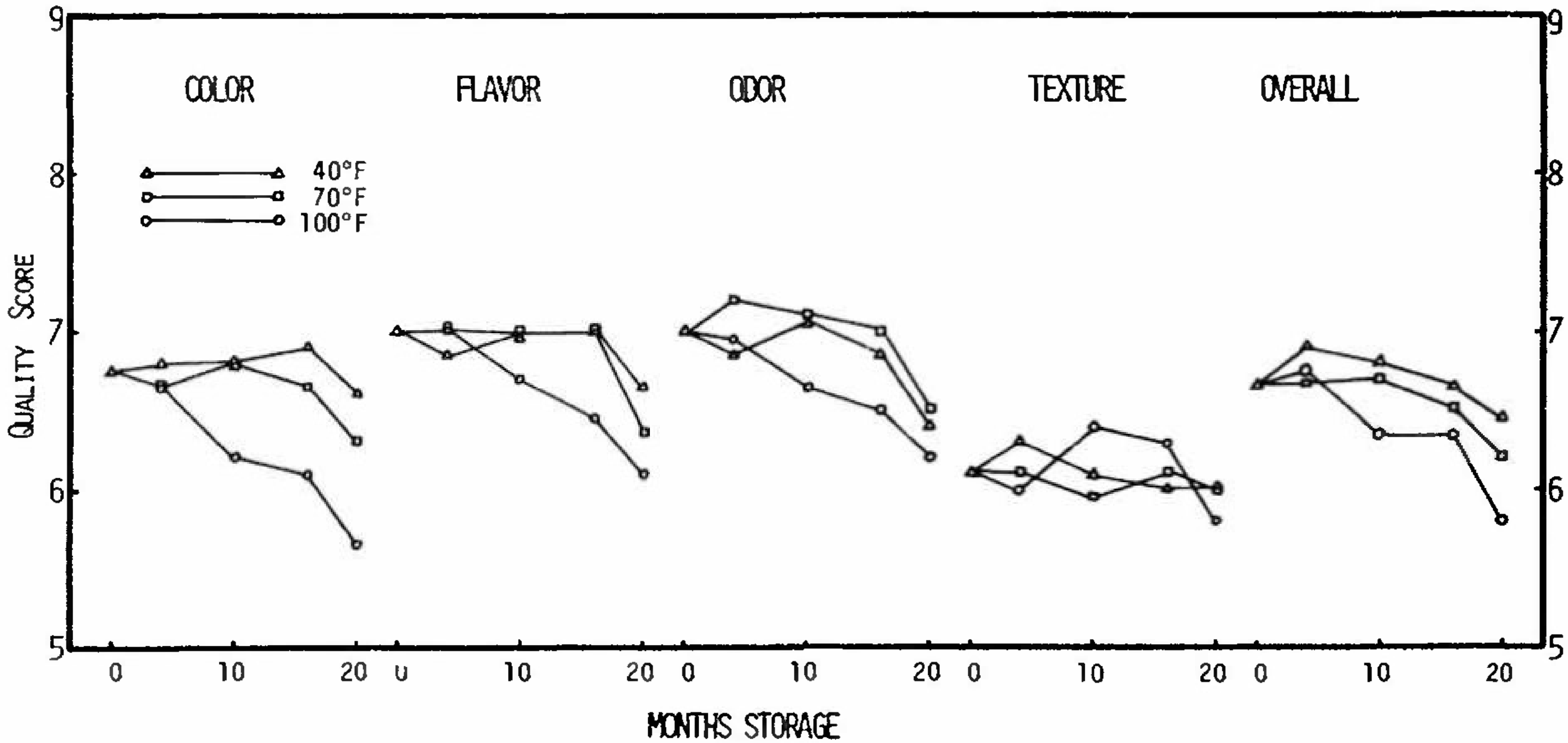


Fig. 15. Effects of temperature and duration of storage on quality of freeze dehydrated beef and rice.

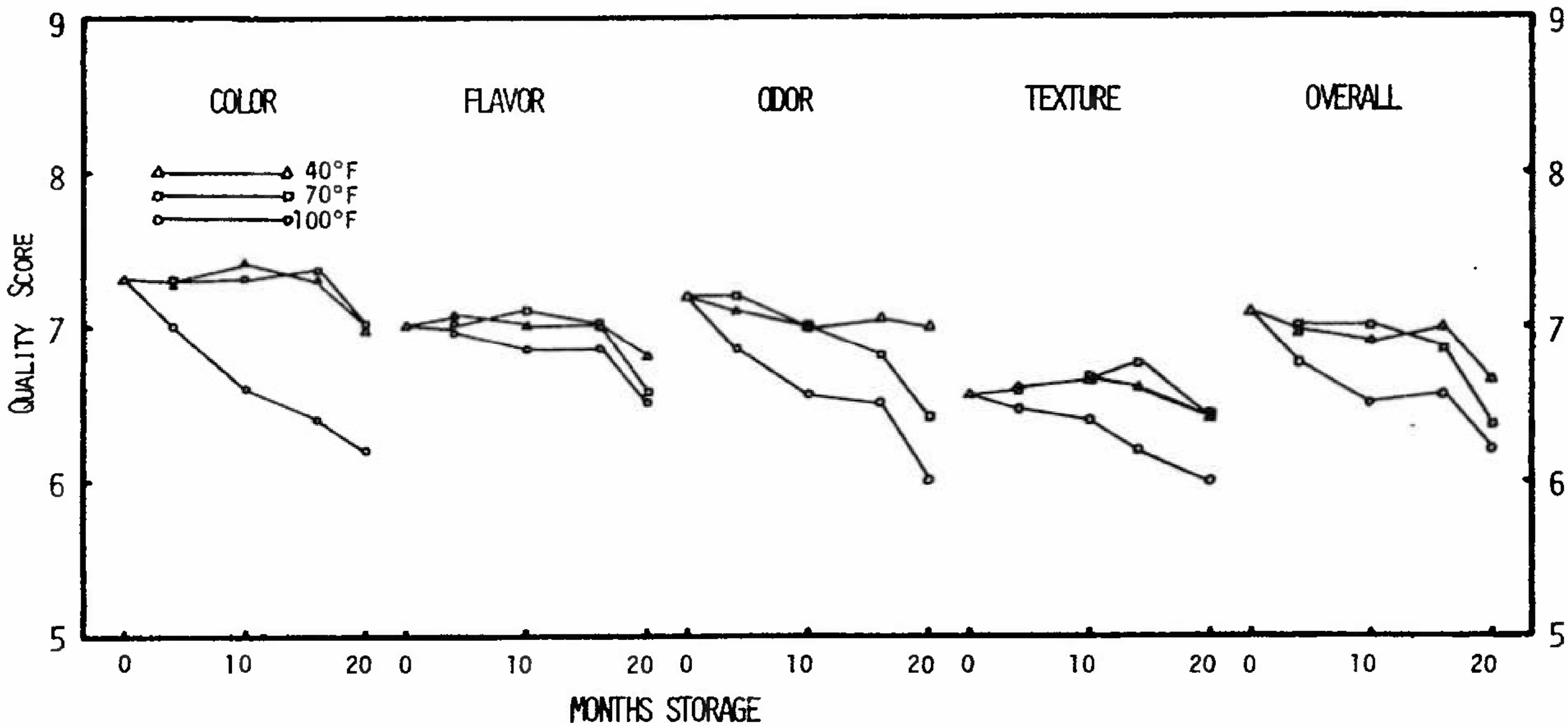


Fig. 16. Effects of temperature and duration of storage on quality of freeze dehydrated spaghetti with meat sauce.

Table 1. Effects of temperatures and duration of storage on some physical and chemical characteristics of ham and chicken loaf.

| Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Rancidity free fatty acid % oleic acid | Titratable acidity meq acid/100 g | Thiamine µg/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|
| – | 0 | 55.8 | 7.2 | 12.7 | 0.580 | 0.035 | 8.10 | 121.7 | 0.161 | 4.906 |
| 40 | 4 | 55.8 | 7.2 | 12.7 | 0.591 | 0.035 | 8.08 | 120.6 | 0.163 | 4.913 |
| | 8 | 55.4 | 7.3 | 12.7 | 0.593 | 0.039 | 8.13 | 120.9 | 0.160 | 4.894 |
| | 12 | 55.1 | 7.2 | 13.0 | 0.582 | 0.040 | 8.12 | 120.1 | 0.160 | 4.890 |
| | 18 | 55.3 | 7.3 | 12.8 | 0.577 | 0.039 | 8.10 | 120.4 | 0.164 | 4.872 |
| | 24 | 55.3 | 7.2 | 12.6 | 0.580 | 0.041 | 8.13 | 120.0 | 0.160 | 4.876 |
| | 30 | 55.4 | 7.0 | 12.8 | 0.574 | 0.040 | 8.12 | 120.2 | 0 158 | 4.881 |
| 70 | 4 | 54.9 | 7.3 | 12.7 | 0.560 | 0.048 | 8.19 | 112.9 | 0.155 | 4.900 |
| | 8 | 54.3 | 7.5 | 12.8 | 0.545 | 0.057 | 8.36 | 99.5 | 0.149 | 4.832 |
| | 12 | 54.0 | 8.0 | 13.8 | 0.550 | 0.054 | 8.60 | 74.3 | 0.143 | 4.762 |
| | 18 | 54.0 | 7.8 | 13.9 | 0.543 | 0.057 | 8.58 | 60.9 | 0.139 | 4.661 |
| | 24 | 53.8 | 7.8 | 14.1 | 0.538 | 0.060 | 8.65 | 58.4 | 0.140 | 4.633 |
| | 30 | 53.5 | 8.0 | 14.3 | 0.533 | 0.069 | 8.72 | 58.0 | 0.134 | 4.602 |
| 100 | 4 | 54.0 | 8.1 | 14.0 | 0.553 | 0.064 | 8.81 | 87.6 | 0.128 | 4.731 |
| | 8 | 52.3 | 9.6 | 15.3 | 0.542 | 0.081 | 9.09 | 51.0 | 0.104 | 4.707 |
| | 12 | 50.4 | 10.3 | 16.4 | 0.544 | 0.087 | 9.20 | 40.4 | 0.094 | 4.626 |
| | 18 | 50.1 | 10.6 | 16.0 | 0.538 | 0.094 | 9.37 | 28.2 | 0.092 | 4.506 |
| | 24 | 50.0 | 10.9 | 16.8 | 0.526 | 0.099 | 9.51 | 28.0 | 0.095 | 4.488 |
| | 30 | 50.2 | 10.7 | 16.6 | 0.529 | 0.100 | 9.66 | 29.3 | 0.091 | 4.411 |
| HSD | | 1.0 | 0.8 | 0.6 | 0.028 | 0.008 | 0.10 | 5.0 | 0.018 | 0.153 |

Table 2. Effects of temperatures and duration of storage on some physical and chemical characteristics of frankfurters.

| Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Rancidity free fatty acid % oleic acid | Titratable acidity meq acid/100 g | Thiamine µg/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|
| – | 0 | 48.5 | 15.0 | 14.6 | 0.780 | 0.110 | 4.82 | 88.0 | 0.136 | 1.830 |
| 40 | 4 | 48.5 | 15.0 | 14.2 | 0.769 | 0.115 | 4.85 | 85.4 | 0.138 | 1.838 |
| | 8 | 47.5 | 15.3 | 14.3 | 0.766 | 0.113 | 4.85 | 86.7 | 0.135 | 1.831 |
| | 12 | 47.2 | 15.5 | 14.3 | 0.784 | 0.116 | 4.86 | 84.9 | 0.135 | 1.835 |
| | 18 | 47.7 | 15.2 | 14.6 | 0.773 | 0.119 | 4.80 | 84.7 | 0.134 | 1.836 |
| | 24 | 47.5 | 15.0 | 14.4 | 0.782 | 0.117 | 4.88 | 84.9 | 0.136 | 1.830 |
| | 30 | 47.1 | 15.2 | 14.3 | 0.780 | 0.122 | 4.85 | 84.0 | 0.131 | 1.823 |
| 70 | 4 | 45.5 | 15.7 | 14.0 | 0.764 | 0.120 | 4.86 | 80.2 | 0.133 | 1.830 |
| | 8 | 43.2 | 16.4 | 14.5 | 0.778 | 0.123 | 4.92 | 76.1 | 0.130 | 1.800 |
| | 12 | 42.6 | 17.0 | 14.5 | 0.780 | 0.114 | 5.06 | 58.8 | 0.122 | 1.755 |
| | 18 | 43.0 | 16.8 | 14.6 | 0.789 | 0.133 | 5.13 | 53.0 | 0.120 | 1.743 |
| | 24 | 42.8 | 17.2 | 14.2 | 0.802 | 0.136 | 5.24 | 50.6 | 0.116 | 1.748 |
| | 30 | 42.4 | 17.5 | 14.5 | 0.815 | 0.141 | 5.39 | 48.8 | 0.111 | 1.740 |
| 100 | 4 | 43.0 | 18.0 | 14.5 | 0.791 | 0.164 | 5.24 | 71.6 | 0.129 | 1.797 |
| | 8 | 41.1 | 20.1 | 14.7 | 0.796 | 0.197 | 6.08 | 56.9 | 0.111 | 1.754 |
| | 12 | 40.5 | 20.8 | 14.9 | 0.893 | 0.269 | 6.54 | 39.0 | 0.104 | 1.719 |
| | 18 | 39.6 | 20.2 | 15.1 | 0.918 | 0.287 | 6.79 | 30.9 | 0.102 | 1.701 |
| | 24 | 39.0 | 20.5 | 15.3 | 0.937 | 0.298 | 6.90 | 28.7 | 0.097 | 1.654 |
| | 30 | 38.6 | 20.9 | 15.8 | 0.949 | 0.311 | 7.06 | 28.1 | 0.092 | 1.633 |
| HSD | | 1.1 | 0.7 | 0.8 | 0.053 | 0.021 | 0.17 | 7.1 | 0.017 | 0.089 |

Table 3. Effects of temperatures and duration of storage on some physical and chemical characteristics of beef steak.

| Storage temperature °F | Months storage | Hunter Color | | | Volatile reducing substances | Titratable acidity | Rancidity free fatty acid | Thiamine | Riboflavin | Niacir |
|---|---|---|---|---|---|---|---|---|---|---|
| | | L units | a units | b units | meq/100 g | meq acid/100 g | % oleic acid | µg/100 g | mg/100 g | mg/100 g |
| – | 0 | 31.4 | 9.8 | 9.7 | 0.797 | 13.26 | 0.066 | 19.6 | 0.160 | 4.454 |
| 40 | 4 | 31.4 | 9.8 | 9.7 | 0.790 | 13.30 | 0.060 | 19.8 | 0.164 | 4.432 |
| | 8 | 31.2 | 9.9 | 9.6 | 0.794 | 13.31 | 0.063 | 19.9 | 0.162 | 4.440 |
| | 12 | 31.2 | 9.7 | 9.8 | 0.781 | 13.34 | 0.061 | 19.6 | 0.162 | 4.427 |
| | 18 | 31.3 | 9.8 | 9.8 | 0.776 | 13.14 | 0.065 | 19.6 | 0.161 | 4.401 |
| | 24 | 31.0 | 10.0 | 9.9 | 0.783 | 13.16 | 0.069 | 19.4 | 0.162 | 4.412 |
| | 30 | 31.2 | 9.7 | 10.1 | 0.791 | 13.38 | 0.073 | 19.0 | 0.159 | 4.410 |
| 70 | 4 | 31.0 | 10.3 | 9.5 | 0.763 | 13.30 | 0.069 | 19.0 | 0.169 | 4.433 |
| | 8 | 30.6 | 10.4 | 9.5 | 0.728 | 13.07 | 0.076 | 18.6 | 0.160 | 4.405 |
| | 12 | 30.3 | 10.6 | 9.8 | 0.693 | 12.95 | 0.078 | 17.0 | 0.152 | 4.374 |
| | 18 | 30.7 | 10.4 | 9.9 | 0.683 | 12.88 | 0.092 | 14.2 | 0.154 | 4.369 |
| | 24 | 30.5 | 10.3 | 9.9 | 0.690 | 12.90 | 0.098 | 14.0 | 0.150 | 4.377 |
| | 30 | 30.0 | 10.5 | 9.6 | 0.679 | 12.94 | 0.107 | 13.7 | 0.146 | 4.355 |
| 100 | 4 | 30.8 | 10.2 | 9.9 | 0.737 | 12.67 | 0.094 | 18.1 | 0.150 | 4.311 |
| | 8 | 29.4 | 10.9 | 10.2 | 0.650 | 10.20 | 0.155 | 13.3 | 0.149 | 4.302 |
| | 12 | 29.0 | 11.2 | 10.5 | 0.616 | 9.66 | 0.197 | 12.4 | 0.144 | 4.225 |
| | 18 | 28.5 | 12.0 | 10.3 | 0.602 | 9.40 | 0.214 | 10.8 | 0.139 | 4.192 |
| | 24 | 28.8 | 11.7 | 10.1 | 0.611 | 9.48 | 0.221 | 10.1 | 0.135 | 4.108 |
| | 30 | 28.4 | 11.9 | 10.4 | 0.606 | 9.53 | 0.234 | 9.2 | 0.131 | 4.072 |
| HSD | | 0.8 | 0.6 | 0.6 | 0.051 | 0.40 | 0.017 | 2.5 | 0.017 | 0.110 |

Table 4. Effects of temperatures and duration of storage on some physical and chemical characteristics of beef stew.

| Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Rancidity free fatty acid % oleic acid | Hydrolysis of protein mg amino acid/100 g | Titratable acidity meq acid/100 g | Thiamine µg/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|---|
| – | 0 | 32.6 | 12.4 | 13.8 | 0.792 | 0.128 | 230 | 6.36 | 22.6 | 0.107 | 1.80 |
| 40 | 4 | 32.7 | 12.4 | 13.8 | 0.790 | 0.130 | 230 | 6.33 | 22.9 | 0.106 | 1.80 |
| | 8 | 32.4 | 12.8 | 13.6 | 0.794 | 0.136 | 234 | 6.31 | 21.4 | 0.106 | 1.78 |
| | 12 | 32.5 | 12.6 | 13.7 | 0.779 | 0.134 | 230 | 6.30 | 21.7 | 0.105 | 1.79 |
| | 18 | 32.2 | 12.6 | 13.8 | 0.785 | 0.130 | 237 | 6.34 | 21.0 | 0.103 | 1.76 |
| | 24 | 32.5 | 12.8 | 14.0 | 0.781 | 0.135 | 235 | 6.38 | 21.4 | 0.105 | 1.77 |
| | 30 | 32.3 | 13.0 | 13.7 | 0.784 | 0.142 | 238 | 6.41 | 21.1 | 0.102 | 1.73 |
| 70 | 4 | 32.0 | 13.6 | 13.4 | 0.791 | 0.151 | 231 | 6.69 | 20.8 | 0.106 | 1.80 |
| | 8 | 31.3 | 14.0 | 13.5 | 0.766 | 0.169 | 238 | 6.94 | 20.0 | 0.102 | 1.74 |
| | 12 | 31.0 | 14.2 | 13.0 | 0.743 | 0.183 | 244 | 7.70 | 18.4 | 0.102 | 1.65 |
| | 18 | 31.3 | 14.0 | 13.0 | 0.735 | 0.192 | 250 | 7.82 | 16.1 | 0.100 | 1.65 |
| | 24 | 31.4 | 13.7 | 13.1 | 0.736 | 0.199 | 256 | 7.89 | 15.5 | 0.096 | 1.60 |
| | 30 | 31.0 | 14.1 | 13.0 | 0.730 | 0.214 | 263 | 7.98 | 15.2 | 0.097 | 1.60 |
| 100 | 4 | 31.8 | 13.9 | 13.3 | 0.771 | 0.204 | 240 | 6.97 | 16.7 | 0.100 | 1.67 |
| | 8 | 30.6 | 14.4 | 13.1 | 0.750 | 0.269 | 249 | 7.33 | 13.3 | 0.095 | 1.60 |
| | 12 | 30.7 | 14.9 | 12.9 | 0.728 | 0.289 | 268 | 8.21 | 9.6 | 0.093 | 1.46 |
| | 18 | 30.2 | 14.6 | 12.4 | 0.714 | 0.298 | 276 | 8.55 | 7.9 | 0.089 | 1.44 |
| | 24 | 30.5 | 14.5 | 12.6 | 0.704 | 0.316 | 281 | 8.74 | 7.4 | 0.083 | 1.41 |
| | 30 | 30.1 | 14.5 | 12.3 | 0.683 | 0.331 | 292 | 8.80 | 7.2 | 0.084 | 1.40 |
| HSD | | 0.9 | 1.4 | 1.1 | 0.017 | 0.011 | 25 | 0.23 | 2.3 | 0.011 | 0.13 |

Table 5. Effects of temperatures and duration of storage on some physical and chemical characteristics of cheese spread.

| Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Rancidity free fatty acid % oleic acid | Hydrolysis of protein mg amino acid/100 g | Titratable acidity meq acid/100 g | Thiamine μg/100 g | Riboflavin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|
| — | 0 | 75.3 | 7.9 | 31.4 | 0.296 | 0.160 | 711 | 16.81 | 15.4 | 0.396 |
| 40 | 4 | 75.3 | 8.0 | 31.0 | 0.299 | 0.165 | 715 | 16.79 | 15.0 | 0.397 |
| | 8 | 75.0 | 8.0 | 31.0 | 0.312 | 0.168 | 720 | 16.77 | 15.1 | 0.396 |
| | 12 | 75.0 | 8.1 | 31.0 | 0.304 | 0.165 | 729 | 16.86 | 14.9 | 0.396 |
| | 18 | 74.3 | 8.1 | 29.9 | 0.316 | 0.174 | 738 | 16.84 | 14.6 | 0.393 |
| | 24 | 74.6 | 8.0 | 31.0 | 0.311 | 0.179 | 736 | 16.88 | 14.8 | 0.396 |
| | 30 | 74.2 | 8.2 | 29.7 | 0.319 | 0.183 | 741 | 16.95 | 14.3 | 0.390 |
| 70 | 4 | 75.1 | 8.1 | 31.0 | 0.319 | 0.183 | 768 | 16.80 | 14.9 | 0.396 |
| | 8 | 74.6 | 8.0 | 31.0 | 0.327 | 0.184 | 783 | 16.74 | 14.0 | 0.390 |
| | 12 | 74.1 | 8.3 | 29.7 | 0.344 | 0.191 | 840 | 17.12 | 13.3 | 0.393 |
| | 18 | 71.0 | 8.4 | 28.4 | 0.369 | 0.202 | 870 | 17.29 | 13.0 | 0.390 |
| | 24 | 70.6 | 8.6 | 28.0 | 0.365 | 0.227 | 896 | 17.43 | 12.6 | 0.382 |
| | 30 | 70.0 | 8.9 | 27.5 | 0.377 | 0.240 | 904 | 17.71 | 12.3 | 0.366 |
| 100 | 4 | 74.8 | 8.9 | 29.1 | 0.414 | 0.211 | 1016 | 17.49 | 12.4 | 0.390 |
| | 8 | 71.5 | 9.0 | 28.9 | 0.485 | 0.240 | 1084 | 18.95 | 10.1 | 0.374 |
| | 12 | 68.2 | 9.2 | 28.3 | 0.537 | 0.278 | 1197 | 19.28 | 9.2 | 0.350 |
| | 18 | 66.9 | 9.5 | 28.0 | 0.587 | 0.294 | 1249 | 19.80 | 8.7 | 0.334 |
| HSD | | 0.8 | 0.5 | 0.6 | 0.036 | 0.014 | 76 | 0.21 | 2.9 | 0.013 |

Table 6. Effects of temperatures and duration of storage on some physical and chemical characteristics of pineapple.

| Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Titratable acidity % citric acid | Sugar Total g/100 g | Sugar Reducing g/100 g | Ascorbic acid mg/100 g |
|---|---|---|---|---|---|---|---|---|---|
| – | 0 | 44.4 | 3.4 | 20.3 | 0.343 | 0.692 | 32.11 | 17.93 | 5.33 |
| 40 | 4 | 44.2 | 3.5 | 20.4 | 0.340 | 0.708 | 32.10 | 18.10 | 5.30 |
| | 8 | 44.0 | 3.9 | 20.1 | 0.348 | 0.715 | 32.03 | 18.51 | 5.30 |
| | 12 | 43.8 | 3.9 | 20.0 | 0.360 | 0.758 | 32.04 | 18.77 | 5.19 |
| | 18 | 43.4 | 3.8 | 20.1 | 0.364 | 0.744 | 32.01 | 18.94 | 5.14 |
| | 24 | 43.5 | 4.0 | 20.0 | 0.369 | 0.766 | 32.03 | 18.99 | 5.10 |
| | 30 | 43.3 | 4.1 | 20.2 | 0.372 | 0.760 | 32.05 | 18.93 | 5.02 |
| 70 | 4 | 42.1 | 4.0 | 19.9 | 0.355 | 0.734 | 32.01 | 19.58 | 5.24 |
| | 8 | 40.6 | 4.5 | 19.2 | 0.378 | 0.792 | 31.82 | 22.41 | 5.11 |
| | 12 | 40.2 | 4.8 | 19.1 | 0.404 | 0.976 | 31.54 | 23.09 | 4.80 |
| | 18 | 39.2 | 5.1 | 18.4 | 0.413 | 0.950 | 31.44 | 25.02 | 4.03 |
| | 24 | 39.0 | 5.0 | 18.1 | 0.425 | 0.992 | 31.40 | 25.16 | 3.94 |
| | 30 | 38.5 | 5.3 | 18.1 | 0.419 | 1.025 | 31.37 | 25.29 | 3.90 |
| 100 | 4 | 38.7 | 5.8 | 18.5 | 0.410 | 0.805 | 30.69 | 27.40 | 4.36 |
| | 8 | 34.9 | 7.3 | 16.1 | 0.456 | 0.853 | 31.51 | 31.24 | 2.97 |
| | 12 | 33.7 | 7.7 | 15.4 | 0.497 | 0.891 | 31.52 | 31.18 | 2.66 |
| | 18 | 32.1 | 8.4 | 14.2 | 0.509 | 0.902 | 31.39 | 31.08 | 0.98 |
| HSD | | 0.7 | 0.4 | 0.5 | 0.022 | 0.018 | 0.09 | 0.08 | 0.15 |

Table 7. Effects of temperatures and duration of storage on some physical and chemical characteristics of fruit cake.

| Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Titratable acidity meq acid/100 g | Rancidity free fatty acid % oleic acid | Sugar Total g/100 g | Sugar Reducing µg/100 g | Thiamine g/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| – | 0 | 36.0 | 12.1 | 17.0 | 0.794 | 9.70 | 0.131 | 41.01 | 19.04 | 95.6 | 0.150 | 3.109 |
| 40 | 4 | 36.0 | 12.0 | 17.0 | 0.781 | 9.70 | 0.131 | 41.00 | 19.27 | 94.8 | 0.150 | 3.098 |
| | 8 | 35.9 | 12.1 | 17.0 | 0.788 | 9.68 | 0.129 | 41.00 | 20.50 | 95.0 | 0.149 | 3.105 |
| | 12 | 35.6 | 11.8 | 16.5 | 0.790 | 9.75 | 0.129 | 40.94 | 20.82 | 94.9 | 0.152 | 3.091 |
| | 18 | 35.3 | 11.8 | 16.6 | 0.792 | 9.74 | 0.134 | 40.96 | 20.89 | 94.3 | 0.155 | 3.080 |
| | 24 | 35.1 | 11.8 | 16.4 | 0.789 | 9.79 | 0.137 | 40.94 | 20.93 | 94.4 | 0.151 | 3.087 |
| | 30 | 35.1 | 11.6 | 16.5 | 0.790 | 9.83 | 0.142 | 40.97 | 20.90 | 94.0 | 0.148 | 3.074 |
| 70 | 4 | 35.4 | 12.0 | 16.6 | 0.785 | 9.74 | 0.130 | 40.83 | 19.61 | 94.0 | 0.151 | 3.094 |
| | 8 | 33.8 | 11.4 | 14.5 | 0.772 | 9.89 | 0.149 | 40.81 | 21.34 | 86.7 | 0.141 | 3.067 |
| | 12 | 32.2 | 11.0 | 13.9 | 0.779 | 9.93 | 0.178 | 40.63 | 21.91 | 80.1 | 0.133 | 3.024 |
| | 18 | 31.4 | 10.9 | 13.4 | 0.768 | 9.98 | 0.188 | 40.70 | 22.10 | 77.0 | 0.130 | 3.001 |
| | 24 | 31.0 | 10.8 | 13.0 | 0.760 | 10.03 | 0.194 | 40.71 | 22.17 | 75.3 | 0.132 | 3.004 |
| | 30 | 30.6 | 10.7 | 12.7 | 0.764 | 10.11 | 0.205 | 40.76 | 22.28 | 74.8 | 0.128 | 2.993 |
| 100 | 4 | 33.0 | 11.6 | 15.3 | 0.786 | 11.06 | 0.186 | 40.62 | 23.71 | 81.4 | 0.144 | 2.933 |
| | 8 | 31.4 | 11.1 | 14.2 | 0.791 | 12.33 | 0.275 | 40.09 | 25.74 | 69.8 | 0.129 | 2.901 |
| | 12 | 27.7 | 10.1 | 10.4 | 0.784 | 12.92 | 0.320 | 39.75 | 27.76 | 63.0 | 0.125 | 2.796 |
| | 18 | 26.2 | 10.4 | 10.0 | 0.774 | 13.04 | 0.340 | 39.59 | 28.44 | 49.6 | 0.122 | 2.760 |
| | 24 | 25.1 | 10.0 | 9.6 | 0.763 | 13.26 | 0.351 | 39.53 | 28.56 | 45.1 | 0.120 | 2.744 |
| | 30 | 24.4 | 9.8 | 9.5 | 0.752 | 13.68 | 0.377 | 39.55 | 28.78 | 44.5 | 0.116 | 2.705 |
| HSD | | 0.8 | 0.5 | 0.4 | 0.029 | 0.23 | 0.027 | 0.11 | 0.14 | 4.1 | 0.008 | 0.105 |

Table 8. Effects of temperatures and duration of storage on some physical and chemical characteristics of chocolate brownies.

| Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Titratable acidity meq acid/100 g | Rancidity free fatty acid % oleic acid | Sugar Total g/100 g | Sugar Reducing g/100 g | Thiamine µg/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| – | 0 | 28.3 | 8.3 | 8.3 | 0.426 | 6.53 | 0.110 | 41.60 | 3.36 | 130.6 | 0.341 | 2.466 |
| 40 | 4 | 28.0 | 8.3 | 8.2 | 0.425 | 6.50 | 0.114 | 41.44 | 3.39 | 130.0 | 0.346 | 2.469 |
| | 8 | 27.9 | 8.2 | 8.3 | 0.422 | 6.50 | 0.119 | 41.41 | 3.38 | 130.4 | 0.330 | 2.450 |
| | 12 | 28.0 | 8.0 | 8.1 | 0.439 | 6.49 | 0.115 | 41.40 | 3.40 | 129.3 | 0.332 | 2.461 |
| | 18 | 28.1 | 8.0 | 8.0 | 0.446 | 6.54 | 0.119 | 41.40 | 3.38 | 127.9 | 0.329 | 2.412 |
| | 24 | 28.0 | 8.1 | 8.1 | 0.440 | 6.59 | 0.124 | 41.44 | 3.41 | 128.2 | 0.330 | 2.423 |
| | 30 | 28.0 | 8.0 | 8.1 | 0.445 | 6.62 | 0.128 | 41.41 | 3.45 | 128.4 | 0.333 | 2.420 |
| 70 | 4 | 27.8 | 8.0 | 8.0 | 0.420 | 6.50 | 0.126 | 41.56 | 3.41 | 118.4 | 0.335 | 2.411 |
| | 8 | 26.2 | 7.9 | 7.8 | 0.431 | 6.48 | 0.143 | 41.34 | 3.40 | 115.5 | 0.340 | 2.405 |
| | 12 | 26.3 | 8.0 | 7.8 | 0.453 | 6.44 | 0.153 | 41.31 | 3.47 | 99.0 | 0.326 | 2.410 |
| | 18 | 26.6 | 7.8 | 7.9 | 0.463 | 6.60 | 0.167 | 41.33 | 3.49 | 95.6 | 0.337 | 2.407 |
| | 24 | 26.4 | 7.8 | 7.7 | 0.470 | 6.72 | 0.175 | 41.31 | 3.56 | 94.8 | 0.326 | 2.383 |
| | 30 | 26.1 | 7.5 | 7.7 | 0.482 | 6.83 | 0.180 | 41.34 | 3.58 | 94.2 | 0.323 | 2.385 |
| 100 | 4 | 26.7 | 7.4 | 7.6 | 0.429 | 7.16 | 0.190 | 41.24 | 3.44 | 116.3 | 0.319 | 2.395 |
| | 8 | 24.3 | 6.9 | 6.7 | 0.438 | 7.73 | 0.255 | 41.00 | 3.49 | 107.5 | 0.310 | 2.309 |
| | 12 | 24.2 | 6.8 | 7.0 | 0.485 | 8.24 | 0.312 | 40.92 | 3.58 | 71.6 | 0.291 | 2.306 |
| | 18 | 24.5 | 6.7 | 7.3 | 0.498 | 8.58 | 0.336 | 40.79 | 3.66 | 49.7 | 0.274 | 2.293 |
| | 24 | 24.7 | 6.5 | 7.0 | 0.511 | 8.75 | 0.349 | 40.48 | 3.73 | 47.3 | 0.260 | 2.146 |
| | 30 | 24.4 | 6.5 | 7.1 | 0.526 | 8.91 | 0.358 | 40.52 | 3.77 | 46.5 | 0.249 | 2.133 |
| HSD | | 0.9 | 0.5 | 0.7 | 0.015 | 0.09 | 0.028 | 0.08 | 0.07 | 4.8 | 0.024 | 0.108 |

Table 9. Effects of temperatures and duration of storage on some physical and chemical characteristics of freeze-dehydrated items.

| Item | Storage temper-ature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Rancidity free fatty acid % oleic acid | Titratable acidity meq acid/100 g | Thiamine µg/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chicken stew | — | 0 | 58.0 | -0.9 | 24.0 | 0.849 | 0.073 | 14.3 | 179.0 | 0.312 | 5.406 |
| | 40 | 4 | 58.1 | -0.5 | 24.2 | 0.831 | 0.073 | 14.4 | 178.2 | 0.310 | 5.437 |
| | | 10 | 58.3 | -0.5 | 24.1 | 0.844 | 0.072 | 14.4 | 173.9 | 0.304 | 5.451 |
| | | 16 | 58.4 | -0.7 | 24.0 | 0.840 | 0.073 | 14.4 | 175.6 | 0.306 | 5.440 |
| | | 20 | 58.3 | -0.8 | 24.2 | 0.845 | 0.075 | 14.6 | 176.5 | 0.307 | 5.425 |
| | 70 | 4 | 58.9 | -0.2 | 23.9 | 0.844 | 0.078 | 14.7 | 173.8 | 0.308 | 5.396 |
| | | 10 | 58.9 | -0.6 | 24.4 | 0.848 | 0.076 | 14.9 | 179.4 | 0.311 | 5.380 |
| | | 16 | 59.1 | -0.6 | 24.2 | 0.836 | 0.079 | 15.0 | 176.3 | 0.302 | 5.394 |
| | | 20 | 59.0 | -0.7 | 24.1 | 0.831 | 0.080 | 15.3 | 174.4 | 0.304 | 5.368 |
| | 100 | 4 | 60.4 | -1.9 | 24.0 | 0.820 | 0.082 | 15.4 | 176.7 | 0.315 | 5.403 |
| | | 10 | 61.2 | -2.3 | 24.6 | 0.815 | 0.085 | 15.8 | 171.8 | 0.300 | 5.428 |
| | | 16 | 61.7 | -2.7 | 24.7 | 0.808 | 0.089 | 16.1 | 171.4 | 0.308 | 5.415 |
| | | 20 | 61.9 | -2.9 | 24.9 | 0.802 | 0.095 | 16.6 | 167.5 | 0.301 | 5.377 |
| | HSD | | 0.8 | 0.6 | 0.7 | 0.043 | 0.006 | 0.5 | 16.2 | 0.035 | 0.155 |
| Chicken and rice | — | 0 | 51.1 | 11.2 | 29.8 | 0.728 | 0.090 | 15.3 | 268.8 | 0.219 | 6.155 |
| | 40 | 4 | 51.1 | 11.4 | 30.0 | 0.746 | 0.090 | 15.3 | 265.4 | 0.219 | 6.148 |
| | | 10 | 51.3 | 11.7 | 29.8 | 0.731 | 0.093 | 15.5 | 270.3 | 0.214 | 6.123 |
| | | 16 | 51.6 | 11.5 | 29.9 | 0.734 | 0.091 | 15.3 | 269.6 | 0.216 | 6.130 |
| | | 20 | 51.8 | 11.5 | 30.2 | 0.739 | 0.094 | 15.4 | 264.8 | 0.217 | 6.144 |
| | 70 | 4 | 54.1 | 9.0 | 31.7 | 0.765 | 0.093 | 15.5 | 266.0 | 0.216 | 6.144 |
| | | 10 | 54.0 | 8.5 | 31.1 | 0.754 | 0.098 | 15.7 | 264.8 | 0.207 | 6.165 |
| | | 16 | 54.4 | 8.7 | 31.0 | 0.748 | 0.096 | 15.7 | 262.6 | 0.210 | 6.142 |
| | | 20 | 54.7 | 8.4 | 31.1 | 0.740 | 0.099 | 15.8 | 260.3 | 0.208 | 6.105 |
| | 100 | 4 | 59.2 | 6.7 | 31.6 | 0.722 | 0.100 | 15.6 | 264.2 | 0.210 | 6.106 |
| | | 10 | 60.4 | 6.0 | 31.9 | 0.720 | 0.107 | 16.0 | 261.4 | 0.211 | 6.070 |
| | | 16 | 59.8 | 6.2 | 32.4 | 0.729 | 0.112 | 16.2 | 260.3 | 0.211 | 6.084 |
| | | 20 | 60.6 | 6.0 | 32.7 | 0.736 | 0.115 | 16.5 | 256.7 | 0.201 | 6.025 |
| | HSD | | 1.4 | 0.7 | 0.8 | 0.062 | 0.007 | 0.7 | 14.9 | 0.021 | 0.167 |

Table 10. Effects of temperatures and duration of storage on some physical and chemical characteristics of freeze-dehydrated items.

| Item | Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Rancidity free fatty acid % oleic acid | Titratable acidity meq acid/100 g | Thiamine µg/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Beef hash | – | 0 | 41.0 | 4.0 | 12.1 | 1.004 | 0.107 | 15.0 | 184.2 | 0.180 | 4.850 |
| | 40 | 4 | 41.2 | 3.8 | 12.2 | 1.063 | 0.118 | 15.1 | 185.0 | 0.183 | 4.811 |
| | | 10 | 41.0 | 4.0 | 12.0 | 1.024 | 0.120 | 15.5 | 183.2 | 0.179 | 4.783 |
| | | 16 | 41.1 | 4.0 | 11.9 | 1.036 | 0.118 | 15.6 | 184.6 | 0.176 | 4.790 |
| | | 20 | 40.9 | 3.9 | 12.1 | 1.044 | 0.122 | 15.7 | 183.1 | 0.177 | 4.806 |
| | 70 | 4 | 42.1 | 4.0 | 12.3 | 0.985 | 0.124 | 15.3 | 181.4 | 0.182 | 4.842 |
| | | 10 | 42.4 | 3.8 | 12.2 | 1.061 | 0.131 | 15.9 | 185.0 | 0.184 | 4.847 |
| | | 16 | 42.6 | 3.7 | 12.0 | 1.008 | 0.135 | 16.2 | 184.9 | 0.180 | 4.838 |
| | | 20 | 42.8 | 3.7 | 11.9 | 1.035 | 0.139 | 16.4 | 180.5 | 0.175 | 4.815 |
| | 100 | 4 | 42.6 | 2.0 | 11.8 | 1.017 | 0.133 | 15.2 | 183.7 | 0.176 | 4.833 |
| | | 10 | 42.9 | 1.7 | 11.5 | 1.002 | 0.147 | 15.9 | 180.9 | 0.173 | 4.820 |
| | | 16 | 43.2 | 1.4 | 11.6 | 1.019 | 0.151 | 16.3 | 181.7 | 0.171 | 4.816 |
| | | 20 | 43.8 | 1.5 | 11.4 | 1.047 | 0.160 | 16.8 | 176.4 | 0.164 | 4.765 |
| | HSD | | 0.7 | 0.4 | 0.5 | 0.188 | 0.014 | 0.5 | 11.2 | 0.017 | 0.142 |
| Escalloped pork with potato | – | 0 | 60.1 | 11.2 | 30.0 | 2.411 | 0.135 | 17.3 | 686.4 | 0.366 | 4.490 |
| | 40 | 4 | 60.0 | 11.4 | 30.0 | 2.509 | 0.133 | 17.2 | 683.2 | 0.364 | 4.456 |
| | | 10 | 60.2 | 11.5 | 30.0 | 2.487 | 0.138 | 17.4 | 685.3 | 0.367 | 4.481 |
| | | 16 | 60.3 | 11.0 | 30.2 | 2.466 | 0.135 | 17.3 | 681.9 | 0.360 | 4.447 |
| | | 20 | 60.0 | 10.9 | 30.0 | 2.480 | 0.136 | 17.4 | 682.4 | 0.360 | 4.462 |
| | 70 | 4 | 60.3 | 8.0 | 31.0 | 1.939 | 0.140 | 17.6 | 684.0 | 0.360 | 4.413 |
| | | 10 | 60.0 | 8.4 | 30.8 | 1.912 | 0.144 | 17.7 | 679.6 | 0.358 | 4.392 |
| | | 16 | 60.0 | 8.1 | 30.9 | 1.904 | 0.146 | 17.8 | 680.8 | 0.364 | 4.408 |
| | | 20 | 59.2 | 8.0 | 30.4 | 1.914 | 0.148 | 18.0 | 678.8 | 0.356 | 4.421 |
| | 100 | 4 | 59.2 | 6.7 | 31.6 | 1.743 | 0.151 | 17.8 | 680.7 | 0.365 | 4.405 |
| | | 10 | 59.1 | 5.8 | 31.9 | 1.704 | 0.159 | 18.2 | 682.0 | 0.363 | 4.366 |
| | | 16 | 58.8 | 5.5 | 32.3 | 1.711 | 0.164 | 18.4 | 680.0 | 0.361 | 4.375 |
| | | 20 | 58.1 | 5.2 | 32.6 | 1.708 | 0.170 | 18.7 | 676.1 | 0.351 | 4.349 |
| | HSD | | 0.7 | 1.1 | 0.7 | 0.096 | 0.011 | 0.4 | 12.3 | 0.025 | 0.217 |

Table 11. Effects of temperatures and duration of storage on some physical and chemical characteristics of freeze-dehydrated items.

| Item | Storage temperature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Rancidity free fatty acid % oleic acid | Titratable acidity meq acid/100 g | Thiamine µg/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chili con carne with beans | – | 0 | 37.1 | 8.1 | 16.7 | 1.153 | 0.141 | 25.4 | 173.1 | 0.210 | 4.203 |
| | 40 | 4 | 37.4 | 8.0 | 17.0 | 1.202 | 0.145 | 25.4 | 173.0 | 0.211 | 4.190 |
| | | 10 | 37.4 | 8.1 | 16.9 | 1.213 | 0.148 | 25.4 | 169.3 | 0.204 | 4.197 |
| | | 16 | 37.0 | 8.1 | 16.9 | 1.184 | 0.145 | 25.5 | 170.5 | 0.206 | 4.166 |
| | | 20 | 37.3 | 8.0 | 16.7 | 1.192 | 0.149 | 25.5 | 171.6 | 0.210 | 4.174 |
| | 70 | 4 | 37.6 | 8.0 | 16.9 | 1.137 | 0.149 | 25.7 | 172.5 | 0.209 | 4.200 |
| | | 10 | 37.7 | 8.3 | 16.8 | 1.106 | 0.157 | 25.6 | 173.4 | 0.213 | 4.207 |
| | | 16 | 37.9 | 8.0 | 16.9 | 1.180 | 0.160 | 25.8 | 173.0 | 0.200 | 4.187 |
| | | 20 | 38.2 | 8.3 | 17.0 | 1.163 | 0.163 | 25.9 | 170.4 | 0.198 | 4.166 |
| | 100 | 4 | 40.3 | 9.2 | 17.9 | 1.149 | 0.162 | 25.8 | 169.8 | 0.207 | 4.185 |
| | | 10 | 40.6 | 9.5 | 17.6 | 1.098 | 0.170 | 26.2 | 166.5 | 0.196 | 4.142 |
| | | 16 | 40.1 | 9.4 | 17.5 | 1.166 | 0.177 | 26.6 | 164.2 | 0.199 | 4.130 |
| | | 20 | 40.3 | 9.6 | 17.8 | 1.152 | 0.182 | 27.1 | 160.5 | 0.191 | 4.115 |
| | HSD | | 1.0 | 0.5 | 0.7 | 0.106 | 0.010 | 0.5 | 13.7 | 0.030 | 0.157 |
| Beef stew | – | 0 | 43.0 | 4.7 | 14.8 | 1.250 | 0.098 | 20.5 | 155.4 | 0.177 | 4.960 |
| | 40 | 4 | 43.3 | 4.3 | 15.1 | 1.239 | 0.100 | 20.7 | 151.6 | 0.172 | 4.944 |
| | | 10 | 43.6 | 4.8 | 14.9 | 1.247 | 0.095 | 20.9 | 153.0 | 0.170 | 4.942 |
| | | 16 | 43.4 | 4.7 | 14.8 | 1.244 | 0.102 | 20.9 | 153.8 | 0.171 | 4.911 |
| | | 20 | 43.3 | 4.9 | 14.9 | 1.255 | 0.100 | 21.0 | 152.7 | 0.168 | 4.924 |
| | 70 | 4 | 43.9 | 4.2 | 15.7 | 1.315 | 0.103 | 20.7 | 154.7 | 0.169 | 4.937 |
| | | 10 | 44.0 | 4.0 | 15.5 | 1.296 | 0.114 | 20.9 | 157.3 | 0.174 | 4.886 |
| | | 16 | 44.2 | 4.0 | 15.8 | 1.308 | 0.119 | 21.2 | 153.0 | 0.170 | 4.893 |
| | | 20 | 44.5 | 4.0 | 15.6 | 1.319 | 0.121 | 21.7 | 150.4 | 0.162 | 4.868 |
| | 100 | 4 | 44.6 | 3.9 | 17.1 | 1.283 | 0.114 | 20.9 | 152.2 | 0.174 | 4.952 |
| | | 10 | 44.9 | 3.7 | 17.4 | 1.299 | 0.127 | 21.4 | 150.6 | 0.163 | 4.904 |
| | | 16 | 45.3 | 3.9 | 17.6 | 1.311 | 0.134 | 21.8 | 151.9 | 0.166 | 4.916 |
| | | 20 | 45.5 | 3.6 | 18.0 | 1.338 | 0.138 | 22.3 | 147.9 | 0.160 | 4.851 |
| | HSD | | 1.3 | 0.6 | 0.7 | 0.068 | 0.014 | 0.4 | 14.2 | 0.020 | 0.194 |

Table 12. Effects of temperatures and duration of storage on some physical and chemical characteristics of freeze-dehydrated items.

| Item | Storage temper-ature °F | Months storage | Hunter Color L units | Hunter Color a units | Hunter Color b units | Volatile reducing substances meq/100 g | Rancidity free fatty acid % oleic acid | Titratable acidity meq acid/100 g | Thiamine µg/100 g | Riboflavin mg/100 g | Niacin mg/100 g |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Beef and rice | – | 0 | 45.4 | 3.9 | 14.0 | 0.975 | 0.100 | 11.3 | 244.0 | 0.185 | 5.109 |
| | 40 | 4 | 45.3 | 3.7 | 14.4 | 0.948 | 0.103 | 11.2 | 243.1 | 0.180 | 5.090 |
| | | 10 | 45.5 | 3.7 | 14.5 | 0.966 | 0.105 | 11.2 | 243.6 | 0.181 | 5.040 |
| | | 16 | 45.5 | 3.7 | 14.4 | 0.960 | 0.101 | 11.4 | 241.3 | 0.182 | 5.084 |
| | | 20 | 45.7 | 3.6 | 14.6 | 0.983 | 0.108 | 11.8 | 240.0 | 0.180 | 5.062 |
| | 70 | 4 | 46.9 | 3.0 | 15.0 | 1.066 | 0.108 | 11.6 | 240.8 | 0.183 | 5.114 |
| | | 10 | 47.2 | 2.9 | 15.0 | 1.117 | 0.133 | 11.8 | 238.0 | 0.174 | 5.122 |
| | | 16 | 47.6 | 3.0 | 15.2 | 1.132 | 0.139 | 11.9 | 239.8 | 0.176 | 5.109 |
| | | 20 | 47.9 | 3.0 | 15.4 | 1.154 | 0.146 | 12.4 | 236.4 | 0.172 | 5.046 |
| | 100 | 4 | 48.5 | 2.6 | 15.2 | 1.212 | 0.174 | 12.5 | 240.2 | 0.179 | 5.066 |
| | | 10 | 48.9 | 2.4 | 15.7 | 1.249 | 0.196 | 12.7 | 241.3 | 0.177 | 5.104 |
| | | 16 | 49.0 | 2.3 | 15.3 | 1.266 | 0.210 | 12.9 | 240.5 | 0.173 | 5.100 |
| | | 20 | 49.2 | 2.1 | 15.9 | 1.295 | 0.231 | 13.5 | 233.5 | 0.166 | 5.019 |
| | HSD | | 0.8 | 0.7 | 0.5 | 0.099 | 0.010 | 0.7 | 10.9 | 0.024 | 0.175 |
| Spaghetti with meat sauce | – | 0 | 43.5 | 10.1 | 19.6 | 0.709 | 0.129 | 27.2 | 268.0 | 0.251 | 4.963 |
| | 40 | 4 | 43.3 | 10.2 | 19.8 | 0.726 | 0.131 | 27.2 | 265.5 | 0.252 | 4.960 |
| | | 10 | 43.3 | 10.2 | 19.7 | 0.734 | 0.134 | 27.4 | 268.4 | 0.241 | 4.883 |
| | | 16 | 43.7 | 10.0 | 19.8 | 0.711 | 0.130 | 27.5 | 264.3 | 0.244 | 4.903 |
| | | 20 | 43.5 | 10.3 | 19.6 | 0.719 | 0.134 | 27.4 | 264.0 | 0.249 | 4.906 |
| | 70 | 4 | 43.7 | 11.0 | 20.5 | 0.693 | 0.141 | 27.5 | 263.7 | 0.240 | 4.903 |
| | | 10 | 43.9 | 11.4 | 20.8 | 0.721 | 0.149 | 28.2 | 265.2 | 0.238 | 4.907 |
| | | 16 | 44.0 | 11.2 | 20.9 | 0.706 | 0.151 | 28.4 | 260.9 | 0.245 | 4.919 |
| | | 20 | 44.3 | 11.2 | 21.1 | 0.715 | 0.156 | 28.9 | 257.7 | 0.233 | 4.885 |
| | 100 | 4 | 45.7 | 11.4 | 21.8 | 0.713 | 0.148 | 29.7 | 260.4 | 0.249 | 4.896 |
| | | 10 | 46.2 | 11.7 | 22.0 | 0.708 | 0.161 | 30.9 | 258.6 | 0.246 | 4.942 |
| | | 16 | 46.1 | 11.8 | 22.2 | 0.710 | 0.167 | 31.6 | 259.4 | 0.241 | 4.924 |
| | | 20 | 46.5 | 12.0 | 22.4 | 0.701 | 0.175 | 32.4 | 254.0 | 0.029 | 4.817 |
| | HSD | | 0.5 | 0.4 | 0.6 | 0.088 | 0.016 | 0.9 | 17.2 | 0.024 | 0.176 |