TECHNICAL REPORT
68-26-GP

AD

STORAGE STABILITY OF CIVIL DEFENSE SHELTER RATIONS (ANNUAL REPORT)

by

S. R. Cecil

and

J. G. Woodroof

University of Georgia
Experiment, Georgia

Contract No. DA19-129-QM-2050 (N)

December 1967

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

U.S. ARMY MATERIEL COMMAND

General Equipment & Packaging Laboratory

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J. G. Woodroof

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FOREWORD

In 1962, under the Civil Defense Shelter Program, large quantities of food were stored in warehouses or in selected shelters for possible need during a national emergency. The types of food, which had not been procured previously, represented new formulations and new processing procedures. As a result, there was little or no information available on the stability of these foods and their containers when stored for extended periods.

This study was proposed to simulate conditions likely to exist in these shelters and to collect data at selected intervals that would provide current guidance as to the effect of long storage on foods and the containers in which they are stored.

On 20 June 1962, Contract DA19-129-QM-2050 was awarded by the U. S. Army Natick Laboratories to the Georgia Experiment Station, University of Georgia, to provide the facilities for the study and collect the required data. Authorization for this contract is included in Work Order Number OCD-OS-62-156 between the Department of the Army, Office of the Secretary of the Army, Office of Civil Defense, and the Department of the Army, Army Materiel Command.

This report contains the work performed under the above contract. However, the storage study will be continued under the direction of the Office of Civil Defense lead laboratory, Stanford Research Institute, until the stock of rations in storage is exhausted or falls below the acceptable range.

Project Officers for this contract were Mr. Jesse Hill, General Equipment and Packaging Laboratory, and Mr. Otto J. Stark, Food Laboratory, both of the U. S. Army Natick Laboratories.

EDWARD A. NEBESKY, Ph.D.
Acting Director
General Equipment & Packaging Laboratory

APPROVED:

DALE H. SIELING, Ph.D.
Scientific Director

CLIFFORD T. RIORDAN
Colonel, QMC
Commanding

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ABSTRACT

Results are reported on the stability of ten lots of fallout shelter cereal rations stored for 4 years and 3 lots of carbohydrate supplement stored for 3 years at 100°F/80% r.h., 100°/57%, 70°/80%, 70°/57%, 40°/57%, and 0°/ambient r.h. Rations include 4 lots of survival crackers, 4 lots of survival biscuits, 2 lots of bulgur wheat wafers, and 3 lots of mixed lemon and cherry flavored hard candies. Data include 48-month and 36-month values, respectively, for (1) bursting strength, moisture content, and general conditions of V3c fiberboard cases; (2) residual oxygen, leaking, corrosion, and coating defects of 2-1/2-gallon and 5-gallon metal cans; (3) breakage and general condition of package seals, seams and materials, and product units; (4) fracture strength, peroxides, and free fatty acids of wheat products; (5) pH and sugar contents of carbohydrate supplements; and (6) moisture content, color, sensory quality, and hedonic ratings for all products. Results of all examinations of stored rations, initially and through 36 and 48 months, are discussed.

STORAGE STABILITY OF CIVIL DEFENSE SHELTER RATIONS
(ANNUAL REPORT)

Introduction

A storage study was conducted over a four-year period to determine the stability of a variety of Civil Defense shelter rations. During this period, 10 cereal items were deposited in storage over an interval of four months. In addition, 3 carbohydrate supplements were stored for a three-year term. Determinations were also made of the stability of packaging materials in which the rations were stored.

Items stored for 4 years were:

Crackers code	Contract number	Biscuits code	Contract number	Bulgur Wafers code	Contract number
CD1	2692-62	CD2	2686-62	CD9	2254-62
CD3	2689-62	CD4	2694-62	("white" wheat)	
CD5	2687-62	CD6	2688-62	CD10	2254-62
CD8	2691-62	CD7	2687-62	("red" wheat)	

Carbohydrate supplements, stored 3 years, were:

Code	Contract Number
CD11	24018-63
CD12	24016-63
CD13	24023-63

Storage conditions for the period were:

Code	Temperature °F	Relative Humidity percent
100/80	99.9, +1.3, -1.3	81.0, +5.5, -3.9
100/57	100.1, +1.5, -1.5	58.0, +4.0, -2.6
70/80	70.0, +2.0, -0.8	80.6, +3.0, -2.4
70/57	69.9, +1.0, -1.0	57.8, +2.1, -1.9
40/57	40.6, +4.3, -1.3	60.2, +10.3, -3.6
0/ambient	0.4, +8.5, -1.6	ambient

The unusually large deviations above the means were incurred as a result of transferring all of the storage samples to new facilities in a new building; these included fluctuations in atmospheric conditions during the transfer and during the subsequent periods of adjustment in the six storage rooms.

Samples withdrawn for examination at the end of the respective fourth-year or third-year periods consisted of one case and two cans from each of the six storage conditions for each item. Basic procedures and sample replications for the various observations and determinations included in the examinations are given with the results and data reported below. Statistical treatment of data employed standard procedures for analysis of variance, multiple range testing for significance, and calculation of simple correlation coefficients.

Methods and Results

I. Fiberboard (V3c) Cases

Entire cases were used in all examinations excepting those for biscuit CD4 and crackers CD3 and CD1. These three items were packed in 2-1/2-gallon cans, six cans per case, and only 1/3 case was available for each withdrawal from storage. Samples at 48 months for CD4 and CD3 were the first third of newly-opened cases; those for CD1 were the remainder of cases previously sampled at 24 and 36 months.

Ten 4-inch squares were cut from available locations on side and end panels of each case and placed in sealed containers before removal from the storage room. Containers were then removed to a 73°F condition, allowed to equalize at this temperature, and bursting strength determined as rapidly as possible after opening the container, using a manually operated Mullen-type tester.

1. Bursting strength (Table 1)

As indicated by the comparative data in Table 1, bursting strength continued to exhibit an inverse relationship to storage temperature. Decreases at 100°F have been definite and progressive, with much less definite trends for moderate increases at 40° and 0°F. Results from 70°F and from 0°F have been quite variable, averages generally remaining near initial at 70° and failing to show proportional increases at 0°.

Temperature	Bursting Strength, changes from initial values (lbs.)								
	Cereal Item Cases					Carbohydrate Supplement Cases			
	1 yr	2 yr	3 yr	4 yr	±	1 yr	2 yr	3 yr	±
100	-48	-74	-91	-145	40	-58	-42	-91	33
70	- 1	-16	-11	- 21	40	-19	12	7	34
40	22	22	37	43	33	6	18	12	21
0	20	37	51	28	42	-12	33	18	58

There have been suggestions of lower bursting strength at the higher relative humidities in several sets of these data, as in those for 48 months in Table 1, and correlations between higher moisture and lower bursting strength have been variously observed. However, neither of these relationships has exhibited any consistent degree of significance.

TABLE 1

BURSTING STRENGTH OF V3c FIBERBOARD
(pounds per square inch)

A. Wheat Item Cases Stored 48 Months

Condition °F/% r.h.	CD1	CD3	CD4	CD2	CD5	CD6	CD7	CD8	CD9	CD10	Mean	Std.dev. 10 reps
100/80	334	320	288	282	353	319	334	381	276	275	316	26
100/57	304	335	356	319	351	342	366	387	323	319	340	22
70/80	384	425	477	452	380	432	462	477	364	350	420	41
70/57	526	458	479	497	463	441	487	525	462	480	482	31
40/57	540	496	580	545	464	439	531	554	517	485	515	34
0/amb	534	485	586	541	410	426	519	563	477	485	503	38
std.dev.,10 reps	32	26	42	34	32	38	15	48	47	15	35	-
sign.dif., 5%	28	23	38	30	30	34	13	43	42	13	13	35[a]
Mean	437	420	461	439	403	400	450	481	403	399	429	16[b]

B. Carbohydrate Supplement Cases Stored 36 Months

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dev. 10 reps
100/80	434	302	300	346	66
100/57	434	314	357	369	30
70/80	447	362	390	400	26
70/57	429	321	428	393	68
40/57	573	374	416	454	41
0/amb	589	375	417	460	58
std.dev.,10 reps	55	52	54	54	-
sign.dif., 5%	49	48	49	32	48[a]
Mean	484	341	385	404	22[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

Supplement CD12 was the only item with initial bursting strength below 400 psig (av. 365). As seen in Table 1, all samples held four years at 100°F were below this specification (20% being below 300), and four of ten samples from 70°/80% were also below the stated minimum.

2. Moisture Content (Table 2)

Samples for moisture determination were obtained at the same time and in the same manner as those for bursting strength. Moisture was calculated from weight losses of 5-grams of chopped fiberboard after heating 5 hours at 100°C under a 29-inch vacuum.

Levels of moisture in cases from the six storage conditions are given in Table 2. Although recorded temperatures and relative humidities averaged approximately the same as for the previous year, and the within-rooms range of the 13 items was 1.1 ± 0.4% for both years, levels in the new storage rooms averaged 2.9% higher at 100°/80%, 1.1% higher at 100°/70% and 2.2% higher at 0°/ambient. These rooms have different types of heat and moisture control systems from those in the older rooms used previously. On the other hand, the new 70° and 40°F rooms are essentially the same as the older rooms, and moisture averages differed by only 0.1 ± 0.4%. Thus, though averaging approximately the same at the point of location of the recorder (which was placed in all instances near the center of the "load" of ration cases), it is obvious that overall equilibria of the rooms varied with the type and location of control equipment.

A summary of average conditions recorded during the weeks when sampling was done, and results as shown in Table 2, is as follows:

100.0°/79.8%; range 11.4-12.2, mean 11.6%	70.1°/57.3%; range 7.5- 8.2, mean 7.7%
70.0°/80.1%; range 10.9-12.5, mean 11.9%	99.1°/57.2%; range 7.7- 8.5, mean 8.1%
-0.4°/ambient, range 13.5-15.1, mean 14.4%	40.4°/59.1%, range 8.7-10.0, mean 9.3%

As grouped, these correspond to four different types of control equipment. The effects of the "wetter" atmospheres on moisture content of the fiberboard are readily apparent, but assumption of any temperature influence would be extremely questionable.

3. General Condition of Cases

With the exception, noted above, that none of the cereal item cases and only a third of supplement cases stored at 100°F retain the specified minimum 400 psig bursting strength, with about 25% of the 70°F cases also under this minimum, the general condition of cases remained adequate for continued storage after four years. All showed some evidence of staining

TABLE 2

MOISTURE CONTENT OF V3c FIBERBOARD
(percent)

A. Wheat Item Cases Stored 48 Months

Condition °F/% r.h.	CD1	CD3	CD4	CD2	CD5	CD6	CD7	CD8	CD9	CD10	Mean
100/80	11.5	11.4	11.4	11.6	12.2	11.5	11.6	11.6	11.6	11.4	11.59
100/57	8.0	8.2	8.1	8.1	8.5	7.7	8.1	7.8	7.8	7.8	8.01
70/80	12.1	12.5	12.1	12.0	12.1	12.3	12.2	11.8	11.7	11.4	12.08
70/57	7.9	8.2	7.6	7.6	7.7	7.5	7.7	7.5	7.5	7.5	7.67
40/57	9.5	10.0	8.7	9.8	9.6	9.4	9.5	9.1	9.1	9.3	9.41
0/amb	13.8	14.3	14.7	14.7	15.1	14.0	14.8	14.8	14.9	14.8	14.58
std.dev., 2 reps	.04	.04	.04	.03	.11	.09	.05	.05	.05	.05	.06
sign.dif., 5%	.09	.08	.10	.08	.26	.20	.10	.11	.12	.11	.17
Mean[a]	10.46	10.77	10.42	10.64	10.88	10.39	10.65	10.46	10.45	10.42	10.56

B. Carbohydrate Supplement Cases Stored 36 Months

Condition °F/% r.h.	CD11	CD12	CD13	Mean
100/80	11.9	11.5	11.9	11.74
100/57	8.4	8.1	8.2	8.22
70/80	11.3	10.9	11.3	11.19
70/57	7.6	7.6	7.7	7.61
40/57	9.3	8.9	9.2	9.12
0/amb	13.9	13.5	14.0	13.77
std.dev., 2 reps	.06	.04	.08	.06
sign.dif., 5%	.14	.08	.19	.14
Mean[b]	10.39	10.07	10.35	10.27

[a] Significant differences were 0.24% for item means, 0.13% for items in rooms.
[b] Significant differences were 0.10% for item means, 0.13% for items in rooms.

and "wear" as a result of active use of the storage rooms, and of two or three necessary transfers or re-stackings during this period, but the resulting "slightly used" appearance has had practically no influence on their function as containers for the ration cans. Certain of the minor imperfections observed during the most recent examinations are given below; ratings for extent, where given, are on a 9-point scale.

Loose Seals. There has been no evidence of progressive loosening of seals in storage. While no completely unsealed flaps have been observed, several instances of partial spreading of adhesive have been noted, with no apparent association to time or storage condition. From all examinations to date, three items (CD2, 6, and 12) have had no inadequately glued flaps, while about 65% of the flaps of items CD5, 7 and 11 were unglued around the edges, resulting in slight "fraying" with handling of the cases. The other seven items average about 12% of such partially loose flaps, again with no impairment of case function other than slight damage to the edges of some of the flaps.

Delamination. Of the approximately 500 cases examined during the period of the study, about 5% have had slightly delaminated areas in loose flap corners. Only three cases have exhibited panel delamination, all three from 70°/80% storage. These were CD1 at 3 years, rating 1.5; CD4 at 3 years, rating 2.0, and CD6 at 2 years, rating 4.0. These were, however, only 3 of 65 cases examined from the 70°/80% condition, so delamination is apparently not a serious problem in the V3c cases.

Mold. Small areas of very light mold were observed on the outside and inside surfaces of some of the cases. Percentages of cases examined and average rating for severity of molding, were as follows:

	1st and 2nd years		3rd year		4th year	
	cases %	extent 0-9	cases %	extent 0-9	cases %	extent 0-9
Outside Mold						
100°/80%	6	.9	8	.3	–	
70°/80%	15	1.0	31	.4	40	.3
57% rooms	–		–		7	.3
Inside Mold						
100°/80%	11	.5	23	.5	10	.6
70°/80%	8	.7	54	.7	40	.9
57% rooms	3	.5	3	.2	10	.4

Practically all of the molded areas were on or near the bottoms of the cases, very few exceeded a few millimeters in diameter, and there was little or no damage to the cases. Many of the spots were small enough to pass unnoticed except on very close inspection.

Sweating of Cases. Moisture staining of outside surfaces of cases remained very slight, and with cereal item cases, was becoming somewhat difficult to differentiate from general staining and slightly soiled areas incurred in long storage and relatively frequent handling. Average rating for sweating of carbohydrate supplement cases was 0.5 ± 0.3 which is very low, and there was no significant difference among cases from the various storage conditions. This apparent reduction in staining resulted from the fact that the cases which had initially become stained from storage too near the doors, corners or "control" areas of the original smaller rooms had been utilized on previous examinations, before transferring to the new and larger rooms. The older and more frequently handled cereal item cases averaged slightly higher, 0.8, with some difference among storage conditions. For these cases, staining averaged 1.3 ± 1.0 from 70°/80% storage, 0.9 ± 0.3 from 100°/80% and 40°/57% storage, and 0.6 ± 0.3 from the other conditions. None of the staining was severe enough to detract from further utility of the cases.

Sweating of Cans in Cases. Evidence of sweating of cans was scored as rust or, in some instances, dark corrosion staining as these stains have become quite definite after three and four years of storage. Most of these were in the tops and bottoms of the cases, where the edges of the can seams had been pressed against the fiberboard by the weight of the rations in the stacks. As items, CD3, 8 and 11 averaged 0.4 ± 0.1, the other ten averaged 0.8 ± 0.1; i.e., the previously observed trend for greater amounts of sweating in cases of the heavier items CD9-CD13 was not observed at the latest examination period. Also, the carbohydrate supplements, previously averaging ca 0.3 higher than the cereal items, were as a group within less than 0.1 point of the same average rating. Storage condition means for all items were 1.2 ± 0.5 for 70°F/80% r.h., 0.8 ± 0.5 for 100°/80%, and 0.5 ± 0.3 for the other four rooms.

Collapse. As none of the four-case stacks were heavy enough to cause deformation of cans, collapse consisted in the extent of wrinkling or bulging of the cases in settling down to rest solidly on the cans. Association of extent of this defect with case weights was relatively close, though not as close as in some of the previous examinations. Items CD1 and CD3, 55 lb cases, averaged ratings of .85, slightly higher than before, and CD6 (40 lbs) and CD4 (55 lbs) at 1.08 ± .06 were definitely higher than usual for these weight groups. Items CD10, 12 and 13 (71-78 lbs) were about "normal" at 1.10 ± .18; the other six items at .49 ± .09 were lower, particularly CD9 and CD11 which had been stored near the tops of stacks in the above-70 lb group.

There was still no definite pattern for effects of storage conditions on wrinkling or bulging of the cases. Cases for carbohydrate supplements averaged .67 ± .23 at 100°, .81 ± .22 at 70° and 40°, and 1.47 ± .42 at 0°F. Cereal item cases averaged .82 ± .36 at 100°/80% and 40°/57%, .66 ±

.53 at the other four conditions. In other words, the effects of storage conditions, if any, are apparently obscured by weight, stacking, handling or other influences.

4. Condition of Case Markings

From all practical aspects, there has been no significant fading or blurring of case markings in storage. No item or storage condition mean rating was more than 0.3 different from initial rating, and 74% of the individual case ratings were below 0.5 for defects in printing. Of the 26% rated above 0.5 (20 cases, range .53-1.48, average .78), there were a few instances of blurring of print at the time of application, all others being due to scraping or scuffing in handling the cases. In all of the cases examined during the four years of the study, however, the only letters or numerals which could not be read without difficulty were those which were completely obliterated by physical damage before the cases were placed in storage.

II. Metal Cans

Cans of items CD1, 3 and 4 were 2-1/2-gallon size, contain approximately 7 lbs of crackers or biscuits. All other cans were 5-gallon size, containing 12-1/2 - 18-1/2 lbs of crackers or biscuits (CD2 and 5-8), 32-33 lbs of bulgur wafers (CD9, 10), or 34-36 lbs of carbohydrate supplement. All samples consisted of two cans each.

1. Residual Oxygen in Cans. (Table 3)

Oxygen remaining in the can space was determined as the lowest reading obtained while passing gases from the can through a direct-reading oxygen analyzer adjusted to a fresh air reading of 20.9% by volume. Determinations were made only for cereal items, CD1-10.

Item means as given in Table 3 were lower than at any previous period for all items except CD1 (slightly lower at 18 and 24 months) and CD4 (in which all cans were leakers at 48 months). Only three items, however, had lowest readings in cans from all six storage conditions; these were CD2, CD8, and CD10. For the other six items (excluding CD4), values lower than those in Table 2 have been obtained as follows:

Condition °F/% r.h.	Items CD	Lower Oxygen Values Periods range mo.	mode mo.	Amount lower %	48 Months %
100/80	1,3,5,9	12-36	24	1.81 ± 1.18	7.69 ± 3.29
100/57	1,3,9	12-36	24	1.72 ± 1.13	8.05 ± 2.92
70/80	1	–	18	.75 ± .75	13.90 ± .80
70/57	6,9	18-36	36	2.29 ± 2.02	10.90 ± 3.25
40/57	5	–	36	1.25 ± .25	17.40 ± .00
0/ambient	5,7	6-36	all	.57 ± .33	20.17 ± .48

TABLE 3

RESIDUAL OXYGEN IN CANS OF WHEAT ITEMS STORED 48 MONTHS
(percent by volume)

Condition	Crackers				Biscuits				Wafers		Mean	Std.dif.
°F/% r.h.	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10		cans
100/80	12.8	8.3	4.5	4.6	10.4	15.6	1.7	5.1	5.2	2.9	7.11	3.83
100/57	12.2	5.8	2.3	4.2	8.2	19.2	1.9	3.7	6.1	3.9	6.75	3.21
70/80	13.9	8.5	6.7	9.7	12.6	20.6	3.4	15.7	2.7	2.9	9.66	2.18
70/57	12.4	10.7	10.7	11.9	15.8	20.8	14.1	16.6	7.6	3.2	12.36	4.72
40/57	14.3	14.1	17.4[a]	15.6	18.2	20.7	13.4	17.9	3.2	6.4	14.12	1.55
0/amb	16.3	17.8	19.7	18.4	17.8	20.9	16.4	20.6	11.4	12.1	17.14	2.15
std.dif.,cans	2.59	1.90	1.24	2.20	2.63	1.51	.62	3.86	7.17	1.71	3.16	-
sign.dif., 5%	NS	3.29	2.14	3.81	4.55	2.60	1.08	6.68	NS	2.96	1.51	5.09[c]
	13.65	10.87	10.22	10.73	13.83	19.63[b]	8.48	13.28	6.02	5.23	11.20	2.89[d]

[a]Both cans were leakers. Single leakers, omitted here, averaged 3.3 ± 1.1% higher than duplicate non-leakers.

[b]All cans were leakers.

[c]Significant difference for items in rooms.

[d]Significant difference for item means.

There were 32 samples included in the readings which were lower than those at 48 months, from a total of 300 samples read at 6-36 months. This could have resulted from can variations, but suggests that at least some of the cans read at the later periods may have had very slow leaks which were not detected by leak testing. Apart from these discrepancies, depletion of canspace oxygen has been relatively progressive with time, temperature, and the amount of rations contained in the cans (CD6 contained 18-1/2 lbs, others 7, 12-14, or 32-33 lbs as given above).

2. Leaking Cans. (Table 4)

Leaks were detected as streams of bubbles when cans at 73°F were immersed 2 minutes in water at 103-105°F; questionable leakers were those cans emitting only a few bubbles, but whose oxygen, moisture or rancidity values indicated that leaking had probably occurred.

During the four years of storage, leakers and questionable leakers have amounted to 10% or more of total cans opened in items CD4 (80% total, 100% at 48 months) CD6 (28%) CD5 and 11 (15-17%) and CD1, 3 and 13 (11-13%). The other six items, CD2, 7-10, and 12, have had few leakers, averaging only 2.5% of which 1.8% were questionable. As noted above, certain discrepancies in periodic oxygen readings, and in some instances in moisture and rancidity values as well, suggest that some very slow leakers, or cans which leaked at some period but later resealed, may have passed undetected.

As seen in Table 4, there was no significant increase in leaking cans beyond the 2nd-3rd year except in CD4 and in the average for 40°/57% storage. Total leakers averaged 17.33% at 0°F, 16.16% at 40°/57%, 12.00% at 100°/57%, and 14.89 ± .32% at the other three conditions.

3. Corrosion of Cans. (Tables 5 and 6)

External. As external corrosion consisted almost entirely of rusting, practically all was of the pitted type. For the first time during the storage study, there was about as much rusting on bottom and side panels as along the seams on cans from 100°/80% and 70°/80% conditions (excepting the 5-gallon cans of supplement CD12). While only three items averaged higher than at any previous examination, CD3 (2-1/2-gallon) and CD8 and 11 (5-gallon), there was more corrosion than at any other period on five items at 100°/80% (CD3, 4, 6, 11, 13), six at 100°/57% (CD1, 3, 6, 8, 9, 11), four at 70°/80% (CD4, 8, 10, 11), three at 70°/57% (CD2, 8, 10), and two each at 40°/57% and 0°F (CD7, 8 and CD5, 8). Although most of the cans at 100°/80% and many at 70°/80% were somewhat unattractive (again excepting CD12) as indicated in Tables 5 and 6, no leak has been attributed to corrosion during the entire course of the study.

TABLE 4

LEAKING CANS
(as percentages of cans examined)

Items	Definite Leakers				Questionable Leakers			
CD	0-18 mo.	24-36 mo.	48 mo.	total	0-18 mo.	24-36 mo.	48 mo.	total
(2½-gal)								
1	4.9	16.7	.0	7.79	2.4	12.5	.0	5.19
3	7.3	16.7	.0	9.09	4.9	4.2	.0	3.90
4	39.0	83.3	100.0	62.34	34.1	.0	.0	18.18
(5-gal)								
2	.0	.0	.0	.00	2.4	4.2	.0	2.60
5	12.2	4.2	16.7	10.39	2.4	12.5	.0	5.19
6	17.9	41.7	16.7	25.33	2.6	4.2	.0	2.67
7	.0	4.2	.0	1.30	4.9	.0	.0	2.60
8	.0	.0	.0	.00	.0	4.2	.0	1.32
9	.0	4.2	.0	1.30	.0	4.2	.0	1.30
10	.0	.0	.0	.00	.0	.0	8.3	1.30
(5-gal)	0-18 mo.	24 mo.	36 mo.	total	0-18 mo.	24 mo.	36 mo.	total
11	12.2	8.3	.0	9.23	12.2	.0	.0	7.69
12	2.4	.0	.0	1.54	2.4	.0	.0	1.54
13	12.2	.0	.0	7.69	4.9	.0	.0	3.08
Condition °F/% r.h.	6-18 mo.	24-36 mo.	48 mo.[a]	total	6-18 mo.	24-36 mo.	48 mo.[a]	total
100/80	3.8	11.5	10.0	7.33	10.3	3.8	5.0	7.33
100/57	7.7	9.6	10.0	8.67	3.8	3.8	.0	3.33
70/80	10.3	19.2	10.0	13.33	3.8	.0	.0	2.00
70/57	7.7	13.5	10.0	10.00	5.1	5.8	.0	4.67
40/57	11.5	9.6	25.0	12.67	5.1	3.8	.0	4.00
0/amb	9.0	17.3	15.0	12.67	6.4	3.8	.0	4.67
total	8.33	13.46	13.33	10.60[b]	5.77	3.53	.83	4.37[b]

[a]Wheat items only (CD1-10); other columns include all items (CD1-13).
[b]Includes initial leakers.

TABLE 5

CORROSION OF WHEAT ITEM CANS STORED 48 MONTHS
(0-9 scale, 0 = none)

Condition °F/% r.h.	2½-gallon type CD1	CD3	CD4	Mean	Std.dif. cans	5-gallon type CD2	CD5	CD6	CD7	CD8	CD9	CD10	Mean	Std.dif. cans
External, pitted:														
100/80	1.35	2.0	1.5	1.62	.39	1.6	2.1	3.4	2.5	2.5	3.5	2.2	2.54	.45
100/57	.6	.9	.9	.80	.20	.9	1.1	1.2	1.3	.8	1.5	.9	1.10	.63
70/80	.9	.9	1.4	1.07	.29	1.3	1.6	1.3	2.1	1.3	2.2	1.8	1.66	.67
70/57	.3	.5	.5	.43	.26	.8	1.0	1.1	.6	.6	.8	1.1	.86	.46
40/57	.1	.4	.5	.33	.17	.6	.4	1.4	.7	.8	.7	1.1	.81	.68
0/amb	.2	.35	.2	.25	.13	.45	1.0	1.3	.4	.6	.7	.5	.71	.42
std.dif.,cans	.21	.22	.32	.26	-	.28	.28	.85	.47	.22	.91	.49	.56	-
sign.dif.,5%	.36	.39	.56	.22	.38[a]	.48	.48	1.47	.80	.38	1.58	.84	.31	.80[a]
Mean	.58	.84	.83	.75	.18[b]	.94	1.20	1.62	1.27	1.10	1.57	1.27	1.28	.37[b]
Internal, surface; also pitted (P) where marked:														
100/80	.7P	.9P	1.0P	.87	.29	.5	.9P	.6	1.1	.9	1.3P	1.1	.91	.17
100/57	.5P	.5	.2	.40	.17	.5	.8	.9	.7	1.0	1.2P	.7	.83	.20
70/80	.8P	.5	.5	.60	.20	.7	.8	.5	1.4P	1.2	.9	1.1	.94	.28
70/57	.9P	.4	.5	.60	.20	.6	.9	.8	.7	.9	.6	.7	.74	.16
40/57	.5	.6	.6P	.57	.17	.55	.7	.6	.8	1.2	.6	.5	.71	.25
0/amb	.5	.35	.5	.45	.13	.55	.9	.7	1.0	1.2	.3	.6	.75	.18
std.dif.,cans	.19	.19	.22	.20	-	.13	.28	.19	.24	.20	.17	.24	.21	-
sign.dif.,5%	NS	.33	.40	.17	.32[a]	NS	NS	.30	.41	.30	.29	.41	.12	.34[a]
Mean	.65	.54	.55	.58	NS[b]	.57	.83	.68	.95	1.07	.82	.78	.81	.19[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

TABLE 6

CORROSION OF CARBOHYDRATE SUPPLEMENT CANS STORED 36 MONTHS
(0-9 scale, 0 = none)

Condition	5-gallon type									
°F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	External, pitted:					Internal, surface; also pitted (P) where marked:				
100/80	2.7	.7	2.3	1.90	.20	.7	.7	1.1P	.83	.20
100/57	.95	.3	1.2	.82	.27	.45	.8	1.2P	.82	.06
70/80	1.5	.4	1.2	1.03	.69	.65	.7	1.1P	.82	.24
70/57	.7	.3	.6	.53	.20	.55	.9	1.4P	.95	.48
40/57	.3	.2	.5	.33	.12	.7	.7	1.0P	.80	.20
0/amb	.45	.25	1.0	.57	.15	.6	.8	1.0P	.80	.24
std.dif.,cans	.43	.17	.34	.33	-	.14	.22	.39	.27	-
sign.dif.,5%	.71	.30	.61	.30	.52[a]	.24	NS	NS	NS	.40[a]
Mean	1.10	.36	1.13	.86	.32[b]	.61	.77	1.13	.84	.16[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

Internal. Most of the internal corrosion was surface darkening with occasional light pitting as indicated in Tables 5 and 6. All pitting and practically all surface darkening was located in spots where products were in direct contact with interior can surfaces. Much of this was caused by direct contact through torn or perforated corners of packages in cracker and biscuit items and, of course, with the bulk-packed carbohydrate supplements which had no packaging or can lining material. Contact was with wrapping materials in the bulgur wafer cans, however, and in many cans of the other packaged products, although this usually resulted in surface corrosion only (see note below under III.A.1. condition of packages).

Only three items averaged as high (CD6) or higher (CD10, 13) on internal corrosion than at some previous examination. In individual rooms, CD3, 4, 6, 10 rated higher than previously at 100°/80%, CD6 and 13 at 100°/57%, CD2, 7, 10, 13 at 70°/80%, CD1, 2, 6, 13 at 70°/57%, and CD13 only at 40°/57% and 0°F. There was no apparent temperature or humidity effect in carbohydrate supplement cans, but a possible humidity effect is seen in the 100°/80% sample of CD4 (all of which leaked), CD7 and CD10, the 70°/80% samples of CD7 and 10 and the 0° sample of CD7, with a possible temperature effect in 100°F samples of CD9. In general, however, there were no definite indications of condition effects on internal corrosion.

4. Defects of Can Coatings (Table 7)

No softening, peeling or flaking of coatings per se have been observed in any of the 2½-gallon or 5-gallon ration cans. Thus, all coating defects have resulted from abrasion in 2½-gallon cans, and from uneven application, abrasion or both in the 5-gallon type. Much of the external corrosion, possibly all of it, has been located in areas or spots from which coating was removed while seaming (5-gallon cans), knocked or rubbed off in handling (CD4 and 6) or applied unevenly enough (CD4, 5, 6, 9, 13) to leave thin easily-damaged areas. Some secondary flaking was observed in spots where rust had spread in under the edges of the coating around damaged areas.

The observation that high average defects for various items have occurred at all periods is thus not surprising; three items each averaged highest at 18, 24 and 36 months, two at 48 months, one each at 6 and 12 months. General averages were higher for 5-gallon cans (.86) than for the smaller cans (.68); the fact that the lighter cans were less subject to damage in handling probably contributed to this, as well as the difference in type of coating. Storage differences were not very pronounced for the 2½-gallon cans, general averages being .79 at the two 80% r.h. conditions and .63 at the other four, indicating little or no temperature effect. Defect ratings for the larger cans averaged 1.17 from 100°/80%, .84 from 100°/57% and 70°/80%, and .75 for the three less severe conditions; both temperature and humidity apparently influenced these coatings to some extent, possibly associated with the further effects of corrosion.

TABLE 7

DEFECTS IN CAN COATINGS
(0-9 scale, 0 = none)

Condition °F/% r.h.	2½-gallon type CD1	CD3	CD4	Mean	Std.dif. cans	5-gallon type CD2	CD5	CD6	CD7	CD8	CD9	CD10	Mean	Std.dif. cans
Wheat Item Cans Stored 48 Months:														
100/80	.9	1.0	1.2	1.03	.48	1.1	1.3	2.4	1.4	1.5	2.2	1.2	1.59	.28
100/57	.2	.4	1.1	.57	.12	1.0	1.4	1.0	.6	.3	.8	.5	.80	.33
70/80	.8	.35	1.6	.92	.06	.9	1.2	1.0	1.2	.8	1.1	.9	1.01	.32
70/57	.3	.2	1.8	.77	.33	.9	.8	.9	.45	.4	.5	.7	.66	.20
40/57	.4	.3	1.4	.70	.12	.9	1.3	1.6	.5	.5	.8	.7	.90	.28
0/amb	.4	.35	1.2	.65	.24	1.1	1.0	1.4	.3	.4	.8	.5	.79	.31
std.dif.,cans	.20	.06	.41	.27	-	.20	.35	.30	.15	.22	.43	.26	.29	-
sign.dif.,5%	.35	.32	NS	.23	.43[a]	NS	NS	.52	.26	.38	.74	.45	.16	.46[a]
Mean	.50	.43	1.38	.77	.23[b]	.98	1.17	1.38	.74	.65	1.03	.75	.96	.25[b]

Carbohydrate Supplement Cans Stored 36 Months:

Condition °F/% r.h.	5-gallon type CD11	CD12	CD13	Mean	Std.dif. cans
100/80	1.3	.6	1.7	1.20	.17
100/57	.7	.6	1.2	.83	.29
70/80	.9	.6	.9	.80	.20
70/57	.8	.8	.8	.80	.24
40/57	.7	.7	1.4	.93	.44
0/amb	1.1	.5	1.2	.93	.20
std.dif.,cans	.29	.29	.24	.27	-
sign.dif.,5%	.50	NS	.41	.23	.42[a]
Mean	.92	.63	1.20	.92	.21[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

III. The Rations

A. Cereal Items

1. Condition of Packages (Table 8)

The percentages of broken seals and torn packages were calculated from the numbers of packages per can. These were 15 for CD1, 3 and 4, 24 for CD2, 5, 7 and 8, 28 for CD6, and 126 for wafers CD9 and 10. Only seal breaks or torn places large enough for one unit of product to escape the package were counted. Thus, many packages with small corner perforations, sufficiently large to allow the product to touch the inside surface of the can (as mentioned above in connection with internal corrosion) but not to allow units to slip out of the package, were not included in the data for package breakage shown in Table 8.

Broken Seals. The first major seal breaks observed in the storage of CD2 (waxed paper) and CD6 (cellophane) consisted of one unsealed package in twelve cans of each item at 48 months. Wafer packages CD9 and CD10 (waxed glassine) continued the small periodic increases in broken seals which were observed at every examination after the first year. Practically all of these breaks, which have never exceeded 2.0% for CD9 or 3.2% for CD10, were in the top layer of packages where package arrangement is irregular because of the raised center lid of the can. Biscuit CD7 (waxed paper) has also been low in seal breakage, averaging about 2.5% for the first two years and 1.1% for the 3rd and 4th periods; no sample of this item has exceeded ca 10% unsealed packages.

The other five rations, CD1, 3, 4, 5, 8 (waxed glassine), have had more seal breaks and been more variable. The 48 cans of each which have been examined since the end of the first year averaged 6.9% broken seals for CD1, 4.3% for CD3, 15.0% for CD4, 4.1% for CD5, and 10.6% for CD8. Highest percentages were observed variously at all periods, but periodic averages for the five items at 12, 18, 24, 36, 48 months were 0.1%, 5.3%, 9.0%, 13.2%, and 5.3%, respectively, indicating an apparent time effect up to three years. Storage condition averages from 18 through 48 months were 5.2% from 100^o/80%, 7.4% from 40^o and 70^o/57%, 8.1% from 100^o/57%, 9.1% from 0^o, and 11.8% from 70^o/80%, a rather irregular pattern. Thus, though general averages were higher for crackers and biscuits in waxed glassine than for wafers in glassine or crackers and biscuits in waxed paper and cellophane, individual item and can differences were by far the greatest sources of variance in percentages of broken seals.

Torn Packages. As with broken seals, percentages of torn packages have remained low, though not progressive, in wafers CD9 and 10, four year averages being .33% and .11%, respectively. There have been no torn packages in CD2, but the other waxed paper package, CD7, averaged

TABLE 8

PACKAGE DEFECTS IN WHEAT ITEMS STORED 48 MONTHS
(as percent of packages)

Condition °F/% r.h.	Crackers CD1[a]	CD3[a]	CD5	CD8	Biscuits CD2[b]	CD4[a]	CD6[c]	CD7[b]	Wafers CD9	CD10	Mean	Std.dif. cans
Broken Seals:												
100/80	.0	.0	.0	.0	2.1	.0	.0	.0	.8	2.0	.49	1.60
100/57	.0	.0	.0	2.1	.0	3.3	1.8	.0	.4	2.4	1.00	2.79
70/80	6.7	.0	.0	27.1	.0	6.7	.0	2.1	1.2	1.6	4.53	17.71
70/57	.0	.0	.0	29.2	.0	.0	.0	.0	1.2	.4	3.08	18.47
40/57	13.3	.0	2.1	10.4	.0	13.3	.0	.0	.8	1.2	4.12	11.59
0/amb	6.7	.0	2.1	2.1	.0	33.3	.0	4.2	.0	3.2	5.15	5.41
std.dif.,cans	7.70	-	2.41	33.68	1.71	12.48	1.46	3.81	1.69	1.80	11.75	-
sign.dif.,5%	13.09	-	NS	NS	NS	21.22	NS	NS	NS	NS	4.35	16.62[d]
Mean	4.44	.00	.69	11.81	.35	9.44	.30	1.04	.73	1.79	3.06	6.85[e]
Torn Packages:												
100/80	.0	.0	.0	.0	.0	.0	8.9	2.1	.0	.4	1.14	1.76
100/57	3.3	.0	2.1	.0	.0	3.3	.0	2.1	.0	.4	1.12	3.53
70/80	.0	.0	.0	12.5	.0	3.3	.0	6.3	.0	.4	2.25	8.30
70/57	.0	.0	.0	4.1	.0	.0	1.8	.0	.8	.0	.67	2.87
40/57	.0	.0	6.3	6.3	.0	20.0	5.4	.0	.0	.0	3.79	14.24
0/amb	3.3	.0	6.3	.0	.0	30.0	14.3	2.1	.0	.0	5.60	5.61
std.dif.,cans	3.85	-	7.42	11.91	-	17.00	5.65	3.41	.65	.56	7.38	-
sign.dif.,5%	NS	-	NS	NS	-	28.90	9.61	5.80	NS	NS	3.35	11.80[d]
Mean	1.11	.00	2.43	3.82	.00	9.44	5.06	2.08	.13	.20	2.43	5.06[e]

(Continued)

Table 8 (continued)

Condition °F/% r.h.	Crackers CD1[a]	CD3[a]	CD5	CD8	Biscuits CD2[b]	CD4[a]	CD6[c]	CD7[b]	Wafers CD9	CD10	Mean	Std.dif. cans
Total Packages Broken:												
100/80	.0	.0	.0	.0	2.1	.0	8.9	2.1	.8	2.4	1.63	2.30
100/57	3.3	.0	2.1	2.1	.0	6.7	1.8	2.1	.4	2.8	2.12	5.37
70/80	6.7	.0	.0	27.1	.0	10.0	.0	8.3	1.2	2.0	5.53	17.79
70/57	.0	.0	.0	29.2	.0	.0	1.8	.0	2.0	.4	3.33	18.50
40/57	13.3	.0	6.3	10.4	.0	23.3	5.4	.0	.8	1.2	6.07	17.51
0/amb	10.0	.0	6.3	2.1	.0	56.7	14.3	6.3	.0	3.2	9.87	12.44
std.dif.,cans	8.61	-	7.42	33.68	1.71	24.20	5.84	5.65	1.69	1.59	13.87	-
sign.dif.,5%	11.90	-	NS	NS	NS	41.14	9.93	7.98	NS	NS	6.20	19.61[d]
Mean	5.56	.00	2.43	11.81	.35	16.11	5.36	3.13	.86	1.96	4.76	9.38[e]

[a] $2\frac{1}{2}$-gallon cans; all others 5-gallon.
[b] Waxed paper.
[c] Cellophane; all others waxed glassine.
[d] Significant difference for items in rooms.
[e] Significant difference for item means.

5.4% since 18 months and the cellophane package, CD6, has had more than twice as many torn packages (13.7%) as any other item. Four year averages for waxed glassine packages of CD1, 3, 4, 5, 8 ranged 1.5 - 3.3%, average 2.8%.

Periodic averages for the seven crackers and biscuits (excluding CD2) at 12, 18, 24, 36, 48 months were 1.7%, 2.8%, 9.4%, 6.6%, and 3.4% respectively. Corresponding averages for storage conditions were 3.4% for 100° and 40°F, 5.2% for 70°F, and 7.9% for 0°F. As with broken seals, item and can differences were the greatest sources of variance.

Total Packages Broken: As shown in Table 8, there were no broken packages at 48 months in CD3, and total breakages for CD1, 6, 7, 9 and 10 were the sums of unsealed and torn packages. The single broken seal was the only defect in the waxed paper packages of CD2. All unsealed packages were also torn in CD5, and all torn packages also unsealed in CD8; in CD4, some but not all defective packages were both unsealed and torn.

The time effect was definite for wafer CD10 (general average 1.30%) and fairly definite for wafer CD9 (average .77%); together these averaged .68%, 1.06%, 1.32% and 1.43% broken packages for the four years. The other seven items reached maximum values at 18-36 months, possibly because the best cases of each item were scheduled for longest storage and cases showing any sign of even slight damage were utilized during the first to third years. If this had any influence on the maxima, the time effect may have actually extended beyond the periods at which they were reached. At any rate, item differences were quite large, 12-48 months averages being 4.7% for CD3 and 5, 7.1% for CD1 and 7, 9.9% for CD8, 14.0% for CD6 (cellophane), and 15.3% for CD4. For storage conditions over this period, the seven items averaged 5.8% for 100°/80%, 7.6% for 100° and 40°/57%, 9.2% for 70°/57%, 11.0% for 70°/80%, and 12.7% for 0°F. Increased flexibility at 100° and greater brittleness at 0°F may have influenced breakage at these temperatures, but the 70° and 40°F averages do not fit the pattern. In general, both time and temperature effects on unsealing or tearing of packages are open to question.

2. Condition of Products (Table 9)

Breakage of products were calculated as percentages of score-lines broken in the multi-unit layers and percentages of broken units. Can totals determined for these calculations were as follows:

CD	Score Lines	Units	CD	Score Lines	Units
1	227	454	5	1286	1286
2	1172	1172	6	1713	1713
3	906	906	7	1363	1363
4	223	446	8	584	1168

TABLE 9

PRODUCT BREAKAGE IN WHEAT ITEMS STORED 48 MONTHS
(as percent of total units)

Condition	Crackers				Biscuits				Wafers[b]			
°F/% r.h.	CD1[a]	CD3[a]	CD5	CD8	CD2	CD4[a]	CD6	CD7	CD9	CD10	Mean	Std.dif. cans
Score Lines Broken in Layers:												
100/80	48.5	15.5	17.5	7.7	4.5	3.4	1.2	13.0	24.1	47.3	13.89	5.54
100/57	24.3	16.1	19.8	3.8	6.4	5.6	2.0	11.7	37.5	27.7	11.21	11.48
70/80	19.7	12.1	13.6	10.6	3.5	5.2	.5	12.6	34.3	71.3	9.71	8.52
70/57	21.7	11.8	13.0	4.6	3.6	6.3	.5	23.0	18.7	53.6	10.56	3.00
40/57	21.9	21.3	20.0	9.4	3.6	4.0	1.2	22.8	24.3	39.4	13.04	12.12
0/amb	22.6	17.3	11.8	3.3	4.8	6.1	3.0	6.8	18.6	44.6	9.46	3.82
std.dif.,cans	19.09	4.50	9.42	3.35	3.10	3.68	2.04	5.36	9.37	7.53	8.22	-
sign.dif.,5%	26.81	7.65	NS	5.70	NS	NS	NS	9.27	15.93	13.03	3.69	11.70[c]
Mean	26.44	15.68	15.94	6.58	4.40	5.08	1.40	14.97	26.25	47.31	11.31[b]	5.18[d]
Moderate Unit Breakage:												
100/80	12.1	8.8	23.1	14.1	1.1	12.7	2.0	3.4	.0	.2	9.65	4.03
100/57	16.8	7.6	18.3	11.8	1.6	16.9	2.4	5.3	.0	.1	10.07	5.07
70/80	7.6	6.4	11.5	14.7	1.1	20.8	2.3	4.8	.1	.1	8.64	3.58
70/57	12.3	7.7	13.0	9.2	1.1	19.9	.3	7.7	.0	.1	8.90	3.63
40/57	20.4	12.5	19.8	14.5	1.8	20.7	2.4	4.0	.1	.2	12.00	5.05
0/amb	7.5	10.5	29.3	20.3	1.1	22.7	2.1	3.8	.0	.1	12.15	4.66
std.dif.,cans	7.08	3.90	5.15	4.28	.42	5.31	1.35	3.66	.12	.13	4.38	-
sign.dif.,5%	12.04	NS	8.91	7.40	.70	9.03	2.00	NS	NS	NS	2.21	7.04[c]
Mean	12.76	8.90	19.14	14.11	1.29	18.93	1.90	4.84	.03	.15	10.24[b]	3.24[d]

(continued)

Table 9 (continued)

Condition °F/% r.h.	Crackers CD1[a]	CD3[a]	CD5	CD8	Biscuits CD2	CD4[a]	CD6	CD7	Wafers[b] CD9	CD10	Mean	Std.dif. cans
Units Crushed:												
100/80	.0	.0	.4	.2	.0	.0	.0	.1	.0	.0	.09	.16
100/57	.0	.0	.5	1.1	.0	.0	.0	.3	.0	.0	.23	.83
70/80	.0	.0	.2	6.5	.0	.0	.0	.1	.0	.0	.85	4.61
70/57	.0	.0	.9	.4	.0	.7	.0	.2	.0	.0	.26	.57
40/57	.0	.0	5.1	3.6	.0	.0	.0	.3	.0	.0	1.13	2.68
0/amb	.0	.0	10.1	2.1	.0	.0	.0	.0	.0	.0	1.53	1.36
std.dif.,cans	-	-	2.74	5.81	-	.56	-	.39	-	-	2.29	-
sign.dif.,5%	-	-	4.90	NS	-	NS	-	NS	-	-	1.15	3.72[c]
Mean	.00	.00	2.86	2.33	.00	.11	.00	.15	.00	.00	.68[b]	1.59[d]
Total Product Breakage:												
100/80	36.3	24.3	40.6	18.2	5.6	14.4	3.2	16.4	24.1	47.5	19.86	5.91
100/57	28.9	23.7	37.8	14.8	7.9	19.7	4.4	17.3	37.5	27.8	19.31	12.43
70/80	17.4	18.5	25.1	26.5	4.6	23.4	2.7	17.5	34.4	71.4	16.97	7.13
70/57	23.1	19.5	26.9	11.9	4.7	23.7	.9	30.8	18.7	53.8	17.68	5.85
40/57	31.3	33.8	44.4	22.8	5.4	22.7	3.6	27.2	24.4	39.6	23.91	4.56
0/amb	18.8	27.8	48.6	24.1	5.9	25.7	5.1	10.5	18.6	44.7	20.82	5.43
std.dif.,cans	11.24	6.77	9.41	7.50	2.79	5.74	3.31	8.03	9.39	7.63	7.36	-
sign.dif.,5%	18.81	11.51	16.28	12.15	NS	9.76	NS	13.61	15.97	13.20	3.71	10.47[c]
Mean	25.96	24.58	37.24	19.72	5.69	21.59	3.30	19.96	26.28	47.47	19.76[b]	5.47[d]

[a] $2\frac{1}{2}$-gallon cans; others are 5-gallon
[b] Values for wafers, which are separate units, are for crumbled edges and unit breakage; not included in mean values for crackers and biscuits.
[c] Significant difference for items in rooms.
[d] Significant difference for item means.

Wafers CD9 and CD10 both had 756 units per can, packed as individual units (six units per package, no score lines).

Score Lines Broken. For the eight cracker and biscuit items, periods of highest and lowest percentages of separation of units at score lines both ranged from 12 to 48 months and averaged between 24 and 30 months.

Compared to the 48 months values of Table 9, previous low item values were 2.5 $\pm$ 3.8% lower, previous high item values were 1.1 $\pm$ 1.7% higher, and the 12-48 months mean values were 0.7 $\pm$ 1.9 lower. Thus, considering the wide ranges of high and low periods and of individual item levels, any statement as to a possible time effect on broken score lines would appear to be extremely questionable. As groups, crackers averaged 15.7%, biscuits 5.9%, but cracker CD8 (7.7%) was lower than biscuit CD7 (10.9%).

Effects of storage conditions on score-line breakage were also quite indefinite. For crackers, 12-48 months averages were 16.7% at $100^\circ/80\%$ and $40^\circ/57\%$, 15.6 $\pm$ .1% at $70^\circ/80\%$ and 0°, 14.8 $\pm$ .1% at $100^\circ/57\%$ and $70^\circ/57\%$. For biscuits, 0° average was 6.8%, $100^\circ/57\%$ was 5.1%, the other four conditions averaging 5.8 $\pm$ .3%. Thus score-line breakage varied with products, items, and cans within items, but apparently not with storage time or storage conditions.

Crumbling of edges of units was recorded for bulgur wafers as shown in Table 9. Time and storage condition effects were also indefinite for this defect. For CD9, crumbled edges ranged from 20.9% at 18 months to 42.5% at 24 months, average 32.8% of the units. Corresponding values for CD10 were 36.5% to 73.6%, average 50.2%. For storage conditions, CD9 averaged 36.7 $\pm$ 1.8% for the $100^\circ F$ and $70^\circ/57\%$ samples, 28.9 $\pm$ 2.3% for the other three; CD10 averaged 54.3 $\pm$ .8% for $100^\circ F$ and $70^\circ/80\%$, 46.2 $\pm$ 1.9% for $70^\circ/57\%$, $40^\circ/57\%$, and $0^\circ F$. Thus the main sources of variance were apparently items and cans, although slightly more crumbling at higher temperatures is suggested.

Moderate Unit Breakage. There was little indication of a time effect on moderate unit breakage of any item except biscuit CD4, which ranged progressively from 11.3% average at 12 months to 18.9% at 48 months. High and low averages for other items ranged over the entire storage period. General averages were .18 and .36% for wafers CD9 and CD10; 1.8, 3.4 and 5.4% for biscuits CD2, 6 and 7; 12.5 $\pm$ .2% for crackers CD1 and 3; 14.9 $\pm$ .2% for biscuit CD4 and cracker CD8; and 19.0% for cracker CD5. Thus items in $2\frac{1}{2}$-gallon cans (CD1, 3, 4) averaged 13.2 $\pm$ 1.1%, while crackers in 5-gallon cans were higher (17.0 $\pm$ 2.0%) and biscuits and wafers in 5-gallon cans were lower (5.4 - 0.2%); it is probable, however, that this resulted from item differences without association with can size.

Temperature effects were also rather indefinite. Wafers averaged .20% breakage at 100°F, .25% at 70°, .34% at 40°, and .39% at 0°; corresponding averages for crackers CD5 and 8 were 16.2%, 15.6%, 19.0%, and 19.3%. Items CD1, 3 and 4, however, averaged 14.7 $\pm$ 2.5 at 70°F and 12.5 $\pm$ 2.0 at other temperatures, while biscuits CD2, 6 and 7 averaged 4.2 $\pm$ 2.0% at 70°/57% and 0°F, 3.2 $\pm$ 1.4% at other conditions. Despite the suggestion that breakage may have tended to be higher at lower temperatures, product, item and can differences were too large to permit any definite assumptions of a temperature influence.

Crushed Units. Although only four items had crushed units at 48 months, severe breakage was observed at various periods in all items except wafer CD9. Among the 60 cans of each of the other nine items examined from 12-48 months, crushed units were observed in 179 of 540 cans, or about 33.1% of the cans contained crushed units. By periods, there were 59, 47, 30, 18, 25 cans at 24, 12, 36, 18, 48 months, so a time effect seems questionable. Temperature differences were also quite variable, 0°F and 70°/80% conditions averaging 2.12% crushed units in 55 cans of crackers and biscuits, 100°/80% and 40°/57% averaging 1.60% crushed in 54 cans, and 70°/57% and 100°/57% averaging 1.19% crushed in 67 cans. By items, crackers CD5, 8, 1 and biscuit CD4 had 50, 30, 17, 13 cans averaging 2.09-1.94% crushed units, cracker CD3 and biscuit CD6 had 21 and 15 cans averaging 1.28 and 1.07% biscuits CD7 and CD2 had 26 and 4 cans averaging .53 and .19% crushed, while wafer CD10 had 3 cans averaging 6.03% crushing from denting in of can walls. Some of the cracker and biscuit crushing was in dented cans, while there were some showing no physical evidence of damage.

Total Product Breakage. Total breakage, calculated from total units per can as given above, was the sum of score line and unit breakage, with two exceptions: (1) score line breakage in 2-unit layers was counted at half value for total, as there were twice as many units as score lines, and (2) combined breakage per layer was limited to two breaks for 2-unit layers and four breaks for 4-unit layers, even though three and five-eight breaks may have been counted for separate calculations of score-line and unit breakages. As shown in Table 9, crumbled edges instead of score-line breaks are included for wafers CD9 and 10, but the general condition means and total mean value (19.76%) include only crackers and biscuits CD1-CD8.

Periodic total means for crackers and biscuits were 18.65 $\pm$ .10% at 12 and 18 months, 21.52% at 24 months, 19.69 $\pm$ .07% at 36 and 48 months, not enough difference to indicate any time effect in comparison with the wide ranges of item means and can differences as illustrated in Table 9. Similarly, means for storage conditions over this period were 18.10% for 100°/57%, 19.66% for 100°/80%, 19.94 $\pm$ .10% for the 70° and 40°/57% rooms, and 20.25% for 0°F, suggesting increased breakage at lower temperatures when, in fact, almost 45% of the samples compared during the four years of storage had higher total breakage at higher temperatures.

Item differences in total breakage were significant. For the five examinations from 12-48 months, biscuits CD2 and 6 averaged 6.4 $\pm$ 2.2%, biscuits CD4 and 7 and Cracker CD8 averaged 18.0 $\pm$ 2.7%, crackers CD1 and 3 averaged 26.6 $\pm$ 4.0%, and cracker CD5 averaged 37.2 $\pm$ 2.5%; averages for wafers, almost entirely as crumbled edges, were 33.0 $\pm$ 8.2% for CD9 and 50.8 $\pm$ 13.8% for CD10. Many factors such as degree of baking, depth of score lines, sharpness of edges and corners, cupped or flat layers, jamming of loose units from broken packages toward the bottoms of the cans, tenderness or toughness of units and, of course, extent of rough handling and can damage, contributed to the item difference. Time and temperature differences apparently had little influence.

3. Appearance and Color (Table 10)

Sensory scores were assigned by five experienced judges who have a performance record of reacting in similar manner to sample differences (can variance $\pm$ .22 - $\pm$ .67, mean $\pm$ .41), although tending to use somewhat different rating levels (mean judge variance $\pm$ 1.14) on the 10-1 scale indicated in Table 10. Samples were presented six per session (one from each storage room), two sessions per item, so duplicate cans were scored on different sessions; all samples were identified, and comparisons among storage conditions were invited in the comments.

Storage had relative little influence on appearance and color scores of products at 70°F and below, as variations among cans were greater than those resulting from occasional dullness at 0° or "glazing" at 70°. In general, products at 100°F assumed a glazed appearance with some fading of "redness" of color, but these changes were not considered very detrimental in many instances. Thus, item differences, usually associated with degree of browning when baked, have largely determined appearance and color scores.

Combined appearance-color scores of Table 10 are fairly typical of the four-year storage pattern, though slightly lower (6.98) than average scores for the first three years (7.16). Items CD1 and 6, medium brown, CD7, light brown, and CD10, "toasted", were scored lower at 100°F because of fading. Comments by judges indicated that all other scores depended more on can and item characteristics than on storage changes. As examples, CD3 and 4 (pale), CD8 (light brown) and CD5 ("toasted") were unevenly browned in various samples. The 0°F samples of CD2, a light brown item, were baked darker than usual. Wafer CD9 has been the most uniform of the ration items, with general slight fading of the medium brown color at 100°F storage. Item averages for CD2, 3, 4 were .58 $\pm$ .09 lower than averages for the first three years, and CD10 averaged .23 higher than on previous examinations; the other six items were intermediate, CD6 and 9 averaging .21 $\pm$ .11 higher, CD1, 5, 7 and 8 averaging .16 $\pm$ .06 lower than at 6-36 months, but none having maximum or minimum averages at 48 months.

TABLE 10

APPEARANCE-COLOR AND TEXTURE SCORES OF WHEAT ITEMS STORED 48 MONTHS
(scale from 10 = excellent to 1 = poor)

Condition	Crackers				Biscuits				Wafers		Mean	Std.dif.
°F/% r.h.	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10		cans
Appearance-Color:												
100/80	6.9	6.65	6.85	6.65	7.25	7.0	6.9	6.4	7.1	6.55	6.82	.43
100/57	6.75	6.95	6.85	6.65	7.3	6.35	6.95	6.8	7.15	6.5	6.82	.45
70/80	7.05	6.7	6.6	6.5	7.1	6.5	7.7	7.1	7.3	6.85	6.94	.37
70/57	7.15	7.3	7.4	6.45	7.25	6.75	7.8	7.2	7.2	6.95	7.14	.48
40/57	7.0	6.85	6.85	6.95	7.3	6.2	7.75	7.45	7.35	6.75	7.05	.33
0/amb	7.45	6.9	6.6	7.0	6.9	6.85	7.7	7.4	7.35	7.0	7.12	.37
std.dif.,cans	.53	.44	.28	.67	.23	.38	.30	.45	.22	.25	.41	-
sign.dif.,5%	NS	NS	.48	NS	.39	.65	.52	.78	NS	.40	.20	.51[a]
Mean	7.05	6.89	6.86	6.70	7.18	6.61	7.47	7.06	7.24	6.77	6.98	.23[b]
Texture:												
100/80	6.8	6.1	5.4	4.7	6.0	6.1	5.6	6.6	5.9	5.5	5.87	.78
100/57	6.4	6.5	5.4	5.2	6.1	6.1	6.2	6.5	5.4	5.7	5.96	.56
70/80	7.6	7.1	5.8	6.0	6.7	6.9	6.6	7.0	5.7	5.8	6.52	.58
70/57	7.7	7.1	6.1	6.4	6.9	7.4	7.1	7.1	5.9	5.8	6.75	.46
40/57	7.6	7.4	6.5	6.8	7.1	7.6	7.0	7.5	5.8	6.0	6.93	.47
0/amb	7.9	6.9	6.3	7.1	7.2	7.5	6.9	7.5	6.1	6.2	6.96	.49
std.dif.,cans	.22	.34	.71	.58	.37	.52	.31	.17	1.09	.71	.57	-
sign.dif.,5%	.38	.61	1.01	1.00	.64	.90	.53	.29	NS	NS	.26	.80[a]
Mean	7.35	6.85	5.92	6.03	6.67	6.93	6.57	7.03	5.80	5.83	6.50	.33[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

4. Hunter Color Values (Table 11)

Color values were determined on duplicate samples from each can, chopped and sieved to 14-mesh, using a Hunter type color and color difference meter set with NBS reference Maize (L = 73.8, a = 1.4, b = 31.4

Hunter L. The L value, a measure of "lightness" of color, tends to increase with fading of color or glazing of sample surface, or decrease with darkening or dulling of the surface. There has been very little darkening of the shelter rations in storage, and relatively little dulling of surface except a slight loss of "shine" with extended storage. Thus the characteristic change in L values has been increase, generally proportional to storage temperature and, somewhat less definitely, to storage time.

The following summary of changes indicates the relationship of the L values shown in Table 11 to trends during the four years of storage:

temperature	maximum increases in L values			subsequent decrease to 48 mo.*	
F	average units	range units	period* av. mo.	average units	range units
100°	5.8 ± .8	4.3 - 7.0	37 ± 10	1.0 ± 1.0	.0 - 3.1
70°	4.7 ± .8	3.1 - 6.0	35 ± 9	1.0 ± .8	.0 - 2.4
40°	3.7 ± 1.2	1.4 - 5.0	35 ± 13	.8 ± .8	.0 - 2.5
0°	2.9 ± .7	2.3 - 4.0	28 ± 9	.9 ± .6	.0 - 1.8

*Periods of maximum L values ranged 18 to 48 months at all storage conditions; thus periods of decrease ranged 30 to 0 months.

Samples reaching maximum L values at 48 months included CD3 (70°/80% and 40°) CD5 (100°), CD6 (100° and 40°), CD7 and CD8 (70°/57%), CD9 (100°, 70°/57%, 40°, 0°) and CD10 (100°/80% and 40°); CD3, 7, 8 are pale to light brown items, CD6 and 9 are medium brown, CD5 and 10 are dark brown.

Hunter a. The "a" values indicate relative amounts of red color when positive, green when negative; the "pale" items CD3 and CD4 were more green than red, but values were so small that the predominant hue was yellow. The red component of other items (Table 11) resulted in appearance ranging from light tan for CD2 to deep brown for CD5 and CD10.

The characteristic change in "a" values was decrease, resulting from fading of color, at higher temperatures. There were also slight increases, particularly at lower temperatures, but many of these could have been due to sample variation, as ranges were not generally greater than those of faded samples at 100°F. A summary of changes, for comparison with values given in Table 11, is as follows:

TABLE 11

HUNTER COLOR VALUES OF WHEAT ITEMS STORED 48 MONTHS

Condition	Crackers				Biscuits				Wafers		Mean	Std.dif.
°F/% r.h.	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10		cans
L Values:												
100/80	64.7	72.9	63.7	72.8	72.3	76.9	65.7	73.7	65.0	60.6	68.82	.73
100/57	64.5	73.0	65.1	74.0	72.7	77.2	66.1	74.0	65.2	58.3	69.02	2.08
70/80	64.1	73.3	61.4	71.3	71.0	75.3	64.0	73.0	63.5	58.9	67.58	.75
70/57	63.6	72.1	61.7	73.1	71.3	76.0	63.9	73.9	65.3	59.0	68.00	1.29
40/57	62.3	73.8	60.7	70.2	69.5	73.7	63.1	73.3	63.7	60.0	67.01	2.18
0/amb	63.6	69.9	59.5	70.3	69.3	73.9	62.9	72.1	63.1	56.8	66.13	.81
std.dif.,cans	1.99	2.26	2.07	.84	1.20	.76	.89	1.40	1.09	.90	1.44	-
sign.dif.,5%	NS	3.80	3.52	1.44	2.08	1.31	1.50	NS	1.89	1.63	.65	2.04[a]
Mean	63.80	72.51	62.00	71.95	71.00	75.51	64.27	73.33	64.33	58.92	67.76	.90[b]
"a" Values:												
100/80	3.5	-.6	4.6	1.5	.3	-.8	3.8	1.1	3.2	4.0	2.05	.77
100/57	4.3	-.5	4.5	1.6	.2	-1.4	3.9	1.0	3.1	5.3	2.20	.53
70/80	4.2	-1.0	4.7	2.2	.8	-.2	4.5	1.1	3.6	4.1	2.40	.79
70/57	4.4	-.6	4.7	1.4	1.0	-.1	4.4	1.4	3.0	4.4	2.40	.55
40/57	4.4	-.3	5.1	2.6	1.3	.1	4.8	1.7	3.2	4.4	2.73	.66
0/amb	4.1	.7	6.3	2.0	1.8	.1	5.0	2.3	3.5	5.0	3.06	.74
std.dif.,cans	.50	.69	.32	.64	.58	1.00	.42	1.06	.35	.77	.68	-
sign.dif.,5%	.85	1.17	.54	1.10	.99	NS	.73	NS	.54	1.15	.31	.96[a]
Mean	4.16	-.39	4.99	1.87	.91	-.40	4.39	1.43	3.25	4.53	2.47	.41[b]

(continued)

Table 11 (continued)

Condition °F/% r.h.	Crackers CD1	CD3	CD5	CD8	Biscuits CD2	CD4	CD6	CD7	Wafers CD9	CD10	Mean	Std.dif. cans
"b" Values:												
100/80	24.6	22.0	25.4	21.9	20.9	20.5	24.1	21.7	21.2	20.5	22.27	.71
100/57	25.1	22.0	25.6	22.1	20.9	19.9	24.5	21.2	22.0	21.3	22.48	.88
70/80	24.8	21.3	24.4	21.6	20.6	20.5	24.2	21.5	22.3	19.8	22.11	.59
70/57	24.8	21.3	24.4	21.6	20.5	20.0	24.3	21.7	21.6	19.8	22.01	.80
40/57	24.8	21.4	24.6	21.7	20.7	20.3	24.6	22.0	21.8	20.7	22.27	.43
0/amb	25.2	22.0	25.0	21.2	20.9	20.7	24.3	22.0	22.1	20.0	22.35	.56
std.dif.,cans	.51	.22	.62	.42	.40	.79	.61	.53	1.27	.81	.68	–
sign.dif.,5%	NS	.38	1.05	NS	NS	NS	NS	NS	NS	1.26	.31	.96[a]
Mean	24.90	21.67	24.91	21.68	20.76	20.31	24.34	21.69	21.84	20.37	22.25	.34[b]
a/b Ratios:												
100/80	.140	-.030	.181	.066	.016	-.037	.156	.052	.151	.196	.092	.034
100/57	.172	-.020	.176	.074	.011	-.073	.159	.047	.139	.249	.098	.026
70/80	.168	-.049	.194	.102	.040	-.012	.187	.052	.160	.207	.108	.037
70/57	.179	-.028	.192	.065	.048	-.005	.181	.063	.138	.223	.109	.024
40/57	.178	-.013	.208	.119	.064	.006	.194	.075	.147	.208	.122	.031
0/amb	.164	.031	.250	.092	.086	.001	.205	.103	.158	.251	.137	.033
std.dif.,cans	.021	.033	.014	.030	.028	.050	.017	.043	.017	.033	.031	–
sign.dif.,5%	.036	.056	.024	.044	.048	.076	.029	NS	NS	.047	.015	.044[a]
Mean	.167	-.018	.200	.086	.044	-.020	.180	.066	.149	.223	.111	.019[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

From storage at 100°F, items CD1, 2, 3 and 8 had no "a" values above initial. Other items averaged .4 ± .4 increase at 20 ± 8 months. For decreases, items CD2, 3, 4, 5 and 9 reached minimum values at 48 months, averaging 1.5 ± .7 below initial values. Other items averaged 1.3 ± .5 decrease at 28 ± 11 months and were 1.0 ± .7 below at 48 months.

At 70°F, all items exhibited slight increases within the first two years, averaging .4 ± .4 above initial at 18 ± 5 months. Items CD2, 3, 5 and 10 reached minimum values at 48 months, 1.4 ± .7 below initial; other items averaged .9 ± .4 below at 31 ± 17 months and .8 ± .4 below at 48 months.

Increases were slightly higher during the early years at 40° and 0°F, averaging .7 ± .2 above initial in 20 ± 9 months at 40° and .9 ± .3 above in 20 ± 7 months at 0°. Items CD4, 6, 7 and 8 at 40°F decreased to .8 ± .3 below initial at 6, 36, 6 and 24 months, respectively, averaging .4 ± .3 below at 48 months; other items were lowest at 48 months, the reduction from initial averaging .9 ± .6 unit. At 0°F, early increases averaged .9 ± .3 at 20 ± 7 months; items CD2, 7 and 10 averaged .4 ± .4 below initial at 30, 6 and 12 months, respectively, and .1 ± .1 below at 48 months; the other seven items reached maximum reduction of .5 ± .3 at 48 months.

In general, the initial increases resulted in an appearance of a richer shade of color, while quite a few of the increases following low values at intermediate periods were accompanied by comments indicating dulling or slight browning of the samples. These late increases averaged only .3 unit at 100°F, .1 unit at 70°, .4 unit at 40°, and .3 unit at 0°, however, and included only five, six, four and three items, respectively, so no serious degree or amount of browning was involved.

Hunter b. The "b" value denotes yellow when positive, blue when negative. Changes in the yellow values of shelter ration samples were very slight, and all trends were for increase. The initial average for the ten items was 21.99; the ten means shown in Table 11 vary from initials by +.26 ± .42. Periodic means averaged 0.02 ± .04 below initial at 6, 18, 24 months and .30 ± .04 above initial at 12, 36 and 48 months, corresponding roughly to periods of slight increase and subsequent decrease in "a" values. Thus the general trend was slight increases in yellow with decreases in red, typical fading but not typical browning.

The temperature pattern, also slight, has nevertheless been relatively consistent with other trends. Averages for the "low" and "high" periods noted above were:

	6, 18, 24 mo.	12, 36, 48 mo.	6-48 mo.
100°F	22.05 ± .07	22.43 ± .05	22.24 ± .20
70°F	21.94 ± .10	22.17 ± .09	22.05 ± .15
40°F	21.90 ± .05	22.21 ± .09	22.06 ± .18
0°F	22.03 ± .08	22.31 ± .12	22.17 ± .17

The trends for relative stability at 70° and 40°F, increased yellow with fading of red at 100°F, and smaller increases with "deepening" of color at 0°F are clearly seen even in these slight changes in the "b" component of ration color.

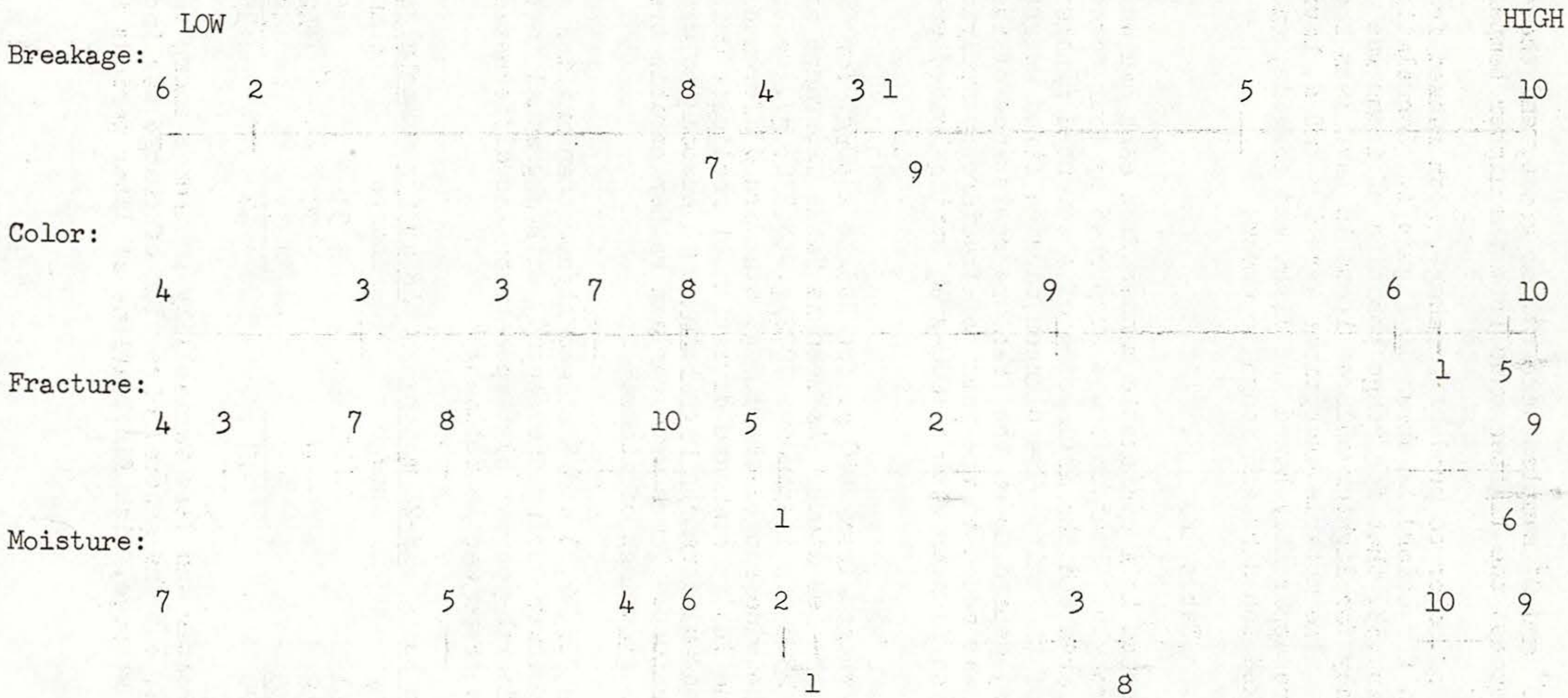
a/b Ratio. Changes in the ratio of "a" to "b" provide a good index of changes in hue for products of the shelter ration types. Initial ratios for the items, in the order listed in Table 11, were .203, .054, .269, and .120 for the crackers; .097, .030, .219, and .115 for the biscuits; and .166 and .238 for the wafers. Thus order of pale to brown for the rations, based on relative values for all components, was CD4, 3, 2, 7, 8, 9, 6, 1, 5, 10, (Figure 1) and the general mean ration, .155, fell between the center items of the array, CD8 and CD9. Initial standard difference among replicate cans was .031, the same as at 48 months.

Reference to the a/b ratios for wafers CD9 and CD10 in Table 11 confirms previous observations that this product did not differ much from initial hue and chroma after four years in storage. There were storage changes--L values increased steadily beginning with the first year as the wafers assumed a somewhat glazed appearance, "a" values increased gradually through the second year and returned to about the initial level by the fourth, and "b" values fluctuated slightly with little net change through the third year and increased moderately during the fourth. Thus the wafers were somewhat brighter and slightly redder in appearance through the third year (higher L and a/b), more glazed but about "normal" in hue and chroma at the fourth year. The temperature effect was generally small, even between the 100° and 0° samples.

The a/b ratios for crackers and biscuits showed the fading effect of higher temperatures on the "a" or red component. With the exception of the darkest item, cracker CD5, which had unusually high "a" values and low "b" values at 36 months, there were no average a/b ratios as high as initial at any period of storage at 100°F. Average decreases in ratios at this temperature were .032 ± .007 at 6-24 months, .039 at 36 months, .070 at four years. All samples of CD1 and CD7 and 83% of other cracker and biscuit samples also remained below initial a/b ratio in storage at 70°F. Decreases at 70° averaged .010 ± .010 at 6-24 months, .019 and .052 at three and four years. These represent easily apparent fading for all periods at 100°F, and for the last two years at 70°.

Changes in crackers and biscuits were more variable at the lower temperatures. In 40°F storage, a/b ratios averaged .007 below initial during the first year, .014 above the second year, .005 above at 36 months, .035 below at four years. Samples from 0°F averaged .005, .011, .030, .017, and .011 above initial at 6, 12, 18, 24, 36 months, and had faded slightly to an average of .022 below initial ratio by the end of the fourth year. Changes at these temperatures were generally not apparent on visual inspection, as

Figure 1. Range Positions for Physical Characteristics of Cereal Items at 48 Months
(positions designated by CD item numbers)



differences between 40° and 0° samples were seldom great, and there were no reference samples except the lighter ones from the higher temperatures.

The relationship of color to product breakage, both ranked from low to high (pale to brown for color) is shown in Figure 1. Correlation of rank order of items was .53, that for range position of items was .43, indicating some tendency for lighter colored items to have less breakage and darker items more. The notable exceptions were CD3 and 4, having about 20% breakage, which were apparently baked too light and fragile, and CD6, which seemed to be baked too dark and tough to break.

5. Fracture Strength. (Table 12)

Twenty units selected in a systematic manner from each can were used to determine fracture strength. Each unit was supported by four corner blocks of about 1/16 sq. in. area and the dull point of a weighted plunger was rested on the center of the unit. The plunger carried fixed weights varying from 400 to 1600 grams, depending on the fracture resistance of the unit, and additional weight was added to the point of fracture by applying increasing pressure on the plunger with a 1000-gram spring-loaded pressure tester.

Initial fracture ranged from 1060 g. for CD3 to 2160 g. for CD9; with a mean of 1415 g. for the ten items. As seen in Table 12, range at 48 months was 1036 g. to 2378 g., item means 1072 g. to 2306 g., general mean 1543 g. In view of the wide range, the 147 g. standard difference between duplicate cans, and the 145 g. standard deviation of replicate units, no consistently significant differences have been found associated with either storage time or temperature. There were certain rather erratic trends, however, among various groupings of items.

In general, items CD1, 2, 3 and 7 showed higher than initial averages during the first year, lower during the second, with a gradual increase during the third and fourth years. By temperatures, as differences from initial averages, this trend was as follows:

storage °F	6 months change	18-24 months change	48 months change	total storage change
100	+ 61	- 60	+ 31	+ 5
70	+149	0	+ 70	+42
40 and 0	+150	+ 6	+ 55	+58
mean	+120	-18	+ 52	+35

There was both greater and less variability in trends among various of the other six items, but the general direction of change was increase from the beginning of storage, with fluctuations at later periods for some

TABLE 12

FRACTURE STRENGTH AND MOISTURE CONTENT OF WHEAT ITEMS STORED 48 MONTHS

Condition °F/% r.h.	Crackers CD1	CD3	CD5	CD8	Biscuits CD2	CD4	CD6	CD7	Wafers CD9	CD10	Mean	Std.dif. cans
Fracture Strength, grams:												
100/80	1565	1036	1464	1177	1626	1074	2306	1176	2214	1563	1520	98
100/57	1497	1080	1537	1242	1655	1077	2229	1212	2203	1639	1537	140
70/80	1595	1132	1559	1340	1708	1116	2279	1252	2230	1314	1552	224
70/57	1497	1092	1553	1270	1710	1078	2291	1177	2378	1510	1556	205
40/57	1595	1123	1514	1301	1622	1049	2309	1186	2168	1323	1519	74
0/amb	1423	1190	1499	1332	1663	1043	2300	1246	2642	1424	1576	64
std.dif.,cans	167	72	263	97	91	55	29	52	275	116	147	-
std.dev.,20 reps	194	175	130	102	117	152	97	88	209	132	145	-
sign.dif.,5%	NS	122	NS	NS	NS	NS	50	69	410	201	NS	207[a]
Mean	1529	1109	1521	1277	1664	1072	2286	1208	2306	1462	1543	89[b]
Moisture Content, percent:												
100/80	2.35	2.61	1.83	2.83	2.31	2.06	2.13	1.55	3.39	3.32	2.44	.12
100/57	2.33	2.64	1.76	2.94	2.46	2.38	2.24	1.67	3.30	3.59	2.53	.34
70/80	1.95	2.99	1.77	2.68	2.23	2.36	2.23	1.66	3.69	3.26	2.48	.21
70/57	2.37	2.80	1.93	2.79	2.44	2.49	2.24	1.64	3.52	3.07	2.53	.38
40/57	2.35	2.73	2.45[c]	2.42	2.32	1.93	2.43[c]	1.60	3.40	3.45	2.51	.25
0/amb	3.04	2.54	2.14	2.87	2.44	2.00	2.29	1.73	3.49	3.18	2.57	.18
std.dif.,cans	.60	.20	.16	.17	.13	.34	.15	.13	.09	.23	.26	-
sign.dif.,5%	NS	.33	.28	.30	.22	.55	.25	NS	.15	.39	NS	.42[a]
Mean	2.40	2.72	1.98	2.76	2.36	2.20[c]	2.26	1.64	3.47	3.31	2.51	.15[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.
[c]All cans were leakers.

items. CD5 increased with every examination, CD4 and 8 increased in two stages with a downward shift at 12 and 24 months, respectively. The wafers, CD9 and 10, increased through the third year, then shifted downward at 48 months, while CD6 increased through 18 months, drifted downward through 36 months, and back to the 18 months level at 48 months. Mean values for the six items at 6, 24, 48 months and for the total period, as differences from initial, were:

storage °F	6 months change	24 months change	48 months change	total storage change
100	- 70	+ 65	+ 119	+ 38
70	- 83	+ 25	+ 135	+ 30
40 and 0	- 22	+ 82	+ 134	+ 58
mean	- 58	+ 57	+ 129	+ 42

Apparent trends as illustrated for both groups of items could very well have resulted from combinations of random variance, but suggestions of possible time and temperature effects were as shown.

The lack of a significant relationship between fracture strength and product breakage may be seen in Figure 1. With both ranged low to high, rank order correlation for items was -.04, that for fracture and breakage range positions -.28. The latter, which is equivalent to the direct correlation between fracture and breakage values, indicates a very slight tendency for items with lower fracture strength to have more breakage, as in the crumbly wafer CD10, or less breakage with higher fracture value, as in tough biscuit CD6. CD2 and 9 ranged in the same direction as CD6, all others in the same direction as CD10, but the comparisons were too variable for significance.

Fracture strength and color corresponded somewhat more closely, rank order and range position correlations from Figure 1 being .50 and .52. Items CD3 and 4 were light-baked and tender, CD7 and 8 medium brown and moderately tender, while CD6 was brown and tough as mentioned previously. Not checking as well, biscuit CD2 was moderately baked but fairly hard, wafer CD9 was a rich medium brown but was quite compact, wafer CD10 quite "toasted" but crumbly, while crackers CD1 and 5 were brown and brittle.

6. Moisture Content (Table 12)

Moisture content was determined on duplicate 14-mesh samples from each can from loss of weight after heating 5-gram aliquants 24 hours at 70°C under a 29-inch vacuum. Initial moistures ranged 1.42% for cracker CD5 to 4.03% for wafer CD10, mean 2.53%. As seen in Table 12, moistures at 48 months had somewhat less range but about the same mean. Periodic mean values have ranged from 2.27% at 18 months to 2.86% at 12 and 24 months, storage condition means have differed by less than half this range, and there has been no consistent association of moisture values with any storage effect.

Several relatively low but statistically significant correlations of moisture with fracture strength have been observed within items; these were characteristically negative for crackers and positive for biscuits and wafers as product groups, but quite variable among items. Figure 1 shows relatively poor agreement between moisture and fracture (rank order correlation .30, range position .34) at 48 months, but the average trend was positive except for CD3, 6, 8 and 10. Items 3, 8 and 10 had relatively higher moisture than fracture value, CD6 high fracture with lower moisture.

Correlation with breakage was slightly higher (.32 rank order, .37 range position), with color somewhat lower (.21 and .20, respectively). Low moisture items CD7 and 5 had moderate (CD7) and high (CD5) breakage and color; high moisture wafer CD9 had moderate breakage and color, though all three measurements were high for wafer CD10. Other moistures were in the moderate range, with higher color for CD1 and 6, lower color for CD3 and 4, lower breakage for CD2 and 6.

Perhaps the best summary for moisture is that it was apparently not very closely related to anything except items.

7. Rancidity Values (Table 13)

Peroxides. As initial products of oxidation, peroxides were determined by extracting fat with chloroform, mixing extract with 1.5 volumes glacial acetic acid, reacting with potassium iodide, and titrating liberated iodine with sodium thiosulfate. The general pattern has been about the same for all items at all temperatures: (1) increase over the first year as oxygen starting at normal tension was utilized in reactions stimulated by baking and canning; (2) more or less sharp decrease to low values at periods ranging from 18-36 months as peroxides were involved in secondary oxidation reactions, and (3) a slow and relatively uniform "steady-state" increase over the last one or two years of the four-year period.

The period timing of the pattern, and the high and low levels reached, have varied considerably with temperatures, products, and to some extent, with leaking cans. All items except CD4, the biscuit with more than 80% leaking cans, reached high 100°F peroxide values at 12 months, crackers averaging 25.4 m-eq., biscuits 6.1, wafers 3.9, from initial values of .8 for crackers and biscuits, 1.7 for wafers. At 70°F, wafers had high values averaging 10.4 at 12 months, while high values for crackers at this temperature, averaging 4.3, were reached variously at 12 months or during the second increase period at 36 or 48 months. All biscuits at 70°F and below, and crackers at 40° and 0°, reached higher values during this second increase period, but high levels for wafers were at 12 months even at the lower temperatures, averaging 5.6 at 40° and 4.1 at 0°F.

TABLE 13

RANCIDITY VALUES OF FATS FROM WHEAT ITEMS STORED 48 MONTHS

Condition	Crackers				Biscuits				Wafers		Mean	Std.dif.
°F/% r.h.	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10		cans
Peroxide Values, milliequivalents per kilogram:												
100/80	3.7	2.2	3.3	5.5	2.7	5.0	5.1	3.0	6.0	1.4	3.79	2.28
100/57	3.3	2.1	4.0	3.1	2.2	4.5	4.9	4.9	2.8	1.3	3.30	1.51
70/80	2.5	3.3	3.7	3.5	2.7	3.1	3.8	4.7	5.2	2.6	3.53	2.18
70/57	1.5	2.7	2.8	6.1	1.9	3.1	3.9	4.8	3.8	3.1	3.36	2.00
40/57	.8	2.3	3.3[a]	4.2	1.9	2.7	3.2[a]	3.1	3.4	4.7	2.96	1.95
0/amb	.9	2.7	1.3	2.3	1.1	2.2	2.4	3.7	2.3	1.9	2.02	.73
std.dif.,cans	1.82	1.29	1.83	2.30	1.61	2.02	2.07	1.28	2.16	1.84	1.85	–
sign.dif.,5%	2.46	NS	NS	3.20	NS	NS	NS	1.76	3.13	2.98	.84	2.62[b]
Mean	2.09	2.56	3.07	4.10	2.09	3.45[a]	3.87	4.03	3.91	2.43	3.16	1.08[c]
Free Fatty Acids, percent as oleic acid:												
100/80	.16	.57	.26	.97	.40	.91	.54	.72	1.04	.72	.629	.078
100/57	.16	.58	.45	.99	.46	.98	.49	.78	1.00	.79	.667	.176
70/80	.09	.25	.14	.50	.11	.60	.14	.43	.53	.44	.325	.059
70/57	.08	.23	.15	.46	.10	.59	.18	.40	.54	.45	.317	.058
40/57	.05	.33	.14	.39	.10	.60	.13	.38	.44	.41	.297	.034
0/amb	.04	.25	.14	.45	.10	.60	.15	.38	.45	.40	.296	.028
std.dif.,cans	.027	.030	.050	.053	.035	.043	.199	.028	.154	.050	.088	–
sign.dif.,5%	.047	.052	.087	.092	.060	.075	.344	.048	.267	.086	.040	.140[b]
Mean	.096	.368	.213	.628	.213	.711	.273	.513	.668	.534	.422	.067[c]

[a]All cans were leakers.
[b]Significant difference for items in rooms.
[c]Significant difference for item means.

The reason for noting the variations in pattern is that aroma and flavor of the products were related to these variations. The sharp increases in oxidation at the higher temperatures during the first year seldom had much influence on sensory quality, except a slight staleness, as the reactions were apparently producing mostly peroxides, which are odorless and tasteless. Staleness appeared during the subsequent periods when peroxides were, it is assumed, being depleted by secondary oxidation reactions. During the intermediate periods, crackers and biscuits dropped to average lows of 1.2 and .7 at 100°F, .6 and .1 at 70°, and .05 for both at 40° and 0°; wafers averaged .1 low at 100° and 70° but did not drop below .2 at the lower temperatures, from highs above those of crackers and biscuits at every temperature except 100°. Thus the wafers apparently established a "steady-state" pattern earlier than crackers and biscuits, and were generally scored lower on aroma and flavor; in fact, wafers at 70°-0°F were scored lower than those at 100° in some instances.

The peroxide levels resulting from the second period of (gradual) increase are given in Table 13. Aroma and flavor scores for rations at 100°F, and to some extent at 70°, have dropped during this period, and most of the samples have been marked rancid at 100° and definitely stale at 70°. The peroxides actually do not vary among temperatures as much as at earlier periods, but aldehydes and other secondary products have apparently accumulated to the limits of taste tolerance at 100°.

The relation of 48-months item residuals of canspace oxygen to mean peroxide levels is shown in Figure 2. Rank order correlation is .24, range position correlation .09, indicating very little association. Higher peroxides with lower oxygen are seen in items CD9 and CD6. Peroxides were relatively high in the high-oxygen leakers of CD4, and relatively low in CD1 and 2, which have retained more oxygen in non-leaking cans than any other items. CD10, however, had low oxygen and peroxides (except at 40°F), while CD3, 5, 7 and 8, with intermediate oxygen levels, spread over 75% of the peroxide range. Thus the relation of peroxides and oxygen residuals is rather obscure.

Free fatty acids. The free fatty acids were titrated by combining equal volumes of neutral ethanol with the chloroform extracts of the fats and neutralizing with ethanolic alkali solution. Initial values, in the order listed in Table 13, were .17, .23, .19, .36, mean .24% for crackers, .16, .61, .13, .28, mean .29% for biscuits, and .34, .32, mean .33% for wafers. Although hydrolysis of fats is frequently associated with high moisture, the only suggestion of such among the CD rations was with the high-moisture wafers; crackers CD3 and CD8 and biscuits CD4 and CD7 contained lower quality fats, particularly CD4.

The pattern of changes in free fatty acids was different from that of peroxides in that there was no general increase in free acids during the first year of storage. The lowest values determined at 100°F averaged .22% for crackers, .28% for biscuits, .42% (some increase) for wafers at periods ranging 6-24

Figure 2. Range Positions for Stability Factors of Cereal Items at 48 Months
(positions designated by CD item numbers)

HIGH LOW

Peroxide Value: 8 7 9 6 4 5 3 10 2

1

Free Fatty Acids: 4 9 8 10 7 3 6 5 1

2

LOW HIGH

Canspace Oxygen: 10 9 6 5 3 7 2 4

8 1

Sensory Quality: 8 7 9 5 4 2 10 1

6 3

Hedonic Quality: 8 5 7 9 1 6 2 3

10 4

months. Corresponding lows at 70°F were .17, .24 and .32% at 6-48, 18-48, and 24 months, respectively; at 40°F and 0°F, lowest values averaged .15% at 18-48 months for crackers, .24% at 24-48 months for biscuits, .31% at 18-24 months for wafers. As free fatty acids oxidize as readily as intact fats, possibly more readily, it seems probable that low acid values were associated with periods of most active oxidation.

All samples averaged higher in free fatty acids with increasing storage at 100°F, and there were slight increases at the lower temperatures, particularly in wafers. Highest values obtained at 100° averaged .67% at 36-48 months for crackers, and .66% and .89% at 48 months for biscuits and wafers. High values from 70° storage, ranging 6-48 months for crackers and biscuits but at 48 months for wafers, averaged .28, .35, and .49% respectively. From 40° and 0°F, corresponding highs were .26, .33, and .42%.

There was less direct association of changes in acids with sensory changes than observed with peroxides, but samples containing more than .5-.6% free acids were usually described as having a slight "soapy" or "acrid" flavor. As seen in Table 13, this applied to the 100°F samples of CD3, 7, 8, 9, 10 and to all samples of CD4, although the latter were noted only infrequently at lower temperatures.

The correlations of free fatty acids with peroxide values are illustrated in Figure 2. Rank order correlation was .636 and range position .614, indicating a fair agreement between the two measures of fat rancidity. CD1 and CD9 corresponded closely on low and high ends of the range, respectively, and agreement was within 20% for CD2, 3 and 8, again covering most of the range. CD6 and CD10 agreed very poorly, CD4, 5 and 7 were divergent by about 30% of the range; there appeared to be no tendency for agreement or lack of agreement to be associated with levels of either peroxides or free acids.

With canspace oxygen and free fatty acids, rank order correlation was .188, and range position .016. No consistent relationship between these two factors has been observed during the study.

8. Sensory Scores for Texture, Aroma and Flavor (Tables 10 and 14)

Texture. All sensory scores were obtained as described above for appearance and color. With moderate periodic fluctuations and some reduction at 100°F, texture scores in general averaged about .45 below initial average through the first three years. At four years (Table 10), cracker CD1 and biscuit CD6 averaged above initial, but the other items averaged about .85 below. Most of the decrease was at 100°, with some at 70°, very little at 40° and 0°F.

Cracker CD1 at 48 months averaged .85 above initial and .53 above the 6-36 months mean, with temperature differences as shown. The other crackers were under initial average, 7.17, by 1.62 at 100°, .75 at 70°, .33 at the lower

TABLE 14

AROMA AND FLAVOR SCORES OF WHEAT ITEMS STORED 48 MONTHS
(scale from 10 = excellent to 1 = poor)

Condition °F/% r.h.	Crackers CD1	Crackers CD3	Crackers CD5	Crackers CD8	Biscuits CD2	Biscuits CD4	Biscuits CD6	Biscuits CD7	Wafers CD9	Wafers CD10	Mean	Std.dif. cans
Aroma:												
100/80	4.2	3.4	4.0	2.2	3.0	3.6	2.2	2.2	3.7	5.0	3.35	.85
100/57	4.3	3.2	3.0	2.2	3.2	3.5	2.5	2.2	3.3	4.9	3.23	.89
70/80	6.3	5.4	5.8	4.8	5.9	5.5	5.3	4.9	4.3	5.2	5.34	.74
70/57	6.5	5.8	6.2	5.8	5.9	5.8	5.5	5.3	4.4	5.7	5.69	.82
40/57	7.0	6.4	6.5	6.8	5.8	6.2	6.5	6.8	5.9	6.2	6.41	.96
0/amb	7.2	7.0	5.7	6.9	6.7	6.4	7.2	6.9	6.4	6.9	6.73	.35
std.dif.,cans	.28	.62	.31	.64	1.09	.35	.52	.87	1.44	.78	.77	–
std.dev.,judges	1.15	1.43	1.33	1.15	1.21	1.58	1.12	.98	1.70	1.34	1.32	–
sign.dif.,5%	.48	1.06	.53	1.11	1.88	.61	.90	1.50	2.49	1.35	.35	1.23[a]
Mean	5.92	5.20	5.20	4.78	5.08	5.17	4.87	4.72	4.67	5.65	5.13	.58[b]
Flavor:												
100/80	3.8	3.3	3.3	1.7	3.4	3.5	2.0	1.7	4.0	5.0	3.17	.92
100/57	3.6	3.6	3.1	2.1	3.3	3.7	2.6	1.8	3.7	5.1	3.26	.89
70/80	5.8	5.5	5.3	4.8	6.3	4.9	4.7	4.7	4.8	3.9	5.07	.54
70/57	6.3	5.8	6.0	4.9	6.5	6.0	5.2	5.1	5.1	4.6	5.55	.47
40/57	6.7	6.5	6.4	6.3	5.6	6.5	6.6	6.8	5.8	6.0	6.32	1.13
0/amb	7.0	6.6	5.8	6.4	7.4	6.8	7.4	6.9	6.2	5.7	6.62	.52
std.dif.,cans	.53	.36	.28	.55	1.18	.44	.25	.91	.96	1.40	.79	–
std.dev.,judges	1.50	1.66	1.64	1.36	1.26	2.01	1.05	1.05	1.91	2.12	1.60	–
sign.dif.,5%	.92	.62	.48	.94	2.04	.76	.43	1.58	1.66	NS	.36	1.25[a]
Mean	5.53	5.22	4.98	4.37	5.42	5.23	4.75	4.50	4.93	5.05	5.00	.74[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

temperatures. Similarly, biscuit CD6 averaged .17 above initial, and exactly the same as at 6-36 months; other biscuits, although higher than CD6, were nevertheless under initial, 8.07, by 1.83 at 100°, 1.07 at 70°, .67 at 40° and 0°. Wafers averaged 6.00 initially, 6.32 at 6-36 months, 5.82 at 48 months, the latter being .38 and .20 below initial at 100° and 70°, .02 above at 40° and 0°.

No explanation was suggested for the increase in texture scores of cracker CD1; this item averaged 6.22 and 6.37 at 6 and 12 months, 6.81 ± .02 at 18-36 months, 7.35 at 48 months. Fracture strength decreased roughly in proportion to increased texture scores through 36 months, but was back near initial level at 48 months. The decrease in other items at 100° and 70°F probably resulted in part as a reaction to increased rancidity and staleness; fracture strength averaged only slightly lower at 100°, no lower at 70°, the only unquestionable difference being in aroma and flavor.

Aroma. General mean scores for aroma were 6.87 for initial averages and 6.03, 5.92, 5.81 and 5.13, at the four yearly examinations. For products, initial averages were 6.95 for crackers; 7.12 for biscuits, and 6.20 for wafers. Scores given in Table 14 averaged the following decreases from 36-months and initial average levels:

temperature °F	crackers decrease from 36 mo.	crackers decrease from initial	biscuits decrease from 36 mo.	biscuits decrease from initial	Wafers decrease from 36 mo.	Wafers decrease from initial
100	.81	3.64	1.65	4.32	.92	1.97
70	.52	1.12	.70	1.61	.30	1.30
40	.33	.28	.62	.80	.35	.15
0	.47	.25	.45	.32	-.15	-.45

Thus, decreases in aroma scores during the fourth year were proportionally larger than for previous periods in all product storages except crackers stored at 100°F and wafers at 70°. Note that all 40° and 0°F averages at 36 months were above initial averages except that for biscuits at 40°, and the 0° average for wafers is still above the initial averages. Present low scores, 2.2 for CD6, 7, 8 at 100°F, correspond to a rating of about 4.65 on the hedonic scale, and the 100° mean score, 3.29, to about 5.25 hedonic, whereas the hedonic averages actually assigned (Table 15) were 3.47 and 4.00 for CD6, 7, 8 and the general mean at 100°.

Flavor. Initial flavor scores averaged lower than aroma scores for crackers, 6.42 and wafers, 5.80, but higher for biscuits, 7.52. General initial and yearly averages were 6.74, 6.15, 5.81, 6.00, and 5.00, higher than aroma averages at one and three years. Product and temperature decreases from 36-months and initial levels for the scores of Table 14 are as follows:

TABLE 15

HEDONIC RATINGS FOR WHEAT ITEMS STORED 48 MONTHS
(scale from 9 = like extremely to 1 = dislike extremely)

Condition	Crackers				Biscuits				Wafers		Mean	Std.dif.
°F/% r.h.	CD1	CD3	CD5	CD8	CD2	CD4	CD6	CD7	CD9	CD10		cans
Aroma:												
100/80	4.26	4.24	4.58	3.56	4.06	4.42	3.38	3.24	4.06	4.58	4.04	.32
100/57	4.00	4.02	3.84	3.32	4.00	4.38	3.92	3.42	4.06	4.58	3.95	.52
70/80	5.20	5.58	5.10	5.02	5.36	5.54	5.30	5.26	4.78	4.74	5.19	.50
70/57	5.48	5.72	5.26	5.04	5.38	5.48	5.24	5.42	4.74	4.84	5.26	.47
40/57	5.76	5.98	5.32	5.62	5.16	5.90	5.58	5.74	5.20	5.24	5.55	.48
0/amb	5.90	6.06	5.04	5.84	5.74	5.94	6.06	5.92	5.34	5.78	5.76	.29
std.dif.,cans	.33	.45	.33	.40	.62	.45	.48	.32	.57	.28	.44	–
std.dev.,judges	1.59	1.43	1.38	1.34	1.56	1.54	1.47	1.43	1.44	1.53	1.47	–
sign.dif.,5%	.57	.77	.56	.69	1.08	.77	.83	.56	.96	.48	.20	.69[a]
Mean	5.10	5.27	4.86	4.73	4.95	5.28	4.91	4.83	4.70	4.96	4.96	.34[b]
Flavor:												
100/80	4.38	4.42	4.72	3.24	4.28	4.44	3.56	3.80	4.52	4.82	4.22	.38
100/57	3.92	4.44	4.02	3.32	4.14	4.56	4.14	3.46	4.46	4.76	4.12	.42
70/80	5.10	5.78	5.14	4.78	5.56	5.36	5.24	5.48	5.12	4.58	5.21	.43
70/57	5.40	5.66	5.28	4.72	5.46	5.46	5.36	5.42	5.30	4.90	5.30	.44
40/57	5.70	5.98	5.20	5.44	5.38	6.02	5.80	5.94	5.66	5.30	5.64	.46
0/amb	5.74	6.06	5.00	5.52	5.76	6.08	5.92	6.04	5.64	6.00	5.78	.26
std.dif.,cans	.35	.43	.34	.51	.56	.39	.38	.33	.48	.11	.41	–
std.dev.,judges	1.61	1.42	1.51	1.53	1.72	1.68	1.43	1.30	1.47	1.47	1.52	–
sign.dif.,5%	.61	.75	.59	.88	.96	.68	.69	.57	.85	.18	.18	.65[a]
Mean	5.04	5.39	4.89	4.50	5.10	5.32	5.00	5.02	5.12	5.06	5.04	.34[b]

(continued)

Table 15 (continued)

Condition °F/% r.h.	Crackers CD1	CD3	CD5	CD8	Biscuits CD2	CD4	CD6	CD7	Wafers CD9	CD10	Mean	Std.dif. cans
Palatability:												
100/80	4.74	4.92	4.80	3.66	4.64	5.18	4.26	3.62	4.56	4.76	4.51	.34
100/57	4.54	4.78	4.54	3.80	4.76	4.96	4.76	3.76	4.48	4.86	4.52	.45
70/80	5.14	5.90	5.20	5.14	5.50	5.64	5.46	5.50	5.16	4.86	5.35	.39
70/57	5.58	5.90	5.26	5.02	5.54	5.52	5.40	5.56	5.26	5.04	5.41	.35
40/57	5.54	6.08	5.26	5.46	5.50	6.04	5.64	6.08	5.66	5.38	5.66	.28
0/amb	5.78	6.00	5.10	5.52	5.86	6.14	5.92	6.08	5.70	5.96	5.81	.21
std.dif.,cans	.28	.38	.12	.32	.37	.48	.36	.39	.43	.12	.35	-
std.dev.,judges	1.81	1.53	1.55	1.60	1.63	1.67	1.76	1.56	1.50	1.52	1.62	-
sign.dif.,5%	.48	.66	.21	.56	.65	.82	.62	.68	.79	.21	.16	.55[a]
Mean	5.22	5.60	5.03	4.77	5.30	5.58	5.24	5.10	5.14	5.14	5.21	.28[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

temperature °F	Crackers		Biscuits		Wafers	
	decrease from		decrease from		decrease from	
	36 mo.	initial	36 mo.	initial	36 mo.	initial
100	1.00	3.36	2.00	4.77	1.27	1.35
70	.91	.87	.96	2.10	1.00	1.20
40	.40	-.05	.77	1.15	1.15	-.10
0	.52	-.02	.47	.40	1.10	-.15

Thus, greatest average decreases were during the fourth year in all products and storages (there were certain item variations). These decreases were from average levels above initial in crackers at 70°F and below, wafers at 40° and 0°, and biscuits at 0°; crackers and wafers still averaged above initial after 48 months at 40° and 0°, as initials were relatively low for these products. The low average, 1.75 for CD7 at 100°F, and the 3.22 mean at 100°, correspond to 4.41 and 5.23 on the hedonic scale, with corresponding hedonic ratings averaging 3.66 and 4.17; the sensory quality judges were apparently scoring somewhat high in an attempt to eliminate "like or dislike" bias from product quality evaluation.

The combined item averages of Table 14 are ranged for comparison with other stability factors as Sensory Quality in Figure 2. Correlations with canspace oxygen and rancidity values as ranged were:

	rank order	range position
sensory quality with:		
canspace oxygen	.21	.20
peroxide values	.98	.91
free fatty acids	.49	.52

The relationship with canspace oxygen is very slight, CD2 (relatively high) and CD6 (relatively low) being the only good matches and CD3, 5 and 9 (moderate to relatively low) being fairly close. Correlation of low to high mean scores with high to low peroxide values was very good. CD1 (lower P.V., higher score) and CD7 and 8 (higher P.V., lower scores) corresponded exactly and CD5 (mid-range) and CD6 and 9 (lower scores with higher P.V.) averaged a spread of less than 10% of the range; CD3 and 10 (lower P.V.); and CD4 (higher P.V.) varied by about 20% of the range.

Though not statistically significant, some relationship was also suggested between sensory quality and free fatty acids. CD1 (lowest F.F.A., highest scores) and CD3 (mid-range) corresponded exactly, while CD8 and 9 (high FFA, low scores) matched within 15% of the range. CD2, 5, 7 and 10, however, spread 23% to 39%, and CD4 and 6 averaged 53%; i.e., scores and F.F.A. were apparently unrelated in these items. The total pattern indicates, nevertheless, a trend for a negative relationship between sensory scores and rancidity values.

9. Hedonic Ratings for Aroma, Flavor and Palatability (Table 15)

The hedonic rating panel consisted of 25 judges selected at random as available from a pool of about 100 people. Samples were rated in sets of six per judge per session, each set containing one can from each of the six storage conditions for a single item; thus, duplicate cans were scored on different sessions. The six samples for each session were randomly assigned to the six positions of a systematically arranged 6 x 25 block plan, the arrangement being such that each sample appeared in each of the six presentation positions (1st to 6th) about the same number of times, and each of the 25 blocks (plates) had the six samples in a different sequence. Arranged thus, the six samples were presented together, with scoring order numbered, so that direct comparisons could be made by any judge who so desired, and comments on these comparisons were invited. The numerical scale was the customary 9-point hedonic range from "like extremely" to "dislike extremely".

Aroma. Initial ratings averaged 5.85 for crackers, 6.42 for biscuits, and 5.45 for wafers. Mean ratings for the four yearly examinations were 5.66, 5.52, 5.48, and 4.96, as compared to initial general mean of 6.00. The ratings for 48 months, shown in Table 15, averaged as follows in comparison to initial ratings and previous low scores:

temperature °F	Crackers		Biscuits		Wafers	
	decrease from		decrease from		decrease from	
	initial	previous low	initial	previous low	initial	previous low
100	1.86	.33	2.57	.92	1.13	.26
70	.55	.29	1.05	.40	.68	.02
40	.18	.02	.83	.23	.23	-.16
0	.14	-.06	.51	.12	-.11	-.36

Thus, crackers and wafers at 0°F and wafers at 40° averaged higher at 48 months than at some previous period, and wafers at 0° averaged .11 higher than initial. As seen in Table 15, 100° samples of CD6, 7, 8 and one of CD5 averaged below 4.00.

Flavor. Initial averages were 5.90 for crackers, 6.72 for biscuits, and 5.60 for wafers for a mean of 6.17. Yearly means were 5.78, 5.66, 5.53 and 5.04. Differences between 48-months ratings and initial and previous low ratings for products and temperatures were:

temperature °F	Crackers		Biscuits		Wafers	
	decrease from		decrease from		decrease from	
	initial	previous low	initial	previous low	initial	previous low
100	1.84	.25	2.67	.87	.96	.21
70	.66	.21	1.30	.53	.63	.04
40	.32	.03	.94	.26	.12	-.06
0	.32	.06	.77	.26	-.22	-.58

Wafers averaged higher than for some previous period at 40° and 0°F, and higher than initial average at 0°. The 100°F samples of CD7 and 8, and one each of CD1 and CD6 were below 4.00.

Palatability. Initial averages were 6.11 for crackers, 6.66 for biscuits, and 5.50 for wafers; for a mean of 6.21; yearly means were 5.97, 5.82, 5.75 and 5.21.

Reductions in ratings at 48 months from initial averages and previous low ratings were:

temperature °F	Crackers decrease from initial	Crackers decrease from previous low	Biscuits decrease from initial	Biscuits decrease from previous low	Wafers decrease from initial	Wafers decrease from previous low
100	1.64	.49	2.16	.79	.84	.39
70	.72	.27	1.14	.42	.42	.17
40	.53	.11	.84	.23	-.02	-.13
0	.51	.10	.66	.14	-.33	-.52

Wafers stored 48 months at 40° and 0°F averaged higher than previous low values and initial values. As seen in Table 15, this did not result from scores being higher than for crackers and biscuits at these temperatures, but from both initial and previous scores for wafers being lower. Wafer scores at 100°F for all three hedonic ratings were above those of items CD6, 7 and 8, however; CD7 and 8 scored below 4.00 for all ratings at this temperature.

Correlations of combined means for the hedonic ratings of the ten items with the other factors connected with stability are illustrated in Figure 2. These were calculated as follows:

hedonic quality with:	rank order	range position
canspace oxygen	.43	.43
peroxide values	.52	.40
free fatty acids	.11	.06
sensory quality	.57	.48

For canspace oxygen and hedonic quality, items CD1, 2, 4 and 5 averaged only 3.5 ± 1.0% spread in range position, CD1, 2 and 5 being mid-range, CD4 having high ratings with high (leaker) oxygen. CD7, also mid-range, was the only other item which was close (spread about 17%), so the general relationship of hedonic quality and canspace oxygen applied to only about half of the items. With peroxides only one item, CD8, checked exactly (highest P.V., lowest rating), and CD5 was within 20% spread with low rating, a moderate oxygen level. Five items, CD2, 3, 7, 9, 10 spread 24-37% of the range, accounting for the low-level correlations but too generally scattered for practical association. Free fatty acids present a different pattern; CD2, 6, 7, 8, 10 ranged within 8-18%, the others from 38-98% spread, so although the group correlations were very low, half of the items checked fairly well. CD8 was on the low rating-high acid end and CD2, 6, 7 and 10 in the mid-range for ratings and somewhat more widely spread in FFA content. Finally, sensory and hedonic evaluations of quality, with the highest correlations of the group, had one item checking exactly, CD8 at the low ends of the ranges, and CD2 was within 6% toward the high range. CD5 spread about 14% in low to mid-range; the other seven items ranged 22-47%, yielding a fair-sized correlation but not close enough for significance.

The above gives some idea of the relationship of the various measurements among items, independent of storage effects except as they influenced general item means.

10. Correlations of Palatability Ratings and Other Measurements (Table 16)

The correlations of Table 16 were among samples, including temperature effects for items and product groups. It is seen that practically all of the correlations with oxygen (except CD9), a few with peroxides, every one with free fatty acids, and every one with sensory aroma and flavor are considerably higher than those illustrated for items only in Figure 2. Thus, such storage effects as increase in L and decrease in "a" and a/b color values, depletion of oxygen, and development of increased peroxide and free fatty acid levels, all associated with higher temperatures, resulted in most of the significant correlations of Table 16, as flavor and aroma are adversely influenced by most of these reactions or by factors which cause them to take place.

One of the interesting sets of correlations is the group for sensory aroma and flavor (by five experienced judges) vs palatability (by 25 judges with less experience). Simple averages and standard deviations of these correlations over the four years of storage are as follows:

6 months:	+.14 ± .40	24 months:	+.59 ± .25
12 months:	+.43 ± .27	36 months:	+.81 ± .13
18 months:	+.50 ± .20	48 months:	+.88 ± .10

It is apparent that the two panels were reacting generally to the same sample characteristics at the third and fourth years. The sensory quality panel noted and scored small differences which the larger hedonic panel tended to ignore at the first three examinations (the hedonic panel frequently rating all samples low because some members had not yet decided to tolerate the rations, good or bad). By the second year, sample differences associated with storage were beginning to bring the results of the two modes of evaluation closer together (there being no longer any question that some samples were becoming more intolerable than others, even among the "dislike" members).

Judging from the correlations at 36 and 48 months, and considering which panel may have been more nearly correct in evaluating the rations during the first two years, it begins to appear that an experienced panel of five or perhaps ten members could probably produce a reliable evaluation with a great deal less expenditure of effort than that required to conduct and process the results of the larger panels.

TABLE 16

CORRELATIONS OF PALATABILITY RATINGS WITH OTHER MEASUREMENTS FOR WHEAT ITEMS STORED 48 MONTHS
(simple correlation coefficient, r)

Palatability with:	Crackers					Biscuits					Wafers		
	CD1	CD3	CD5	CD8	All	CD2	CD4	CD6	CD7	All	CD9	CD10	All
Hunter L	-.639[b]	-.245	-.683[b]	-.735[c]	-.073	-.822[c]	-.850[c]	-.842[c]	-.510	-.087	-.719[c]	-.621[b]	-.267
a	+.389	+.117	+.317	+.638[b]	-.148	+.873[c]	+.855[c]	+.855[c]	+.414	+.052	+.509	+.350	+.222
b	-.063	-.690[b]	-.645[b]	-.551	-.200	-.257	+.507	+.318	+.516	-.042	+.247	-.164	+.047
a/b	+.412	+.105	+.427	+.498	-.172	+.878[c]	+.468	+.855[c]	+.402	+.056	+.423	+.458	+.199
Fracture Strength	+.030	+.466	-.021	+.622[b]	-.072	+.268	-.247	+.231	+.326	-.066	+.451	-.363	-.533[c]
Moisture Content	+.170	+.216	+.462	-.497	+.072	-.088	-.173	+.548	+.296	+.159	+.324	+.230	+.009
Residual Oxygen	+.595[b]	+.695[b]	+.643[b]	+.894[c]	+.587[c]	+.792[c]	+.495	+.780[c]	+.883[c]	+.725[c]	-.024	+.928[c]	+.323
Peroxide Value	-.589[b]	+.525	-.355	-.233[c]	-.336[c]	-.220	-.411	-.723[c]	+.012	-.156	-.476	+.079	-.221
* Free Fatty Acids	-.899[c]	-.891[c]	-.919[c]	-.951[c]	-.639[c]	-.860[c]	-.702[c]	-.896[c]	-.966[c]	-.433[c]	-.933[c]	-.627[b]	-.791[c]
Sensory Scores:													
Appearance-Color	+.399	+.023	+.109	+.074	+.210	-.336	-.237	+.833[c]	+.851[c]	+.277	+.569	+.547	+.323
Texture	+.850[c]	+.844[c]	+.592[b]	+.906[c]	+.742[c]	+.835[c]	+.822[c]	+.875[c]	+.943[c]	+.705[c]	+.317	+.518	+.389
Aroma	+.917[c]	+.924[c]	+.960[c]	+.945[c]	+.833[c]	+.907[c]	+.840[c]	+.927[c]	+.969[c]	+.897[c]	+.899[c]	+.825[c]	+.795[c]
Flavor	+.942[c]	+.910[c]	+.919[c]	+.976[c]	+.876[c]	+.919[c]	+.752[c]	+.921[c]	+.975[c]	+.889[c]	+.977[c]	+.517	+.758[c]

[a]All cans were leakers.
[b]Significant at the 5% level of probability.
[c]Significant at the 1% level of probability.

B. The Carbohydrate Supplements

The hard candies of the carbohydrate supplement consisted of two flavors and colors, lemon and cherry in equal parts. The two types were examined separately for all determinations except taste panel scores, for which only comments were separate. Data and discussions are based on cans and items, however, except in instances where there were distinct differences as in color values, and type variations are noted only when they were observed.

Through three years of storage, 66 cans of each of three items, CD11, 12 and 13, have been examined. The first 18 cans of each were checked in detail, and for certain measurements the first 30 cans were checked. Some of the characteristics associated only with the product and unaffected by storage were checked no further. Among these were counts of pieces per pound, percentages of lemon and cherry types per can, percentages of unsanded, off-shape and off-color pieces and certain measurements on the small kraft bags which were packed in the top of each can.

Characteristics of the product as received, based on 18 cans except that net product weight was recorded for all samples, were as follows:

		CD11	CD12	CD13
net product weight, lbs*		34.20 ± .71	35.78 ± .20	34.03 ± .34
piece count per pound:				
	lemon	118.1 ± 4.1	87.8 ± .5	87.8 ± .4
	cherry	121.1 ± 4.7	90.5 ± 1.8	88.4 ± 1.0
	mean	119.7 ± 4.4	89.2 ± .8	88.1 ± .7
count % per can:				
	lemon	48.3 ± 10.4	48.3 ± 1.9	49.2 ± 4.2
	cherry	51.7 ± 10.4	51.7 ± 1.9	50.8 ± 4.2
unsanded pieces, count %:				
	lemon	.02 ± .05	.15 ± .36	.00 ± –
	cherry	.06 ± .08	.06 ± .26	.01 ± .03
	total	.08 ± .10	.21 ± .52	.01 ± .03
off-color pieces, count %:				
	lemon	.01 ± .03	.01 ± .02	.05 ± .07
	cherry	.01 ± .02	.00 –	.01 ± .05
	total	.02 ± .03	.01 ± .02	.06 ± .06
off-shape pieces, count %:				
	lemon	2.43 ± .93	.58 ± .31	1.68 ± .61
	cherry	2.82 ± 1.52	.51 ± .34	1.26 ± .70
	total	5.25 ± 1.80	1.09 ± .46	2.94 ± .90

*includes all product which rode an 8-mesh screen. Material passing 8-mesh, as percent of total net weight, is discussed below.

1. Condition of Candy Bags (Table 17)

Measurements of internal size and length of top lip of the bags were discontinued after 12 months, giving 28 sets of measurements per item.

Internal size. CD11 were all normal 300 x 500 (3 x 5 inches). CD12 were 85% normal, 6% 213 x 500 (can code, 2-13/16 x 5 inches), 5% 300 x 413, 4% unsealed on one side. CD13 were 83% normal, 14% 300 x 508, 3% 208 x 500.

Top lip. CD11 had 83% normal 04 (4/16 inch), 17% 03. CD12 had 86.5% normal, 5% 07, 4.5% 03, 3.5% 05, 0.5% 02. CD13 had 96.5% normal, 3.5% 05.

Counts of bags per can, measurements of width of side seams (there were no bottom seams, the bags being folded strips sealed along the sides), and tests of strength of seams were made on all cans examined. The seam test was a 1-lb steady pull for 5 minutes at 73°F/50% r.h., using a 1-inch section of seam.

Bags per can. Usable bags (a few were unsealed or torn) were counted in 66 cans of each item. CD11 had 20 bags in 88% of the cans, 19 in 4.5%, 21 in 3%, and 17, 16 and none in 1.5% (1 can) each. CD12 had 20 bags in 71.3% of the cans, 19 in 9.1%, 21 in 7.6%, 18 in 4.5%, 11 in 3%, and 17, 15 and none in 1.5% each. CD13 had 86.3% with 20 bags, 7.6% with 19, and 6.1% with 21.

Width of side seams. Normal width of the side seams is 04 (4/16 inch). Of 3018 seams measured for CD11, 3042 for CD12, and 3074 for CD13, total 9134 seams, percentages having various widths from 00 to 13 were as follows:

width	CD11 %	CD12 %	CD13 %	Total %	width	CD11 %	CD12 %	CD13 %	total %
00	-	.95	-	.32	07	4.28	5.42	11.74	7.17
01	.66	1.35	-	.67	08	-	.66	9.70	3.48
02	5.83	.66	.72	2.39	09	-	.26	.10	.12
03	4.27	2.56	.29	2.37	10	-	1.38	.81	.73
04	66.27	74.56	62.36	67.71	11	-	.59	-	.20
05	1.59	2.07	-	1.22	12	-	.17	-	.05
06	17.10	9.37	14.25	13.56	13	-	-	.03	.01

Seam test. There was no indication of increase in defective seams of item CD12 with storage, and only a small increase in linear amount of separation but no increase in percent of seams involved in CD11. Results for percentages of partially and completely separated seams, and linear amount of separation in those separating only partially, are given for the first

TABLE 17

RESULTS OF SEAM TEST ON KRAFT BAGS STORED 36 MONTHS IN CARBOHYDRATE SUPPLEMENT CANS

Condition °F/% r.h.	CD11 6-24mo.	CD11 36mo.	CD12 6-24mo.	CD12 36mo.	CD13 6-24mo.	CD13 36mo.	Total 6-24mo.	Total 36mo.	Std.dif., cans 6-24mo.	Std.dif., cans 36mo.	Mean, Inches 6-24mo.	Mean, Inches 36mo.
Partial Separation, percentage of seams:												
Initial	4.04%,.062"		2.05%,.062"		2.50%,.125"		2.87%,.081"		4.56%			
100/80	2.2	24.3	1.6	6.1	6.3	3.8	3.33	11.02	6.73	18.45	.109	.135
100/57	11.9	1.3	4.7	2.5	3.7	3.8	6.77	2.50	5.77	3.54	.133	.083
70/80	4.0	.0	2.2	.0	5.6	2.5	3.97	.83	6.09	2.89	.080	.125
70/57	5.3	1.3	1.3	.0	4.4	1.3	3.65	.83	4.85	2.05	.080	.094
40/57	.9	.0	.0	.0	11.6	10.0	4.35	3.33	17.04	5.78	.144	.172
0/amb	4.1	.0	1.3	1.3	4.4	6.6	3.29	2.54	3.20	2.10	.065	.115
std.dif.,cans	4.44	11.80	4.98	5.37	13.25	5.79	8.56	8.20	-	-		
sign.dif.,5%	3.24	20.42	3.64	NS	NS	NS	NS	7.03	6.05[a]	12.18[a]		
mean,percent	4.75	4.22	1.89	1.66	5.98	4.62	4.23	3.49	2.47[b]	NS[b]		
mean, inches	.118	.147	.064	.062	.115	.139	.107	.130				
Complete Separation, percentage of seams:												
Initial	.00		.00		4.50		1.52		5.09			
100/80	.0	2.7	.0	.0	8.1	12.5	2.71	5.08	5.69	6.46		
100/57	.0	.0	.0	.0	4.0	10.0	1.35	3.33	4.86	11.55		
70/80	.0	.0	.0	.0	9.3	40.0	3.31	13.33	3.23	2.89		
70/57	.0	.0	.0	.0	1.3	30.0	.42	10.00	1.73	11.55		
40/57	.0	.0	.0	.0	18.8	13.8	6.52	4.58	13.15	15.88		
0/amb	.0	.0	.7	.0	11.3	.0	4.03	.00	12.50	.00		
std.dif.,cans	-	2.05	1.21	-	14.06	16.74	8.15	9.74	-	-		
sign.dif.,5%	-	NS	NS	-	10.26	28.97	3.33	8.36	5.76[a]	14.47[a]		
mean,percent	.00	.42	.11	.00	8.79	17.86	3.03	6.08	2.35[b]	5.91[b]		

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

two and third years in Table 17. Seams of item CD13 had 8.8% complete separation and 6.0% partial separation up to 24 months, with 17.9% complete and 4.6% partial separation at 36 months. Thus, about 14.8% of the seams in these bags of CD13 were defective during the first two years (with some increase with time within this period), and about 22.5% were defective at three years.

There was no consistent effect of storage conditions on seam defects, as each of the significant differences among conditions resulted from one or more of the more or less randomly scattered high values observed in various samples.

2. Condition of Candy (Table 18)

Chipped and broken pieces and clumping of pieces are characteristics which could be influenced by storage and handling. Percentages of these defects at 36 months, by count, are given in Table 18. Also given are data for material passing an 8-mesh screen, consisting largely of sanding sugar but also including tiny bits of candy which were small enough to pass the mesh.

Chipped pieces. These were defined as pieces which remained at least 75% intact, but from which bits of surface or corners were chipped off. Initial percentages were 4.9 for CD11, 10.3 for CD12, and 5.3 for CD13, for a mean 6.8. CD11 averaged below initial at all examinations (3.25% for 6-36 months) but CD12 and 13 both averaged above, though not higher at 36months than at 6 (CD12 and 13) or 24 (CD12). General storage average for CD12 was 14.78%, that for CD13 was 6.16, so most of the increase over initial was in CD12, with no definite indication of a time effect. There was also no definite temperature effect, although the 40° and 0°F samples averaged slightly higher at the last two examinations.

No average difference was found between chipping of lemon and cherry types in CD11 and 12, but 65% of the cans of CD13 had more chipped cherry than lemon, and total average for this item was 2.78% lemon and 3.32% for the cherry in the chipped pieces.

Broken pieces. These were defined as bits of candy ranging from those large enough to ride the 8-mesh screen up to 75% of a whole piece, but were calculated as count percent broken pieces only for amounts in excess of that required to restore all chipped pieces to normal weight. Thus, with reductions in weight for chipped pieces averaging 24.6%, 2.7%, and 11.6% for CD11, 12 and 13, respectively, .246 x 3.25 = 0.80% of CD11, .027 x 14.78 = 0.40% of CD12 (corrected by an average of .17% "missing bits", as explained below, to 0.23%), and .116 x 6.16 = 0.71% for CD13 were present as broken bits in addition to amounts which have been listed as broken pieces in the data.

TABLE 18

PHYSICAL CONDITION OF CARBOHYDRATE SUPPLEMENT STORED 36 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Chipped Pieces[c], percent by count:					Pieces Stuck Together, percent by count:				
100/80	5.8	11.3	8.9	8.66	3.31	.8	.0	.3	.37	.28
100/57	2.2	14.4	7.3	7.97	2.32	1.9	.1	.4	.80	.19
70/80	3.7	14.7	7.4	8.59	5.00	1.6	.1	.3	.63	.89
70/57	3.7	13.2	9.1	8.67	1.72	.9	.0	.1	.31	.33
40/57	5.1	19.2	7.4	10.60	5.16	1.6	.0	.3	.64	.40
0/amb	6.6	14.6	6.3	9.18	3.86	.4	.1	.2	.23	.14
std.dif.,cans	2.86	5.66	1.63	3.78	-	.74	.11	.20	.45	-
sign.dif., 5%	NS	NS	NS	NS	4.24[a]	1.20	NS	NS	.37	.63[a]
Mean	4.46	14.62	7.74	8.95	1.73[b]	1.18	.04	.26	.49	.26[b]
	Pieces Broken Up[d], percent by count:					Material Passing 8-mesh[e], percent by weight:				
100/80	3.7	-.1	.6	1.39	.42	2.4	.7	.7	1.25	1.04
100/57	1.6	-.6	.9	.64	.08	3.3	1.0	1.3	1.87	.61
70/80	.6	-.2	.2	.18	.30	3.7	.8	.7	1.71	.26
70/57	1.0	.3	1.2	.82	.21	2.7	.8	.9	1.44	.04
40/57	3.0	.5	.3	1.28	.57	7.1	.9	1.0	1.98	.31
0/amb	1.4	.1	.5	.64	.38	3.1	.4	1.0	1.49	.15
std.dif.,cans	.59	.10	.17	.36	-	.87	.15	.18	.52	-
sign.dif., 5%	1.02	.18	.30	.31	.60[a]	1.51	.25	.33	.47	.78[a]
Mean	1.85	.00	.60	.83	.22[b]	3.71	.74	.91	1.79	.32[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.
[c]Pieces with less than 25% broken off; reductions from normal weight for the three items averaged 22.0, 2.8, and 12.7%.
[d]Estimated as count in excess of amounts of chips required to restore chipped pieces to normal weight; negative values indicate chips discarded from chipped pieces before packing in the cans.
[e]Most of this material was sanding sugar.

Count percentages of broken pieces in excess of bits from the chipped pieces averaged 2.65% for CD11, .25% for CD12, and 3.08% for CD13 in the cans examined initially. From storage, with no indication of a time effect, averages for 6-36 months were 1.01, - .17, and .96%, respectively, or an overall average of 1.99 - .60 = 1.39% less than initial. The reduction probably resulted from the difference in amounts of damage for initial and stored cans, as the three cases of each item examined as initials were those which had received the most damage in shipping. The -.17% average for CD12 was derived from the fact that this item averaged .17% more reduction from normal weight of chipped pieces than the total amount of chips found; apparently some of the chipping occurred before the product was packed, so the chips did not get into the cans. Alternately, the shortage could have resulted from underestimation of counts per pound in CD12, but -.07 and -.09% shortages were found in cans from which counts per pound were determined at 6 and 12 months, while shortages in cans opened later, estimated from the earlier counts, averaged -.07, -.60, and .00%. Note: All weights from which the small percentages of defects were determined, as well as those used to determine count per pound, were made in grams to eliminate the possibility of inaccurate weights.

There was no consistent temperature effect for broken pieces from the various storage conditions, and the average difference between lemon and cherry types was .025%, with no item difference in excess of .09%. Apparently, the difference in mean percentages, .98 for CD11 and 13, -.17 for CD12, was the only significant effect connected with broken pieces.

Pieces stuck together. As seen in Table 18, clumping of the candy did not involve any great amounts of the pack, but within the range for each item, can variations were fairly large. Initial percentages, counted for five cans of each item, were 1.69 ± 1.13 for CD11, 0.13 ± .07 for CD12, and 0.46 ± .13 for CD13. Among the 60 cans of each which were examined from storage, CD11 ranged from .05 to 7.87, mean 1.73%, CD12 from .00 to .26, mean .08%, and CD13 from .00 to 1.25, mean .34%.

In CD11, about 71% of the pieces involved were in clumps of 2 pieces, with 13, 5, 3, and 3%, in clumps of 3, 4, 5 and 6 pieces, respectively; the other 5% consisted of 6 clumps of 7 pieces, 5 of 8, 2 of 9, 1 of 11, 3 of 13, and 1 each of 14, 17, 39 and 42 pieces. Two cans, stored at 70°F/57% r.h., had loose lids and the product came from the containers in 34-lb blocks, which broke up in being removed and were finally recorded at 1.8 and 3.4% clumping, these being the amounts which were firmly stuck in doublets and triplets. In CD12, averaging only .08% total clumping, 91% of the sticking was in doublets, 9% in triplets. CD13 averaged higher, .46%, but there was only one clump of 4 pieces and one of 5 pieces, 8% of the stuck pieces being in triplets and 91% in doublets.

As in the two cans of CD11 with loose lids, some of the clumping was associated with leaking cans, but most was apparently not. For example, again in CD11, there were 11 leakers, with clumping below 1% in 5, 1-2% in 4, 3.2% in 1 and 6.1% in 1. In the 54 non-leakers, there were 23 below 1%, 9 at 1-2%, 4 at 3-4%, 1 at 4.7% and 1 at 7.9%. Similarly, 2 leakers in CD12 had .00 and .19% clumping, non-leakers ranged .00 -.26, mean .08%; and 6 leakers in CD13 ranged .00 - .67, mean .43%, while 59 non-leakers ranged .00 - 1.25, mean.34%. The same variation was observed with moisture content, the net result being that, with the exception that CD11 (and CD13) averaged 1.68% moisture as compared to 1.49% average in CD12, there was no consistent relationship between moisture content and clumping in CD11 and CD12. CD13 had an association of type (lemon or cherry), moisture and clumping, as seen in the following comparisons of types.

Item CD11 had an overall average of 48.3% for cherry type candy and 48.9% of the clumping was cherry. General averages for moisture contents were the same, 1.68 and 1.67%, for the two types. It was observed, however, that while the 92% of the clumped pieces in clusters of 5 or less averaged 43.3% cherry, the 8% in clusters of 6-42 pieces averaged 76.3% cherry, the red type being higher in 32 of the 40 clusters involved. Moisture content was not associated with this preponderance of cherry in the high-count clumps. CD12 averaged 38% cherry in the clumps at 0 and 36 months, 47 and 56% at 6 and 12 months, 83 and 87% at 18 and 24 months, general average 61% cherry, with moisture averages 1.49% for lemon, 1.48% for cherry, maximum difference for any can .09%.

Item CD13 presented an entirely different pattern regarding type, moisture and clumping. The 2-count clumps (91% of clumped pieces) averaged 71% lemon, the 3-, 4-, and 5-count clumps were 100% lemon. By periods, moisture contents and types of candy included in the clumps were as follows:

	Initial	6 mo.	12 mo.	18 mo.	24 mo.	36 mo.
moisture, %:						
lemon	1.79	1.96	1.93	1.47	1.73	1.73
cherry	1.27	1.80	1.70	1.30	1.55	1.78
clumping, %:						
lemon	.45	.14	.34	.29	.30	.13
cherry	.01	.10	.11	.08	.08	.13
total	.46	.24	.35	.37	.38	.26

Thus, clumping of CD13 was apparently associated with moisture differences, which were largely between types; the very low clumping of CD12 was probably associated with the generally lower moisture (about 0.20% lower than CD11 and 13). The increased clumping and the type differences of CD11, however, were apparently caused by factors, possibly including variable handling during packing, which were not determined in the present study.

There was no definite association of clumping with storage time, but CD11 was lower (1.17%) than usual (2.00%) at 24-36 months, CD12 and 13 slightly lower at 36 months. Storage conditions may have exerted some influence in that (1) the first, third, fourth and sixth highest values of CD11 were from 100°F (average 4.95%) and the second highest, 6.09%, was from 0°F; (2) of 21 can values above average for CD12, 7 averaging .17% were from 100°, 5 averaging .18% were from 0°, 9 averaging .15% were from 70° and 40°; and (3) 11 high cans of CD13 averaged .54% from 100°, 4 averaged .66% from 0°, but 8 also averaged .66 from the other three conditions. Thus, the extreme temperatures appeared to produce more of the extreme values (about 65%), but the temperature pattern was far from definite.

As clumping probably resulted in most instances from surface moisture, packing under temporarily high humidity, or can leaks (those detected and possibly others which were stopped before leak tests were made) could have accounted for most or all of the clumping. Conditions such as these could cause surface moistening with amounts of moisture slight enough to have little influence on the process moisture levels in the candy.

Material passing 8-mesh screen. Consisting largely of loose sanding sugar but with some tiny bits of candy, material smaller than 8-mesh averaged higher in CD11 and CD12 than at any previous examination, and higher than the previous average in CD13 excepting the initial. Initial, previous average, and material at 36 months, respectively were 2.45, 3.12 and 3.71% for CD11, .66, .54 and .74% for CD12, and 1.08, .86 and .91 for CD13. For the three items, the 36-months material amounted to approximately 21, 4, and 5 ounces per can in addition to the net product weights given above. The slight increases over previous averages probably resulted from extra handling of the candies in transferring to the new storage facilities. Otherwise there has been no apparent time effect; the initial samples also came from cans which had been handled somewhat rougher, in shipping.

There was no consistent association of amounts of loose material with storage conditions in any item, as can variations were quite large. Ranges and general averages were 1.09 - 7.55, average 3.24% for CD11; .24 - .96, average .58% for CD12; and .37 - 1.46, average .86% for CD13.

3. Appearance and Color. (Table 19)

Sensory scores for appearance and color of the carbohydrate supplements stored for 36 months were obtained from the five judges of the product quality panel in exactly the manner described for the cereal rations. The two types of candy were scored together, with comments on each type as the judges desired. Scores given in Table 19 are the means of the separate ratings, which averaged .09 lower for color than appearance of CD11 and 12 but .13 higher for color of CD13, which was scored .25 higher than initial at the two lower temperatures.

TABLE 19

COLOR AND TEXTURE SCORES, MOISTURE CONTENT AND pH VALUES FOR CARBOHYDRATE SUPPLEMENT STORED 36 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Appearance-Color Score, 10-1 scale:					Texture Score, 10-1 scale:				
100/80	6.45	7.4	7.05	6.97	.15	7.1	7.5	7.0	7.20	.29
100/57	7.1	7.4	6.3	6.93	.17	7.2	7.4	6.9	7.17	.12
70/80	7.25	7.4	7.65	7.43	.41	7.7	7.7	7.9	7.77	.20
70/57	7.7	7.55	7.7	7.65	.18	7.9	7.7	7.6	7.73	.17
40/57	7.6	7.15	8.15	7.63	.25	7.8	7.5	7.9	7.73	.29
0/amb	7.45	7.3	8.25	7.67	.19	7.1	7.9	8.0	7.67	.37
std.dif.,cans	.37	.13	.15	.24	–	.33	.19	.22	.25	–
std.dev.,judges	.98	.82	1.15	.99	–	1.13	.58	1.07	.96	–
sign.dif., 5%	.71	.29	.52	.27	.46[a]	.57	.32	.38	.22	.41[a]
Mean	7.26	7.37	7.52	7.38	.19[b]	7.47	7.62	7.55	7.54	NS[b]
	Moisture Content, percent:					pH Value:				
100/80	1.15	1.62	1.84	1.54	.06	6.31	6.36	6.65	6.44	.17
100/57	1.84	1.65	1.75	1.75	.05	6.05	6.63	6.56	6.41	.18
70/80	2.36	1.66	1.77	1.93	.09	6.23	6.83	6.68	6.58	.13
70/57	2.33	1.66	1.57	1.86	.04	6.34	6.56	6.90	6.60	.11
40/57	2.19	1.63	1.83	1.88	.06	6.44	6.73	6.73	6.63	.06
0/amb	1.00	1.59	1.76	1.45	.09	5.89	6.71	6.48	6.36	.17
std.dif.,cans	.07	.07	.06	.06	–	.16	.15	.12	.14	–
sign.dif., 5%	.12	NS	.10	.06	.09[a]	.31	.29	.23	.12	.21[a]
Mean	1.81	1.64	1.76	1.74	.04[b]	6.21	6.64	6.66	6.50	.09[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

Comparisons of the appearance-color scores with initials, which averaged 8.36, 8.24 and 8.20 for the three items, and with previous low scores were as follows:

temperature °F	reduction from initial scores CD11	CD12	CD13	increase from previous low scores CD11	CD12	CD13
100	1.58	.84	1.52	.67	.20	-.32
70	.88	.76	.52	.10	.25	.02
40 and 0	.83	1.01	.00	.00	-.20	.27

The scores shown for CD11 at 0°F, CD12 at 40° and0°, and CD13 at 100° and 70°/80% are the lowest received during the three years of storage (the 70°/57% score for CD13 was up enough to average +.02 at 70°). Previous lows for CD11 were at 18 months, those for CD12 at 6-18 months, those for CD13 at 12-24 months. Scores were reduced primarily for slight "sugaring" and darkening at 100°F, and for "dullness" of surface at lower temperatures. There has been very little fading of color in this product.

4. Hunter Color Values (Tables 20 and 21)

The color of individual pieces of carbohydrate supplement CD11 is quite variable, and CD13 and CD12 are also somewhat variable, in the order listed. Thus, color was determined on duplicate composite samples prepared by chopping and screening about a pint of candy per sample, using different sieve sizes for various determinations. The initial, 6 and 12 months samples were sized to 14-20 mesh for color readings, but it was necessary to use 8-14 mesh samples at 18 and 24 months because, after remodeling the air conditioning equipment of the work room, the 14-20 mesh samples were too "dusty". At 36 months the 8-14 mesh samples were in turn found too dusty when prepared in the work room of the new building, requiring a shift to 4-8 mesh samples cracked by hand to prevent dust.

Each shift in particle size of the samples resulted in a shift of scale position for the Hunter Color readings, making it necessary to evaluate the readings as color differences rather than as finite values. This was done by subtracting the lowest of the six storage means in each group from each mean in the group, thus setting the low mean at zero and converting the others to differences. These were then compared both as differences and by rank order, with the zero difference as rank 1, the largest difference as rank 6 (or rank 4 in instances where only the four temperatures were compared after averaging the 100° and 70°F readings).

Hunter L Values. A comparison of both differences and rank orders for the five storage periods failed to reveal any indication of a general time effect such as was observed in the progressive increases of L values for the cereal items at the higher temperatures. Averages and mean rank orders of temperature differences for the five periods were:

TABLE 20

HUNTER COLOR VALUES OF LEMON TYPE CARBOHYDRATE SUPPLEMENT STORED 36 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Hunter L:					Hunter "b":				
100/80	49.6	52.9	51.2	51.20	1.49	24.6	25.6	23.0	24.42	2.32
100/57	50.0	55.2	53.7	52.98	3.70	26.9	26.5	22.9	25.43	1.85
70/80	50.5	50.0	51.8	50.74	1.93	27.7	24.5	22.2	24.79	2.50
70/57	50.2	52.1	51.6	51.28	2.32	26.4	25.2	23.5	25.03	2.14
40/57	51.1	49.5	51.2	50.60	2.32	25.0	25.1	20.6	23.58	2.45
0/amb	47.5	50.4	51.1	49.66	1.40	24.1	24.7	21.7	23.50	1.11
std.dif.,cans	2.46	2.16	2.33	2.32	-	2.51	2.08	1.67	2.12	-
sign.dif., 5%	NS	3.74	NS	1.99	3.45[a]	NS	NS	NS	1.60	3.14[a]
Mean	49.81	51.66	51.76	51.08	1.41[b]	25.78	25.29	22.30	24.46	1.29[b]
	Hunter "a":					Hunter a/b:				
100/80	.3	5.2	-3.9	.56	2.32	.012	.204	-.168	.023	.087
100/57	-1.2	6.8	-4.4	.42	2.16	-.043	.257	-.193	.016	.072
70/80	.9	6.7	-5.6	.66	4.24	.031	.272	-.251	.027	.150
70/57	.2	7.7	-5.1	.93	2.58	.008	.304	-.215	.037	.083
40/57	-2.3	11.5	-5.6	1.21	.69	-.093	.459	-.270	.051	.032
0/amb	1.5	10.3	-5.7	2.03	1.79	.063	.417	-.264	.087	.074
std.dif.,cans	2.21	3.59	1.17	2.53	-	.084	.124	.046	.090	-
sign.dif., 5%	3.15	5.27	1.55	NS	3.76[a]	.145	.213	.079	NS	.134[a]
Mean	-.10	8.03	-5.03	.97	1.54[b]	-.004	.318	-.225	.040	.055[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

TABLE 21

HUNTER COLOR VALUES OF CHERRY TYPE CARBOHYDRATE SUPPLEMENT STORED 36 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Hunter L:					Hunter "b":				
100/80	27.8	44.2	32.3	34.77	2.56	4.7	10.9	5.0	6.83	.26
100/57	30.9	43.4	34.0	36.07	5.55	4.6	10.6	5.1	6.73	1.59
70/80	28.6	43.7	32.3	34.87	2.92	4.3	10.7	5.1	6.66	1.28
70/57	32.2	44.6	32.5	36.41	1.84	4.5	11.2	5.2	6.93	1.38
40/57	30.6	44.0	30.8	35.13	1.91	4.0	10.8	5.0	6.60	.77
0/amb	31.2	43.9	33.7	36.27	2.68	4.2	11.9	4.0	6.70	.77
std.dif.,cans	2.24	2.90	4.08	3.17	-	1.22	.94	1.14	1.10	-
sign.dif.,5%	3.42	NS	NS	NS	4.70[a]	NS	NS	NS	NS	1.64[a]
Mean	30.20	43.96	32.60	35.58	1.92[b]	4.35	10.99	4.89	6.74	.67[b]
	Hunter "a":					Hunter a/b:				
100/80	7.6	15.4	5.0	9.33	4.20	1.63	1.41	1.01	1.366	.583
100/57	6.0	13.8	9.0	9.61	8.97	1.32	1.31	1.77	1.427	1.285
70/80	6.4	14.9	7.1	9.47	3.25	1.51	1.40	1.40	1.422	.387
70/57	5.5	15.9	6.0	9.12	6.37	1.24	1.42	1.16	1.315	.962
40/57	5.0	15.3	6.0	8.78	3.41	1.26	1.42	1.19	1.330	.435
0/amb	2.2	17.2	4.9	8.09	1.64	.53	1.44	1.22	1.208	.377
std.dif.,cans	4.66	4.08	6.59	5.22	-	.783	.331	1.022	.753	-
sign.dif., 5%	NS	NS	NS	NS	7.75[a]	NS	NS	NS	NS	NS[a]
Mean	5.46	15.40	6.33	9.07	3.17[b]	1.25	1.401	1.296	1.344	NS[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

temperature °F	lemon type supplement CD11	CD12	CD13	Mean	cherry type supplement CD11	CD12	CD13	Mean
mean differences:								
100	1.22	1.66	.94	1.27	2.67	.50	1.65	1.61
70	1.49	.91	.36	.92	1.52	.26	1.17	.98
40	1.17	.45	.67	.76	1.60	.13	1.37	1.03
0	1.67	.73	.31	.90	1.50	.57	1.45	1.17
mean rank order (1-4):								
100	2.2	3.0	2.8	2.67	3.0	3.0	2.8	2.93
70	2.8	2.6	2.0	2.47	1.8	2.4	2.4	2.20
40	2.4	2.0	3.0	2.47	2.4	1.6	2.4	2.13
0	2.4	2.4	2.0	2.27	2.8	3.0	2.4	2.73

As seen, differences were larger and mean rank orders more widely separated in the cherry candy, but periodic temperature fluctuations were quite large; nothing was significant for L values of cherry except the smaller differences of CD12 as compared to CD11 and 13. For lemon candy, CD13 had significantly smaller differences, and CD12 was also smaller than CD11. The increase in mean L value at 100°F was significant when compared to that at 40°. The greatest difference was, of course, in CD12; this candy and the cherry type of CD11 exhibited a considerable amount of variable fading at 100°F, although not seen too clearly at 36 months.

Analysis of the lemon results also revealed a time effect in CD11, this being that the temperature differences became steadily greater during the second and third years, although this was not related to any one temperature. Comments by the score panels indicated a noticeable darkening of color in some samples, again variable as to storage location, and dull surfaces in others. These probably contributed to the increased variability in CD11, and may have accounted for some of the general drop in L values in conjunction with the drops encountered in changing sample particle sizes.

Hunter "a" Values. Changes in "a" values, which indicated the amount of green in CD11 and 13 lemon, faint pink in CD12 lemon, and red in all cherry candy, were even more variable than those of the L values. Increases of particle size of lemon candy to eliminate dusting of surfaces resulted in decreases in green in CD11 and slightly in CD13 and increases in pink of CD12; CD11 shifted finally to an almost exact green-pink balance at 36 months. In the cherry candy, red colors varied but exhibited little actual shift through 24 months; the switch to 4-8 mesh particle size at 36 months coincided with decreases in red with relatively little change in yellow component, which was low enough in CD11 and 13 to give the candy a somewhat purple appearance.

The five-period summary of differences from periodic low values, with mean rank orders of the differences ranked from 1 (lowest value, set at zero) to 4 (largest difference above low at each period) was as follows:

temperature	lemon type supplement				cherry type supplement			
°F	CD11	CD12	CD13	Mean	CD11	CD12	CD13	Mean
mean differences:								
100	2.20	.51	.92	1.21	2.21	.46	1.86	1.51
70	1.68	1.55	.60	1.28	2.03	1.74	1.59	1.79
40	.78	1.90	.39	1.02	2.09	1.68	.29	1.35
0	1.58	1.90	.23	1.24	2.31	1.48	2.09	1.96
mean rank order (1-4):								
100	3.0	2.0	2.9	2.63	2.6	1.4	3.2	2.40
70	2.6	2.4	3.0	2.67	2.8	2.8	2.4	2.67
40	1.8	2.8	2.5	2.37	2.4	2.8	1.5	2.23
0	2.6	2.8	1.6	2.33	2.2	3.0	2.9	2.70

It is obvious from these values that there were no general trends in "a" values for either type of candy, but some definite, and significant trends appear in individual items. In the lemon candy, the 40°F samples of CD11 were greener than those at other temperatures, with some tendency for less green in 100° storage than in any of the other conditions. CD12 was definitely less pink at 100°. Differences were smaller in CD13, but there was a suggestion of greener samples at the two lower temperatures.

In the cherry type, CD11 exhibited a time effect, with smaller readings at 100°F (probably fading) during the first year but at 0° during the latter part of the second and the third years. This shift apparently resulted from a combination of darkening at higher temperatures and purpling at 0° during the last half of the storage period, as both were noted by the score panels at 24 and 36 months. It is seen by reference to Table 21 that both CD11 and CD13 were more purple than red (pure purple, an "imaginary" color, gives zero readings for "a" and "b" or other measurements derived from wavelength). CD13 had lower readings for "a" at 40°F except at 36 months. CD12 was more red than purple, with a tendency toward slight fading and later slight purpling at 100°.

Hunter "b" Values. Values for yellow component of lemon candies did not vary much with the shift of particle size from 14-20 mesh to 8-14 mesh, but averaged 8.8 ± .8 points lower with the shift to 4-8 mesh cracked samples at 36 months. Some of the decrease may have resulted from the dulling and slight "darkening" noted by the score panels for the last period. Yellow component of cherry candies changed very little at any period except a 1.8 ± .6 increase for all three candies at 24 months and a 2.0 ± 1.0 increase for CD12 at 36 months. The slight increases at 24 months were probably sample preparation variations, as all three Hunter readings increased about the same amount; the 36-months increase in CD12 was apparently associated with the change in particle size of the samples.

The summary of differences and rank order for storage conditions, similar to those given above for Hunter L and "a" values, is as follows:

temperature °F	lemon type supplement CD11	CD12	CD13	Mean	cherry type supplement CD11	CD12	CD13	Mean
mean differences:								
100	1.59	1.00	.83	1.14	.53	.05	.42	.33
70	2.56	.35	1.19	1.37	.70	.46	.89	.68
40	.83	.31	.16	.43	.16	.72	.74	.54
0	1.49	.67	.88	1.01	.30	.76	.40	.49
mean rank order (1-4):								
100	2.4	3.5	2.6	2.83	2.6	1.4	2.3	2.10
70	3.2	2.2	3.2	2.87	3.6	2.8	3.4	3.27
40	2.0	2.1	1.6	1.90	1.6	2.8	2.4	2.27
0	2.4	2.2	2.6	2.40	2.2	3.0	1.9	2.37

For lemon candy, yellow readings tended to be lower for all items at 40°F; for cherry, 40° samples were lower for CD11, 100° samples for CD12, while CD13 was variable. Differences were generally smaller for the cherry type, which had generally low "b" or yellow-component values. Rank order means indicate that the larger readings at 70°F for both types of CD11 and 13, and at 100° for CD12 lemon, were fairly consistent trends which would apparently suggest little tendency for darkening, while the reduced values for CD12 cherry at 100° corresponded to the observed trend toward purpling. There was little indication of a time effect except some increase in size of differences at 24 and 36 months.

Hunter a/b ratios. Higher a/b ratios corresponded to shifts toward yellow in CD11 and 13 lemon (i.e., less green or more yellow or both) but toward pink in CD12 lemon (more red or less yellow or both). In the cherry candy the higher ratios resulted from more red or less yellow, or both, which could mean lack of fading, lack of purpling, or darkening.

In general, the higher temperature samples of CD11 and 13 lemon tended to fade or dull slightly, but since the fading was of green, thereby moving toward gray, the score panels usually commented "dull" or "darker" for samples which increased much in ratio (increase meant decrease in negative ratio). The 40°F samples of CD11 lemon and 40° and 0° samples of CD13 lemon changed less than those at other conditions. There was also some tendency for fading of pink (lower positive ratio) in the 100°F samples of CD12 lemon, with relatively little difference in comparative hue at lower temperatures.

Shifts of ratios in the cherry candy were mathematically larger than those in the lemon type, but exhibited no consistent trend for temperature differences except in the lower (slightly more purple) CD13 samples from 40°F storage. There were no apparent time effects in either type except those discussed in connection with "a" or "b" trends in the preceding sections.

5. Moisture Content (Table 19)

The 65-can averages for moisture were:

	CD11 %	CD12 %	CD13 %
lemon	1.66	1.48	1.76
cherry	1.64	1.47	1.60
mean	1.65	1.48	1.68

Maximum differences between the two types were .26% for CD11, .09% for CD12, and .60% for CD13, with cans about evenly divided between the two types in CD11 and 12, but higher for lemon in 70% of the cans examined in CD13 through 24 months. As noted above, clumping was highly correlated with moisture between the two types in CD13, not in the other two items.

There was no trend for differences among storage conditions except a slight reduction in 100°F samples of CD12, which averaged 1.41% compared to 1.53% for lower temperatures (100° samples were lower in 83% of comparisons with other conditions). A time difference was noted as follows:

	CD11 %	CD12 %	CD13 %
Initial, 18, 24 months	1.39 ± .24	1.34 ± .07	1.51 ± .13
6, 12, 36 months	1.86 ± .06	1.59 ± .06	1.82 ± .05

This seems almost certainly due to some difference in technique, which was listed as the procedure used for cereal items with the exception of using 20-mesh pass samples. The early preparation room was used for initial, 6 and 12 months, the second room for 18 and 24 months, the new room at 36 months, which does not coincide with the moisture shifts. Since there were no known variations in weighing and drying techniques, the shifts may have resulted from local variations in humidity of the work rooms, however, as uniform control at 50 ± 2% r.h. can be guaranteed only at the position occupied by the controller-recorder mechanism.

6. pH Values (Table 19)

pH values were determined with the customary glass-electrode pH electrometer, using 1 + 1 solutions of candy prepared with demineralized water. Initials for CD11, 12, 13 were 6.55, 6.70, 6.75, respectively, with an average $\pm$ variation of .10 between lemon and cherry types of candy. With considerable can and sample variation, mean values were above initial at 6 and 12 months, near initial at 18 months, with slight decreases at 24 and 36 months for CD12 and 13 but a further drop for CD11. Means by periods for the three items were 6.84, 6.97 and 7.01 at 6 and 12 months, 6.59, 6.68 and 6.81 at 18 months, and 6.23, 6.60, and 6.66 at 24 and 36 months.

With the exception that CD12 averaged .15 $\pm$ .11 lower at 100°F than at lower temperatures (95% of the cans were lower), there were no consistent temperature effects, so the reason for the period variations was not suggested. There seems little doubt, however, that the samples of CD11 were at least .25 below "normal" at two and three years, as they were only .15 below CD12 and 13 at initial through 18 months and .40 below at 24 and 36 months.

Despite variations ranging as high as .45 between lemon and cherry candy in certain cans, the general averages for the two types were within .02 $\pm$ .02 for CD11 and 13. The cherry candy of CD12, however, averaged .11 lower than the lemon, the cherry being higher than lemon, by .07 $\pm$ .04, in only 11 of the 65 cans examined.

7. Sugar Contents (Table 22)

Sugars were determined by the official Lane-Eynon general volumetric procedure, with acid inversion at 73°F (Association of Official Agricultural Chemists, Washington, D. C.). Reducing sugar titrations were corrected for sucrose effect as directed by Fitelson (J. Assoc. Off. Agr. Chem., 1932, p. 624). All results were calculated on a dry weight basis.

Reducing Sugars as Dextrose. Initial values for the three carbohydrate supplements and average values for the 60 cans examined from storage were:

	CD11 %	CD12 %	CD13 %
Initial:			
lemon	19.23	16.27	17.34
cherry	19.56	16.27	17.49
average	19.39	16.27	17.41
Storage:			
lemon	18.01	16.07	17.53
cherry	17.95	16.09	18.20
average	17.98	16.09	17.86

TABLE 22

SUGAR CONTENTS OF CARBOHYDRATE SUPPLEMENT STORED 36 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Dextrose, percent:					Sucrose, percent:				
100/80	18.3	15.8	18.5	17.50	.08	62.4	64.0	60.3	62.24	1.04
100/57	16.5	15.8	17.5	16.61	.16	64.1	64.3	62.2	63.56	.39
70/80	17.3	15.9	18.2	17.14	.27	63.8	64.3	61.1	63.05	.47
70/57	17.0	15.7	18.3	17.00	.44	63.4	64.7	59.7	62.59	.48
40/57	17.1	16.0	18.2	17.10	.53	63.0	63.9	60.5	62.46	1.19
0/amb	20.3	15.9	17.5	17.89	.13	60.4	64.6	61.8	62.27	.25
std.dif.,cans	.33	.18	.39	.31	-	.50	.43	1.07	.73	-
sign.dif., 5%	.58	NS	.69	.27	.47[a]	.87	.70	1.85	.63	1.21[a]
Mean	17.75	15.84	18.03	17.21	.19[b]	62.86	64.29	60.93	62.69	.44[b]
	Total Sugar, percent:					Dextrose/Sucrose ratio:				
100/80	80.7	79.8	78.8	79.74	.99	.292	.247	.306	.281	.007
100/57	80.6	80.1	79.7	80.17	.32	.258	.245	.282	.261	.005
70/80	81.1	80.2	79.3	80.19	.22	.271	.248	.298	.272	.007
70/57	80.4	80.4	78.0	79.59	.35	.268	.242	.307	.272	.009
40/57	80.1	79.9	78.7	79.56	.70	.272	.250	.300	.274	.014
0/amb	80.7	80.5	79.3	80.16	.29	.336	.246	.283	.287	.003
std.dif.,cans	.37	.36	.81	.55	-	.007	.004	.012	.008	-
sign.dif., 5%	.62	.60	1.38	.48	.82[a]	.012	.007	.019	.007	.013[a]
Mean	80.61	80.13	78.96	79.90	.34[b]	.282	.246	.296	.274	.005[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

Storage samples of CD11 ranged from 16.5% to 20.3% dextrose, but the 60-can average was 1.4% below that of the cans examined initially. Ranges were 15.7 - 16.6% for CD12 and 16.8 - 19.0% for CD13, so differences between initial and storage averages are well within limits of item and can variances.

There were periodic fluctuations, but no significant trend for change of dextrose content with storage time. As compared with the 17.31% average for all examinations from storage for the three items, period averages for 6, 12, 18, 24 and 36 months were 17.29%, 17.05%, 17.36%, 17.62%, and 17.21%, respectively. Temperature differences were also apparently without pattern. The six condition means of CD12 ranged 16.02 - 16.18%, averaging 16.05% at 100°F, 16.09% at 40° and 0°, and 16.12% at 70°. Items CD11 and CD13 had greater spread, averaging 18.30 ± .14% and 17.63 ± .11% at the two 100°F conditions, 17.69 ± .11% and 18.15 ± .09% at the 70° conditions, 17.99 ± .03% at 40°, and 17.77 ± .13% at 0°.

There was one type difference which was relatively consistent, between lemon and cherry candy of CD13. Of the 64 cans examined, including initials, 15 cans averaged .36% higher dextrose in the lemon type, 49 cans averaged .94% higher in the cherry. The mean differences for all storage samples were .31% at 100°F, .81% at 70°, 1.05% at 40°, and .65% at 0°; no reason was suggested for the lower difference at 100°.

Sucrose. Mean values for various periods were:

	CD11 %	CD12 %	CD13 %
initial	62.81	65.13	62.96
6-18 months	63.46	65.10	62.71
24 months	61.33	65.86	62.69
36 months	62.86	64.30	60.93
6-36 months	62.91	65.09	62.35

Total ranges were 56.7 - 64.8% for CD11, 63.9 - 66.9% for CD12, 59.6 - 64.6% for CD13. As with dextrose, CD12 was relatively uniform in temperature means, 64.92 ± .18 at 100°F conditions, 65.26 ± .06% for the two 70° rooms, 65.08 ± .06% for the lower temperatures. CD11 and CD13 averaged 62.57 ± .09 at 100°F/80% r.h., 63.80 and 62.98% at 100°/57%, 63.64 and 62.28% at 70°/80%, 62.05 ± .19% at 70°/57%, 62.12 ± .08% at 40°/57%, and 63.14 and 62.28% at 0°. Thus, sucrose differences were more variable than those for dextrose, but lower sucrose values were usually matched with higher dextrose in CD11 and 13.

Types averaged 62.91% for both lemon and cherry in CD11, 61.07 and 61.11% in CD12, but cherry type was lower in about 85% of the cans of CD13, general averages being 62.96% sucrose for lemon and 61.74% for cherry. Temperature differences were also found for types in CD13, roughly in inverse proportion to those noted for dextrose.

Total Sugars. As samples with higher dextrose usually had lower sucrose and vice versa in CD11 and CD13 (CD12 had an indistinct pattern, but smaller ranges), the variations in total sugars were somewhat less than those in sucrose. Initial and storage values were:

	Initial %	periodic mean range %	total sample range %	general mean %
CD11	82.20	79.9 - 82.0	76.9 - 83.3	80.89
CD12	81.40	80.1 - 82.2	79.8 - 83.5	81.17
CD13	80.37	79.0 - 81.0	78.0 - 82.8	80.21

Temperature differences were also somewhat less than for sucrose in CD11 and CD13, slightly greater in CD12, as seen from the general storage means:

	100°/80% %	100°/57% %	70°/80% %	70°/57% %	40°/57% %	0°/ambient %
CD11	80.92	81.54	81.22	80.48	80.16	81.04
CD12	80.76	81.18	81.50	81.26	81.12	81.22
CD13	80.82	80.50	80.08	79.92	80.06	79.92

Thus, there still seems to be no apparent pattern for changes of sugars in storage of the supplements, nor is there any consistent net change when considered in comparison with ranges of variation.

Dextrose/Sucrose. This ratio was included in the sugar data for the purpose of indexing changes in the two types of sugars, if changes occurred. The ratios have followed the variations discussed above, ranging .258 - .356, mean .286 for CD11; .242 - .251, mean .247 for CD12; .266 - .309, mean .287 for CD13. Further comment on the relationship of the ratios to dextrose and sucrose values is given below.

General Discussion. With the obvious physical changes in color as well as in surface crystal state which have been observed in many samples of the candies particularly at 100°F, some involvement of chemical changes in the sugars might reasonably be expected. The results indicate that, if any inversion has occurred, the amounts of sucrose which have been hydrolyzed have been small and within the limits of item variance.

Several checks were made for invert sugar by gas chromatography, with no indication of activity in the invert area. In candy of the supplement type, however, with very low moisture, a low-rate inversion might yield anhydrides instead of invert sugar, and the levulinic fractions undergo further reactions toward eventual polymerization. Some of the color, or appearance, and flavor changes were not incompatible with the effects of such reactions. Also, slight but varying amounts of hydrolysis probably took place during the cooking of the candy.

On the other hand, all of the variations could have originated in formulation, or some as a result of possible errors in analytical procedure, since four different technicians worked on the analyses. In the latter case, however, it would not seem likely that most of the technical variance would occur in CD11 and the least in CD12, as all of the candies within any period were analyzed by the same technician or technicians using a single lot of reagents.

In an attempt to gain further insight into relationships among the sugars with reference to item characteristics or possible storage effects, data for the 30 storage samples were compared by simple rank order correlations among the sugar values, pH, and moisture contents. The following relationships, or lack of apparent relationships were calculated:

Correlation (rank order)	CD11		CD12		CD13	
	samples	r	samples	r	samples	r
Dextrose with:						
sucrose	22	-.927	NS	-	20	-.827
total sugar	NS	-	22	+.890	NS	-
dextrose/sucrose	30	+.984	20	+.924	30	+.932
moisture	21	-.936	NS	-	NS	-
Sucrose with:						
total sugar	20	+.900	30	+.971	28	+.936
dextrose/sucrose	23	-.948	NS	-	24	-.915
pH	20	+.895	NS	-	NS	-
Dex./Suc. with moisture	21	-.921	NS	-	NS	-

Correlations which were non-significant for all items (i.e., which yielded r values less than .500 using all 28 degrees of freedom) were dextrose with pH, sucrose with moisture content, total sugars with dex./suc., pH, and moisture, and dex./suc. with pH. Samples omitted from the correlations (2 to 10 out of 30, as shown) were those which, although yielding significant results when included in the total 30, did not yield correlations as large as .500 when calculated alone. This was done in order to demonstrate the relatively high degree of association (68% to 90% of the variance) among the remaining numbers of samples out of each group of 30 storage examinations.

The negative correlations of dextrose with sucrose in CD11 and CD13 (but not in the less variable CD12) and with moisture in CD11, and the positive correlation of sucrose and pH in CD11, are relationships which might be expected with hydrolysis or hydrolytic polymerization reactions in low-moisture candies. The correlations of dextrose and sucrose with dextrose/sucrose ratios are obvious, as high ratios result from high dextrose and/or low sucrose, and vice versa. The relation of the ratios to moisture was apparently corollary to the influence of dextrose (negative with moisture) on the ratios.

Correlations of sucrose with total sugar were expected, as the samples contain 3.5 to 4 times as much sucrose as dextrose. These would probably be present with or without hydrolysis, but certainly do not rule it out. On the other hand, the fact that both dextrose and sucrose were positively related to total sugars in CD12 suggests little or no hydrolytic influence in this item.

Thus, while no experimental evidence of hydrolytic reactions of sugars was obtained, the relationships existing among the various analytical results were in accord with the possibility of such reactions either in manufacture or at low levels within the ranges of sample variance in items CD11 and CD13. On the other hand, relationships existing in CD12 suggest normal sample variance only, with considerable less range in carbohydrate composition. It should be noted that neither storage periods nor storage temperatures exhibited any pattern in connection with the correlations in any of the items.

8. Sensory Scores for Texture, Aroma and Flavor (Tables 23 and 24)

Scores were assigned by the 5-member sensory quality panel, scoring identified samples as described above. Initial scores for the carbohydrate supplements were:

	CD11	CD12	CD13
texture	8.24	8.56	8.20
aroma	7.36	7.60	7.80
flavor	7.92	7.32	7.85

Comparisons of the scores shown in Tables 23 and 24 with the initials and with previous low scores were as follows:

temperature	reduction from initial scores[a]			increase from previous low scores[b]		
°F	CD11	CD12	CD13	CD11	CD12	CD13
Texture:						
100	1.09	1.11	1.25	.25	.35	-.55
70	.44	.86	.45	.50	.30	.15
40	.44	1.06	.30	.10	.20	.70
0	1.14	.66	.20	-.30	.60	.60
Aroma:						
100	1.16	1.05	1.85	-.15	-.20	-.75
70	.66	.40	.95	-.25	.40	-.15
40	.26	.70	.50	-.20	-.40	-.10
0	-.54	-.10	-.40	.70	.60	.90
Flavor:						
100	2.17	.67	1.45	-.85	.05	-.60
70	.82	.12	.45	.00	.15	-.15
40	1.12	.52	.05	-.60	-.60	.50
0	1.42	-.08	-.25	-1.00	.10	.50

[a]Negative reductions indicate 36-months scores higher than initial.
[b]Negative increases indicate lowest scores of the 3-year storage period.

TABLE 23

AROMA AND FLAVOR SCORES OF CARBOHYDRATE SUPPLEMENT STORED 36 MONTHS
(scale from 10 = excellent to 1 = poor)

Condition °F/% r.h.	Aroma					Flavor				
	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
100/80	5.9	6.2	5.9	6.00	.29	5.7	6.6	6.4	6.23	.26
100/57	6.5	6.9	6.0	6.47	.44	5.8	6.7	6.4	6.30	.48
70/80	6.6	6.9	6.9	6.80	.17	6.9	7.2	7.3	7.13	.29
70/57	6.8	7.5	6.8	7.03	.26	7.3	7.2	7.5	7.33	.37
40/57	7.1	6.9	7.3	7.10	.39	6.8	6.8	7.8	7.13	.40
0/amb	7.9	7.7	8.2	7.93	.44	6.5	7.4	8.1	7.33	.37
std.dif.,cans	.24	.47	.28	.34	-	.52	.30	.22	.37	-
std.dev.,judges	1.38	.96	1.72	1.39	-	1.15	.77	1.02	.99	-
sign.dif.,5%	.41	.82	.47	.30	.51[a]	.90	.52	.38	.32	.55[a]
Mean	6.80	7.02	6.85	6.89	.21[b]	6.50	6.98	7.25	6.91	.23[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

TABLE 24

HEDONIC RATINGS FOR CARBOHYDRATE SUPPLEMENT STORED 36 MONTHS

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans	CD11	CD12	CD13	Mean	Std.dif. cans
	Aroma:					Flavor:				
100/80	5.78	6.24	6.32	6.11	.11	6.26	6.36	6.62	6.41	.29
100/57	6.14	6.12	6.36	6.21	.25	6.62	6.48	6.72	6.61	.34
70/80	6.24	6.44	6.54	6.41	.16	6.84	6.52	6.86	6.74	.26
70/57	6.22	6.46	6.70	6.46	.31	6.72	6.58	6.96	6.75	.21
40/57	6.46	6.66	6.86	6.66	.17	6.64	6.82	6.90	6.79	.19
0/amb	6.64	6.96	6.62	6.74	.42	6.70	6.92	7.00	6.87	.49
std.dif.,cans	.37	.17	.18	.26	-	.16	.46	.26	.32	-
std.dev.,judges	1.51	1.41	1.50	1.47	-	1.46	1.41	1.39	1.42	-
sign.dif., 5%	.64	.30	.31	.22	.38[a]	.28	NS	NS	.27	.47[a]
Mean	6.25	6.48	6.57	6.43	.16[b]	6.63	6.61	6.84	6.70	.19[b]

Condition °F/% r.h.	CD11	CD12	CD13	Mean	Std.dif. cans
	Palatability:				
100/80	6.34	6.38	6.68	6.47	.33
100/57	6.50	6.54	6.84	6.63	.36
70/80	6.76	6.58	7.04	6.79	.24
70/57	6.70	6.54	7.10	6.78	.12
40/57	6.84	6.80	7.04	6.89	.23
0/amb	6.82	6.72	7.10	6.88	.50
std.dif.,cans	.19	.46	.24	.32	-
std.dev.,judges	1.49	1.42	1.46	1.46	-
sign.dif., 5%	.32	NS	.41	.27	.47[a]
Mean	6.66	6.59	6.97	6.74	.20[b]

[a]Significant difference for items in rooms.
[b]Significant difference for item means.

It is seen that only two samples, CD11 at 0°F and CD13 at 100°, were scored lower on texture than at some previous examination. Texture scores varied with individual samples, being based mostly on "brittle hardness" vs "tough hardness". Most of the 100°F samples were somewhat tougher, or perhaps a bit harder in some instances, but the 0° sample of CD11 and 40° sample of CD12 were scored about as low as the 100° candy.

All 0°F samples were scored higher than initial ratings on aroma. This probably resulted from comparisons with samples from the higher temperatures, all of which except CD12 at 70°F were scored lower than on any previous examination. Off odors, "terpene", were given as the cause of low scores at 100°, and general "flatness" or lack of typical aroma were noted at 70° and 40°, with some traces of off odors in the 70° samples.

Flavor scores, which averaged lower than aroma for CD11 and higher for CD13, were marked down for about the same reasons as those given for low aroma scores. CD12 and CD13 from 0°F were also higher than initial, but CD11 from this temperature was described as "very flat, slightly off". As seen, several of the samples above 0° were scored lower than previously, though none were seriously affected with anything except lack of flavor.

9. Hedonic Ratings for Aroma, Flavor and Palatability (Table 24)

The hedonic ratings were obtained in exactly the manner described above for cereal item ratings, several pieces of each type of candy, lemon and cherry, being presented as each coded sample. Initial ratings for the three items were:

	CD11	CD12	CD13
aroma	6.88	6.76	7.04
flavor	7.76	7.24	7.76
palatability	7.48	7.40	7.76

The ratings given in Table 24 were reduced from initial, and differed from previous low ratings, as follows:

temperature	CD11		CD12		CD13	
	36 months from		36 months from		36 months from	
	initial	previous low	initial	previous low	initial	previous low
°F	decrease	change	decrease	change	decrease	change
Aroma:						
100	.92	.19	.56	-.29	.70	-.25
70	.65	-.08	.31	-.25	.42	-.04
40	.42	.00	.10	-.14	.18	.08
0	.24	.40	-.20	.34	.42	-.20

temperature °F	CD11 36 months from initial decrease	CD11 36 months from previous low change	CD12 36 months from initial decrease	CD12 36 months from previous low change	CD13 36 months from initial decrease	CD13 36 months from previous low change
Flavor:						
100	1.32	.29	.82	-.18	1.09	-.10
70	.98	.07	.69	-.31	.85	.13
40	1.12	-.10	.42	-.18	.86	.06
0	1.06	.02	.32	.20	.76	.22
Palatability:						
100	1.06	.21	.94	-.15	1.00	.02
70	.75	.08	.84	-.31	.69	.32
40	.64	-.02	.60	-.12	.72	.26
0	.66	.26	.68	-.06	.66	.36

The aroma ratings, though reduced less from initial ratings than were those for flavor and palatability, nevertheless averaged about .30 less, as they were lower at the start; i.e., the initial difference of .67 ± .13 in aroma ratings was reduced to .28 ± .13 at 36 months. With ratings ranging 5.78 - 6.96 for aroma, 6.26 - 7.00 for flavor, and 6.34 - 7.10 for palatability, and 100°F mean ratings 6.16, 6.51 and 6.55, respectively, none of the candies were even close to the 4.00 rating usually considered as borderline for acceptability.

In general, CD11 averaged above previous lows at 100° and 0°F, while CD12 was somewhat lower than previously at all conditions except 0°; the net result was that the two items had almost the same total rating. CD13, gaining very slightly over previous lows except at 100°, averaged about .25 higher than the others, whereas it was about .15 and .40 higher for general averages on initial examination. Thus, the general relationship among the three items has not varied by more than about .25, with maximum differences ranging around .50, as a result of three years of storage. Flavor decreases were fairly serious at 100°F, but it is possible that the ultimate termination of storage life at this elevated temperature may result from changes in appearance and color.

10. Correlations of Palatability Ratings and Other Measurements (Table 25)

The correlations shown in Table 25 are fairly typical of the pattern, or lack of pattern, at every storage period. There has been no objective measurement with which palatability has been consistently correlated; aroma and flavor, on which the ratings are primarily based, are the only characteristics which have exhibited a graduated temperature effect. Color changes have usually taken place only at 100°F; other characteristics have

TABLE 25

CORRELATIONS OF PALATABILITY RATINGS AND OTHER MEASUREMENTS
FOR CARBOHYDRATE SUPPLEMENT STORED 36 MONTHS
(simple correlation coefficient, r)

	Lemon Type				Cherry Type				Combined Product			
	CD11	CD12	CD13	All	CD11	CD12	CD13	All	CD11	CD12	CD13	All
Palatability with:												
Hunter L	-.186	-.017	-.078	+.044	+.359	-.027	+.120	-.248				
a	+.097	-.039	-.540	-.505[b]	-.496	+.020	+.202	-.377[a]				
b	-.114	-.501	-.351	-.575[b]	-.369	-.021	-.269	-.370[a]				
a/b	+.077	+.024	-.606[a]	-.516[b]	-.493	+.042	-.116	-.221				
Moisture	+.351	+.526	+.197	+.205	+.295	+.217	-.607[a]	+.144	+.323	+.363	+.181	+.174
pH	-.116	+.085	+.097	+.168	-.217	-.005	-.161	+.132	-.168	+.039	-.014	+.151
Dextrose	+.228	+.082	-.428	+.214	+.113	+.465	+.103	+.477[b]	+.170	+.293	-.064	+.355[b]
Sucrose	-.238	+.179	-.047	-.361[a]	-.237	-.085	-.019	-.547[b]	-.237	+.056	-.018	-.450[b]
Total Sugar	-.020	+.237	-.314	-.260	-.417	+.231	+.046	-.492[b]	-.216	+.211	-.082	-.385[b]
Dextrose/ Sucrose	+.234	+.006	-.315	+.285	+.150	+.371	+.079	+.511[b]	+.192	+.201	-.028	+.393[b]
Sensory Color									+.683[a]	-.163	+.538	+.423[a]
" Texture									+.425	+.254	+.587[a]	+.314
" Aroma									+.785[b]	+.592[a]	+.630[a]	+.473[b]
" Flavor									+.510	+.335	+.690[a]	+.533[b]
Moisture with:												
pH	+.687[a]	-.168	-.321	+.090	+.344	-.571	-.134	+.042	+.503[a]	-.137	-.252	+.058
Dextrose	-.775[b]	+.163	-.288	-.353[a]	-.803[b]	-.253	-.990[b]	-.262	-.788[b]	-.032	-.298	-.295[b]
Sucrose	+.792[b]	-.135	-.112	+.365[a]	+.746[b]	+.097	+.187	+.097	+.769[b]	-.164	-.089	+.170
Total Sugar	+.003	-.088	-.296	+.029	-.162	-.056	+.203	-.059	-.079	-.211	-.130	-.028
Dextrose/ Sucrose	-.784[b]	+.198	-.185	-.427[b]	-.796[b]	-.210	-.159	-.176	-.789[b]	+.060	+.041	-.247[a]

(continued)

Table 25 (continued)

	Lemon Type				Cherry Type				Combined Product			
	CD11	CD12	CD13	All	CD11	CD12	CD13	All	CD11	CD12	CD13	All
pH with:												
Dextrose	-.695[a]	+.287	-.052	-.563[b]	-.326	+.119	+.613[a]	-.033	-.502[a]	+.190	+.140	-.281[a]
Sucrose	+.712[b]	+.313	-.525	+.256	+.208	-.142	-.741[b]	-.263	+.441[a]	+.020	-.648[b]	-.061
Total Sugar	+.010	+.475	-.586[a]	-.517[b]	-.384	-.108	-.683[a]	-.554[b]	-.210	+.117	-.427[a]	-.491[b]
Dextrose/ Sucrose	-.709[b]	+.006	+.166	-.575[b]	-.317	+.145	-.689[a]	+.071	-.503[a]	+.113	+.223	-.180

[a]Significant at the 5% level of probability.
[b]Significant at the 1% level of probability.

demonstrated practically no temperature dependence. Even the correlation between the sensory quality and hedonic rating taste panels, which has become progressively higher with the cereal items, has varied with the carbohydrate supplement. The probable reason is that the smaller panel has given more attention to sample variations in an attempt to evaluate quality than has the hedonic panel in merely eating candy. In this comparison the hedonistic approach has apparently been the better one, at least during the first three years. The more or less gradual loss of aroma and flavor, and development of slight to moderate off flavor at 100°F, have been about the only easily evaluated changes in the product, and the hedonic judges have exhibited very little concern with the more variable and less predictable differences in color and texture.

The more definite correlations among sugars, pH and moisture with item CD11 are seen in Table 25, although the inclusion of CD13 in the pattern at 36 months was not as frequent as it was when all storage periods were evaluated. There appears to be a higher degree of association in the cherry type of CD13, whereas the lemon type has more significant comparisons in CD11. As with the total period, CD12 did not follow the pattern of the other two items at 36 months.

It is possible that more consistent relationships between palatability and other measurements may develop with further storage of the supplements, but there is apparently no "central" pattern to link the various measurement areas, objective and subjective, such as that provided by the oxidative nature of most of the significant changes in the cereal rations.

Conclusions

As storage of rations from original procurements for the project is being continued under subcontract with another agency (see Foreword), only tentative conclusions are possible at the current four-year period of the study. Certain changes in the stability of ration components at higher temperature or humidity conditions, however, were relatively well defined.

The V3c fiberboard of the cases is apparently unstable at 100°F. Average decreases in bursting strength at 100°/80% ranged from 10% in 6 months to 33% in 4 years: decreases at 100°/57% averaged 3-5% less. There was also an 11% decrease at 70°/80% but no change at 70°/57%, and a 9% increase at 40°/57% but only 6% increase at 0°/(high) ambient, so apparently both temperature and humidity affected the bursting strength of the fiberboard. Otherwise, cases remained in satisfactory condition.

As a whole, can coatings provided inadequate protection for prolonged storage at 100°/80% and 70°/80% conditions. Unsightly and potentially dangerous amounts of rust developed in areas where coatings had been burned or rubbed off in soldering or seaming or scraped off in handling. Leaking cans, ranging 10-80% among 7 of the 13 items, were attributed almost entirely to faulty seaming, possibly associated with light-weight metal and "odd" sizes and shapes.

Packaging materials were too light and brittle in most cracker and biscuit items (and completely absent in carbohydrate supplements). Considerable smounts of internal surface corrosion where products touched can walls, and of package and product breakage among crackers and biscuits, were apparently caused by loose packing, inadequate or no stuffing material, and the inability of frail wrappers to withstand sharp corners of products with handling of the cans.

Oxidative reactions at 100°F and to some extent at 70° were major factors in limiting the stability of cereal rations. Hydrolysis of less stable fats at 100° also contributed to adverse changes in flavor of 2 cracker items, 2 biscuits, and the 2 wafers. Darkening and dulling of color, variable changes in crystal structure, and development of off flavors at 100° were the only significant changes in carbohydrate supplement. Maximum storage life of 4 to 5 years at 100° can be variously estimated, wafers apparently tending to remain acceptable somewhat longer than the other three types of rations, but three years at 100° would probably be nearer an optimal replacement schedule. Maximal and optimal periods at 70°F may prove to be about double those at 100°. Results to date offer little indication of stability limits for rations stored at 40° and 0°F.

SUMMARY

Fallout shelter rations from ten procurement lots were stored 4 years, and three lots of carbohydrate supplement were stored 3 years, at six controlled temperature and relative humidity conditions. The ten cereal rations, consisted of four lots of survival crackers, four of survival biscuits, and two of bulgur wheat wafers. Carbohydrate supplements were standard hard candy mixture of lemon and cherry flavors. Storage conditions were 100°F/80% r.h., 100°/57%, 70°/80%, 70°/57%, 40°/57%, and 0°/ambient r.h.

Results of examinations of cereal items at 48 months and carbohydrate supplements at 36 months are given in detail. These include general condition and various stability characteristics of V3c fiberboard cases, 2-1/2-gallon and 5-gallon metal cans, ration packaging materials and candy bags, and of the individual cereal and supplement rations. Brief comparisons with results of previous examinations at 6, 12, 18, 24 and 36 months are also included.

I. Fiberboard Cases.

1. Bursting strength of fiberboard stored at 100°F was reduced by averages of 90 psig at three years and 145 psig at 4 years. All cases were below 400 psig at 4 years, 20% being under 300. There were slight and varying reductions at 70°F, slight increases at lower temperatures.

2. Moisture content of fiberboard at 80% r.h. conditions averaged 11.8%, that at 57% r.h. was 8.4 ± 0.7%, with 14.4% from 0°F/ambient r.h.

3. General condition of cases was satisfactory for continued storage. There was no can collapse, and although some moderate staining was observed at 80% r.h., there was essentially little mold.

4. Case markings remained easily legible, with no significant fading or blurring.

II. Metal Cans.

1. Residual oxygen in non-leaking cereal ration cans averaged 5.8% at 100°F, 10.0% at 70°, 12.9% at 40°, and 16.7% at 0°, with ranges of about 4% around averages at the two higher temperatures.

2. All cans of one item (2-1/2-gallon) were leakers at 48 months, and leakers over 3 and 4 years ranged 28% to 11% of the cans in six items. Leakers in the other six items averaged 2.5% of all cans examined.

3. Corrosion in the form of rust was fairly extensive (5%-10% of external surface) on cans from 80% r.h. conditions, moderate from lower

humidities and temperatures. Internal surface darkening was relatively slight, and no can leaks have been caused by any type of corrosion.

4. There was no softening or flaking of external coatings of cans, although moderate amounts of loosening around corroded areas were observed on cans from higher humidities.

III. The Rations.

A. Cereal Items

1. Seal breaks were few (.6%) in waxed paper and cellophane packages, and ranged .0 - 11.8, with a mean 4.2% in waxed glassine. Torn packaging material averaged slightly higher than seal breaks in waxed paper and cellophane, and slightly less than seal breaks in the glassine packages.

2. Broken score lines ranged 3.3 - 48.5, with a mean 16.2% in crackers and 0.5 - 23.0, mean 6.5% in biscuits. Wafers averaged 26.3% and 47.3% crumbled edges. Moderate unit breakage ranged 6.4 - 29.3, mean 13.7% for crackers, 0.3 - 22.7, mean 6.7% for biscuits, 0.0 - 0.2, mean 0.09% for wafers. Severe breakage or crushing of units was negligible in all rations except two cracker items which ranged 0.2 - 10.1, mean 2.6% as a result of can damage.

3. Appearance and color by sensory evaluation were not seriously affected by storage, although there were slight amounts of surface glazing in all items and of fading of color in 100°F storage. There was little evidence of darkening or browning in any ration item.

4. Hunter Color values, typically increased in L and decreased in "a" at higher temperatures, were highly correlated with observed changes in appearance and color.

5. Fracture strength by items ranged 1109 - 1529 grams for cracker units; 1072 - 2286 grams for biscuits; and 1462 - 2306 grams for wafers. Values were relatively well related to baking, whether tender, brittle or tough, but not to product breakage except in the toughest biscuit.

6. Moisture content varied to some extent with baking in crackers and biscuits, which ranged 1.6 - 3.0, mean 2.3%. Wafers were higher in moisture, ranging 3.1 - 3.7, mean 3.4%.

7. Peroxide values, ranging 6.0 - 1.3, mean 3.5 m.eq. at 100°F to 3.7 - 0.9, mean 1.8% at 0°F, indicated second stages of slow oxidation. The primary cycle, with peak values around 12 months was apparently completed with the low values observed around the end of the second year. Free fatty

acids, ranging from 0.16 - 1.04% at 100°F to 0.04 - 0.60% at 0°F, varied with items, storage temperatures, and slightly with storage time.

8. Sensory scores for texture (10-point scale) ranged 7.0 ± .6 at 0°F to 5.9 ± .6 at 100°F, various items being described as tougher, harder or more brittle at higher temperatures. Aroma and flavor quality scores averaged 3.2 range 3.4 at 100°F, 5.4 range 2.6 at 70°, and 6.6 range 1.8 at 40° and 0°. Reductions were attributed to staleness at 70°F and rancidity at 100°F.

9. Mean hedonic ratings were 5.00 for aroma and flavor, 5.21 for palatability. The three ratings averaged 4.23 range 1.94 at 100°F, 5.29 range 1.18 at 70°, 5.62 range 0.92 at 40°, and 5.78 range 1.14 at 0°.

10. Correlations of palatability rating with measurements associated with oxygen or oxidation and with color were relatively high. Hedonic ratings by 25 judges and sensory quality scores by 5 judges were highly correlated at 36 and 48 months.

B. Carbohydrate Supplements

1. Candy bags exhibited little evidence of storage effect except increase from 2.5 - 5.7% in partial separation and 4.5 - 17.8% in complete separation of seams of one item on seam tests.

2. Physical state of the supplement remained practically unchanged, averaging 8.9 ± 4.3% chipping, 0.8 ± 0.8% additional breakage, 0.5 ± 0.5% clumping, and 1.8 ± 1.4% loose sanding sugar in the cans.

3. Appearance and color were good except at 100°F, where moderate darkening of lemon pieces, slight fading of cherry, and variable "sugaring" of both types reduced quality scores to 6.3 - 7.1 from the 7.2 - 8.2 range at lower temperatures.

4. Hunter Color values for supplements revealed moderate but multi-directional temperature effects on mean difference and rank order analyses, but generally failed to describe the candies as well as did the taste panel judges.

5. Moisture contents, with moderate can variations, averaged 1.48, 1.65 and 1.68% for the three supplement items. Lemon type (1.76%) and cherry type (1.60%) were different in one item only.

6. pH values averaged 6.55, 6.76, and 6.83 for the three items at all periods, being .34, .12, and .17 lower at 36 months. There was little evidence of temperature effect on pH.

7. Dextrose contents, means 15.8, 17.7 and 18.0%, and sucrose contents, means 64.3, 62.9 and 60.9% exhibited no evidence of significant changes with storage. Inverse correlations of dextrose with sucrose and moisture and positive correlation of sucrose with pH were present in the high-dextrose items.

8. Sensory quality scores for texture of the candies were relatively meaningless, although certain samples were scored down for extra brittleness at 100°F. Aroma scores were reduced by averages of 1.35 at 100°, 0.67 at 70°, 0.49 at 40°F, and averaged 0.35 above initial at 0°F, because of loss of typical aroma, and development of slight "terpene" odors at higher temperatures. Reductions of flavor scores for the same reasons averaged 1.43 at 100°F, 0.51 at 70° and 40°, and 0.36 at 0°.

9. Mean hedonic rating for aroma of the three supplements was 6.43, with 6.72 mean for flavor and palatability. Temperature variations from these averaged -0.22 at 100°F, +0.03 at 70°, +0.15 at 40°, and +0.21 at 0°.

10. Correlations of palatability ratings with other measurements were generally poor, and those between sensory quality and hedonic ratings averaged only +.489. An overall sequence of changes, such as the high temperature-fading-oxidation-rancidity pattern in the cereal items, was apparently not present in the carbohydrate supplements.

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13. ABSTRACT

Results are reported on the stability of ten lots of fallout shelter cereal rations stored for 4 years and 3 lots of carbohydrate supplement stored for 3 years at 100°F/80% r.h., 100°/57%, 70°/80%, 70°/57%, 40°/57%, and 0°/ambient r.h. Rations include 4 lots of survival crackers, 4 lots of survival biscuits, 2 lots of bulgur wheat wafers, and 3 lots of mixed lemon and cherry flavored hard candies. Data include 48-month and 36-month values, respectively, for (1) bursting strength, moisture content, and general conditions of V3c fiberboard cases; (2) residual oxygen, leaking, corrosion, and coating defects of 2-1/2-gallon and 5-gallon metal cans; (3) breakage and general condition of package seals, seams and materials, and product units; (4) fracture strength, peroxides, and free fatty acids of wheat products; (5) pH and sugar contents of carbohydrate supplements; and (6) moisture content, color, sensory quality, and hedonic ratings for all products. Results of all examinations of stored rations, initially and through 36 and 48 months, are discussed.

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Rations	4		4			
Survival	4		4			
Civil Defense	4		4			
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14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Idenfiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

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