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TECHNICAL REPORT

70-64-FL

RESPONSE OF COOKED FREEZE-DRIED COMBINATION MEAT ITEMS TO OXYGEN

by

J. M. Tuomy, L. C. Hinnergardt and R. L. Helmer

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Food Laboratory U. S. ARMY NATICK LABORATORIES Natick, Massachusetts

Roreword

The adverse effects of oxygen on freeze-dried foods has been recognized from the beginnings of the Armed Forces program to develop freeze-dried rations. Current specifications for freeze-dried meat items include a maximum limit of 2 percent oxygen in the headspace gas. Storage studies as well as use in the field have shown that this limitation is valid and the products are satisfactory for the intended use. However, foods are very complex and their response to oxygen varies widely from item to item. Since packaging with low oxygen content is expensive and an inspection probelm as well, studies on individual items are necessary to establish their oxygen "tolerances". and the second second second and a second second

The main component items in the Food Packet, Long Range Patrol are dried as complete items rather than as separate ingredients. Thus, they represent a new family of freeze-dried combination foods. Therefore, this study was started to determine the oxygen response of various types of products made this way.

The work was performed under project 1J6-62708-D553, Food Processing and Preservation Techniques.

The work of Mr. Otto Stark and Mrs. Margaret Robertson, U. S. Army Natick Laboratories, in planning and conducting the chromatographic analyses for this study is gratefully acknowledged.

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Abstract

Eight freeze-dried corbination meat items used as main components in the Food Packet, Long Range Patrol were packed with different amounts of oxygen in the headspace gas and stored at 100° , 70° , 40° F. with withdrawals at 0, 2, 4, 12 and 24 weeks. The eight items were beef hash, beef stew, beef with rice, chicken and rice, chicken stew, chili con carne, pork with potatoes, and spaghetti with meat sauce. Oxygen uptake was determined. With the product stored at 100° F., the product was also evaluated by a 10-member technological panel and the rehydration ratio determined.

Regression analysis showed that flavor and odor correlated highly with oxygen uptake and the slopes of the regression lines were almost identical for the eight items. No correlation was found between rehydration ratio and oxygen uptake. Analysis of variance indicated that vacuum, temperature and time had significant effects on oxygen uptake, but the relative importance of temperature and time was different for different products. Multiple linear regression equations were derived using oxygen available, temperature, and time as independent variables and oxygen uptake as the dependent variable. The multiple correlation coefficients ranged between 0.61 and 0.79. Highly significant linear correlation coefficients were found with the regression of time on log mol fraction of oxygen remaining. This indicates that the oxygen uptake reactions have attributes of a first order reaction.

Introduction

Adverse effects of oxygen on freeze-dried foods have been noted by many investigators. A large number of in-house storage studies have shown that most freeze-dried foods are stable enough for military storage and use if they are packed with lass than 2 percent oxygen in the headspace ges or if they are vacuum packed at 28-inches vacuum or better. Furthermore, regular procurements smounting to many thousands of pounds in the last ten years for both field and garrison use have confirmed the validity of these oxygen requirements. Sharp (1953) and Harper and Tappel (1957) pointed out that freene-dried uset takes up oxygen and that deterioration results. Olcott (1962) stated that there is a rapid loss of palatability when freeze-dried meat and fish are stored in exygen or air. Smithles (1962) stated that in an exygen-free atmosphere, freeze-dried meat products suffer only a slow change in quality over periods of several months and air storage of these products can bring about spectacular decreases in rehydration. Exposure to exygen appears to be the most significant factor in the degradation of freeze-dried beef, chicken, carrots and spinsch (koth <u>et al.</u>, 1965).

Storage temperature is generally considered to have a very significant effect on the storage life of freeze-dried foods. Hanson (1961) reported generalized results from a large number of studies and stated that a dehydrated food which will keep for 2 years at $60^{\circ} - 70^{\circ}$ F. could be expected to last 12 - 18 months at 80° F., 6 - 8 months at 90° F., 3 months at 100° F., and about 2 weeks at 120°F. These products were packed with less than 2 percent exygen in the headspace. Freeze-dried meat items intended for operational rations are receive satisfactory ratings from a some state panel at the end of that period. In general, results from these studies agree with Hanson's findings except that freeze-dehydrated combination meat items appear to be more stable in storage than Hanson reports.

The Food Packet, Long Range Fatrol has been very wall received in the field and the quality has been considered excellent. However, theproducers have been quality conscious and have gone cut of their way to meet and exceed specification requirements. Too little is known about the quality parameters of the packet components, however, in particular the effect of oxygen during storage at various temperatures. Therefore, this study was initiated to determine the effect of oxygen on the 8 main component items in the Food Packet, Long Range Patrol and how the oxygen uptake is affected by storage time and temperature. The products studied were beef hash, beef stew, beef with rice, chicken and rice, chicken stew, chili con carne, pork with potatees, and spaghetti with meat sauce.

Experimental Methods

The products were made in accordance with Interim Furchase Description IP/DES S-36-6, Food Packet, Long Nange Patrol, dated April 20, 1966. Due to the large number of samples involved, the study was divided into two parts. In the first part, the products were stored at 100°F, and evaluated by a technological taste panel as well as by analysis of the headspace gas. In the second part, the products were stored at 70°F, and 40°F, with formal technological panel evaluation being omitted. Each product was made as a single batch for each part of the study and dehydrated in one freeze-dehydration chamber. Dehydration was to less than 2 percent moisture and the vacuum in the chamber was broken with nitrogen. Freeze-dehydration conditions were 120° F. platen temperature with radiant heating and a pressure of 400 microns. Packaging was in No. 2-1/2 cans and was accomplished within four hours after the dehydrator was opened. Twenty five cans for the first part of the study and fifty cans for the second part each containing 125 grams of product were closed at each vacuum. Vacuums used were 30, 28, 26, 24, 22, 20 and 0 inches of mercury. The cans closed at 30 inches were evacuated three times with 30 seconds dwell each time and flushed back with nitrogen the first two times. The other cans were closed as soon as the gauge indicated the required vacuum. The vacuums actually attained corresponded to approximately 1, 2, 3.5, 5, 6, 7 and 21 percent oxygen if the cans had been gas packed. A total of 525 cans were stored with 175 cans being stored at each of the three temperatures. Five cans of each vacuum at the three temperatures were withdrawn for evaluation at 0, 2, 4, 12 and 24 weeks. Moisture containt of the stored product was 1 - 2 percent.

Headspace gas analysis was performed by chromatographic means in accordance with the procedure outlined by Bishov and Henick (1966). Prior to analysis the cans were brought to ambient pressure with nitrogen and allowed to equilibrate overnight at ambient temperature. Sample size was 250-500 Å. Experience indicates an anticipated error for the method of approximately \pm 0.25 percent. Results for the 5 cans at each level were averaged for reporting purposes.

Total headspace volume in the filled cans was determined by compressing 125 grams of product in a laboratory press at 5000 lbs. per square inch for 10 seconds and subtracting the volume of the resulting bar from the total volume of the can. This method is not completely accurate. However, since the volume of headspace gas was so large in comparison with the absolute volume of the product any resulting error was considered insignificant.

Taste panel evaluation was made by a 10 member technological panel rating the product on a 9 point scale for flavor, odor, and texture where the highest number was the most acceptable. The same panel was used for all evaluations. Product was rehydrated with water at 180°F. for 5 minutes for tasting. Product in the cans used for chromatographic analysis was used for the panel evaluation.

Rehydration value was obtained by rehydrating 125 grams of product with water at 180°F. for 5 minutes, draining the product for 1 minute on a wire screen with 1/8~inch square openings and reweighing. Rehydration ratio was calculated as weight of rehydrated product divided by weight of dry product.

Results and Discussion

Tables 1 through 8 show the average panel flavor, odor, and texture ratings for the eight items in the first part of the study. Table 9 gives the analysis of variance for these results and indicates that oxygen available and storage time at elevated temperature are two important factors in the deterioration of freeze-dried foods. The Duncan Multiple Range test shows that with five of the eight items there is no significant difference at the 1 percent level between the flavor rating means at full vacuum through 26 inches. Chicken and rice, beef with rice, and chili con carne show no significant difference between full vacuum and 20 inches, which suggests that these three items are less sensetive to oxygen than the other five. For all eight products where vacuum is shown to be significant in Table 9 for odor and texture, the Duncan Multiple Kange test shows that there is no significant difference between full vacuum and 20 to 22 inches. Thus, in an overall evaluation of the effects of available oxygen in the products, the effect on flavor would be the controlling factor. Rehydration ratios were not significantly different over the full vacuum and storage time ranges and, therefore, no data are presented. ',

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Table 10 shows the linear correlation coefficients for oxygen uptake (Tables 12 through 19) versus the technological panel results (Tables 1 through 8) over the entire range of the study. Odor and flavor correlated highly with oxygen uptake whereas texture generally did not correlate quite as high and for three products did not correlate at all at the 5 percent level of significance. It should be noted as stated above there is no significant difference in the upper part of the vacuum range. Slopes of the regression lines for flavor (Table 11) are almost identifical indicating that a given oxygen uptake will result in an equivalent decrease in organoleptic ratings for each product. However, the rate of oxygen uptake is not the same for all items under the same conditions.

Oxygen uptakes at the three temperatures are shown for the eight items in Tables 12 through 19. Analysis of variance for these uptakes and percentage of variation assignable to each factor as determined by the method of Hicks (1956) are given in Table 20. The main factors of vacuum, temperature, and time were significant at the 1 percent level for all eight items. Most of the two factor interactions were significant at either the 1 percent or the 5 percent level. All of the interactions were in the same direction as the main factors as determined by inspection of the data.

Inspection of the components of variance indicates that the eight products can be divided into two general classes according to the factors which contribute the largest percentages to the variance. This is shown in Table 20A. In the first class which includes beef with rice, chicken and rice, pork with potatoes, and chicken stew, the major portion of the variance was caused by vacuum, temperature, and the vacuum X temperature interaction. In the second class which includes the other four products, the major portion of the variance was caused by vacuum, time and the vacuum X time interaction. The reasons for the products dividing into these two general classes are not well understood. However, the implications are very important in the design of military operational rations. Temperature can be controlled for the long term storage of contingency and reserve stocks. In operational situations, temperature depends upon the geographic location and vary little controlled temperature storage can be provided. Time then becomes the important factor. It is evident that much more information is needed in this area.

The percentage of available oxygen taken up by the eight items packed in air and stored at the three temperatures is shown in Table 21 illustrating the wide difference in responses of the items. Beef with rice and chili con carne appear to be less susceptible to oxygen at 100° F. than do the other similars. However, at 70° and 40° F, the responses of chicken and rice and chicken stow are very similar to them. The oxygen uptake of spaghetti with meat sauce was the same for all three temperatures. Although the effect of temperature over the whole study was significant (Table 20) it contributed only a very small amount to the total variance. Multiple linear regression equations were calculated from the data in Tables 12 through 19 using oxygen uptake as the independent variable (y) and oxygen available, temperature, and time as the dependent variables $(X_1, X_2 \text{ and } X_3)$. The derived equations are shown in Table 22 along with the mulitple regression coefficients $(K_1, R_2, \text{ and } R_3)$. The coefficients indicate good linear relationships and analysis of variance indicates that the contribution of each of the independent variables in each case was significant at the 1 percent level. Inspection of the raw data would suggest that the dependence of oxygen uptake on temperature and on time is probably curvilinear. However, the multiple correlation coefficients were not significantly improved when various mathmatical functions of time and temperature were used to develop the equations.

Nomographs can be developed from the regression equations which can be used to predict storage life of the product under different storage conditions by relating oxygen uptake to taste panel ratings. However, the data were obtained over a six month period and extension beyond that time cannot be justified. Furthermore, variations in raw materials, processing, and handling plus inherent variations in the subjective ratings obtained by taste panels rule out using the equations for anything more than generalized conclusions regarding storage stability of the eight products.

Correlation coefficients (r) were calculated for the linear regression of time on the log of mol fraction oxygen remaining (Table 23). In all cases except for chicken stew at 40°F, the coefficients are significant at the 1 percent level at each temperature. With chicken stew at 40°F, the oxygen uptake was so low that the points tend to cluster since the experimental error was of the same magnitude as the effect. The coefficients indicate a good linear relationship, a relationship usually considered a criterion for a first order r ction. This would indicate that the reactions involved are different from those usually associated with the normal oxidative rancidity of meat.

The results of this study confirm the adverse effects of oxygen uptake by freeze-dried combination items, and reinforce Armed Forces specification requirements restricting headspace oxygen to a maximum of 2 percent for operational rations where lengthy storage under possible adverse conditions must be anticipated. However, results also show that certain products are more resistant to oxygen uptake than others. Investigation of these differences should lead to improved product formulations which would permit a larger margin of error in handling and packing.

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	Texture	8.2	5.2	¢•\$	\$°0	5.3
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		5•8	5.5	5.3	4.4	5.6
8	S S S	6.5	5.6	6. 8	5.5	5.6
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22	in the second se	6.5	5.7	6.5	5.6	5 Q
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	Turture	5.8	5.8	5•3	h. 8	3.9 5.3 4.8
24	Otor	6.5	6.2 6.7	5.6	5.8	5.3
	Marver	6.2 6.5	6.2		5.2	3.9
	Texture	5.8	5.Å	\$•\$	5.0	\$* †
58. 1	04 GF	6.5		6.7	5.1	6.1
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	Texture >	5•8	5.9	5.2	Å.9	5.3
8	S S S	6•5	6.k	5.9	5.1	2.2
	FLATCE	6,2	6.2	5*9	5°1	5.6
	Texture Flavor	5.6	6.0	5.7	5°3	5+3
	St Cr	6•5	6.5	6.3	6 ,k	5.6
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	0000	6.k	5-9	5.8	4.2	13
	Flavo	6•5	5.7 5.9	4.6 5.8 h.9	4. 3	0°5
	Texture	6.4 6.1 6.5 6.4 6.1	6.4 5.7	5.k	5.1 5.1 4.3 5.4	5.9
220	Older	6. k	6.k	6.2	5.1	6-4
	FLENCT	6.5	6.4	5.0 5.6 6.2 5.k	4.4	k.2
Г 	facture	6.1	5-3	5.0	5.2	5.7 k.2 k.9 5.9 3.0
34.0	2000	6.4	6.3	5.7	6.1	5.3
	TAVAL	6.5	6.6 6.3	4.4 S.7	4.9 6.1	Å.8 5.3
	Planur Olde Smature Flavur Odor Tarture Flavur Odor Zexture Flavor	6.1 6.5 6.4 6.1 6.5	6.4	5.6	5•4 5.7 5•6	
963	2 S	6. k	7.2 7.3	5.3 6.7	5.7	6a2 5a9 5a6
	Planer	6.5	7.2	5,3	4.2	6.2
	Texture	6.1	6.0	5.1	6.1	5.9
241	Г		7.0	6.2	6.8	6,1
	Viame	6.5	6.4	6.2	6.3	6.3
	Texture Vince Office	6.1	6.0	ñ	5.9	6.3
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y I	80	6.7	6.8 6.0	6el 6a3 5a6	6.4	5.6 5.6
	Flavor	6.3 6.7 6.0	6.5	6.1	6.1 6.4 6.0	5.9
	Terture	6•0	5.7	6.1	6.2	5.6
3	e lor	6.7	6+3 5+7	6.3	6.5	6.0 5.6
	FLANDE	6.8	87	6 _* 0 6 _* 3 6 _* 1	ó.5 6.5 6.2	6.3
1	Texture Flavor	6 • 0	6,Å 6,9 6,1	5.9	6,2	6.1 S.7 5.1
	a de	6.8 6.7	6.9	641 641	6.0 6.5	
	Plance		6.Å	641	6.0	5
	Terture	6.0	5.5	6.0	6*5	4
.9¥	3905	6.7	6.5	6.5	V. 15	1
	V.L.T.C.	6 .8 6.7	6.3 6.5	6.6 6.5	نَّمَ دَمَّ	6 4 4 3
Γ	Flavor Stor Parture Finter Stor Texture	6.8 6.7 6.0	7.0 6.5	T	6.9 6.5 6.5	0
0	Stor	6.7	7.0	6.7	6.5	4
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	TOTAL	6.7	6.0	5.6 6.0 6.5 5.6	5+2	5.3
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22°	ig B B	7.0	6.5	6.6	6.3	6.6
-	PLEADE	6•7	5.8	6.4	5.6 6.3	6.2 6.6
	Texture	7.0 5.9	5.9	5.6	5.7	6.3 5.8
đ	8	7•0	6.7	6.2	6.3	6.3
	7 James	6.7	6.2	5.7	5.4	5.8
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ŝ	Citor	2.5	5.2	5.6	5,2	5.7
	VLOVE	6.7	5.8	6•3	5.5	4.6
	Odry Presture Fixwary Ofer Pertuzed Fiswer	51	2.0	5.1	545	<u><u>k.8</u> k.6 5.7 5.1 k.1 <u>k.7</u></u>
	Side	7.2	6.7	6.0	6.0	52
	P LEVON	6.7	5.7 6.7	4.7	4 .6	* *5
	Teature.	6.7 7.2 5.1 6.7	5.9 6.7 5.2	6.4 6.7 5.5 4.7 6.0	4.7 5.9 5.6 4.6 6.0	5.1 5.9 5.3 4.5 5.5
		•	6.7	6.7	59	5.9
	VIATOR	1	5.9	6.4	7.4	5.1
	racture	5.2	5,1	5.4	5.9	5.3
- RI	Od.oF	7.2	6.8	6 <u>.</u> 8	6*2	6.1
	Turtural Flavor Otor Pratting	6.7	6.7	6.5	5+7	5.5
		5.1	5.7	5,2	6.5 5.8	5.3
-00k	T Skim 1		6.8	ó.8	6.5	6.5
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	Theture	6.3	5+3	ي. م	3.7	6,0
0	1 ł	6.7	6.1	5.2	3.9	2.5
	Alever Utor	1.0	5+2	3.9	3.1	5-5
	Ch. derre	5-3	5.6	5.6	5°4	6.1
8	56.04 0	6.7	6.7	6,2	5.8	5.8
	PLEVCE	7•0	5.6	5.8	¥•\$	5+ h
	Tarbury Plever Clor	6.3	6 <u>.</u> 0	5•Å	5.6	6.1
223-	Color	6.7	6 . 8	5.7	5.6	5.9
	PLETCE	7.0	6.1	5.3	à.9	640
	Parture Flavor Ofor Texture Flavor Ofor	6.3	6•2	5.6	5.6	6.À
R.	Olor	6.7	6.8	5e.7	6.h	6~5
	FLAVOE	7.0	6.2	6.0	5•3	6.1
	Pathers	6 . 3	5 . 8	6.0	6.0	6.2
8	2010	6.7	6,6	41	6.k	6.7
	Y.4TOF	7.0	6.0	6.5	6.1	6.2
	Texture	6•3	5-9	5.6	5.7	6•3
251		6.7	6°9	6,2	7.1	6•6
	Plevor	7.0	6.3	6.0	6 . 3	6.2
	Flavor Olor Texture Flavor Otor	6 . 3	6.6	5.5	7•0	6•3
ÿ.	88	6.7	1.1	و•0	0*1	6 . 8
	PLATOT	7.0	و.6	6.2	6.6	6. 5
NO.	Τ	0	~	-11	ম	Ŕ

Table 6. Penel Retings for

CUILI (NH CAME - Stared at 100%7.

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ſT	T	· T			Ī		Ī			
	A 400 T.L.	5.4 5	£•4	-	7.7	1		4		
10-1	ž	5.3	**		3.5		5°3		18°) 14	
	illun .	4 Y	گ		ĩ	,	242		100	
		5.k	\$.6		j. • •		0%		g Z	
3	10	6.5	à.5 5.5		4.0		5.7		ž	
	YLENE	6.k	č.i		3E		Å.1		8•3	
-05	Taturo	A	Å.8		Ā		Å.6		5.4	
22	2030	6.5	6.2		1.2		5.5		6.0	
	VLETOF	6.k	5.3	T	\$•¥	-	***		2*0	
	Tertura Flaror Olor	4	27	T	2.0		8°4		4.7	
	0000	6.5	6.2	T	6.0		6.0		5.4 4.7	
	Viator Coor	6.4	8		£•5	T	1.4		F.4	
	Odor Texture	4.5	å		5.5	Ī	5.2		20	
	2020	6.5	6.5	T	6.2		6.0		6.3	
	Visited V	6.k	6.1		5.5	T	2.7		6.0	
		2			5-7		\$*5		5.1	
	5	6.5	6.3		6.2 0		6.5		6.3	
	the second second	6.4	8.8		6.0		ęry		6°0	
		1			23		5.7		6• 4	
	2	6+5 6	Y	3	6.8		6.5		Q*9	
		\$181.1E			130		6.2 6		9.4	
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Tuble 7. Presel Betlage for

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SPACHERTI WITH MEAN - SCARES at 100⁰7.

and the second second	PLU XIN	¥.7	4.5	à.6	2.1	2.0
-0-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-	2000	6.k	h.0 4.5	3.9	2.8	077
	ALENES I	5r3	3.1	349	2.5	7.0
	ferture	5.7	5.6	¥•\$		3.5
8	200	6.4 5.7	5.1	1-	4. 3	2.5
	PLATON	6.3	5.1 5.1 5.6	4°4 کینے 1°4	4.3 4.3 4.8	2.5 2.5 3.5
	Tenture Plurer Oles Terture Flaver Cler Tenture	5.7	5.1	4.7	5.1	4. 8
3		6.4	5.4	3.7	5.3	4.1
	JOAN A	6.3	5•0	4.6 3.7	8•4	3.2 Å.1 Å.8
	FLATOR Odde: Thattare Flavor	5.7	5.2	5.5	5.4	5.0
. 10	in S	6.4	5•5	6.0 5.5	5-9	k.5 5.0
	JOANEA	6.3	¥•6	5.1	5.2	4
	resture	5.7	5.8	5.2	5.7	5.5
68	Otor		6.2	5.5	6.2	
	YLXTOC	6.3 6.k	6.0 6.2	5+2 5+5	642	5.5 5.5
	Tarture	5.7	5.8	5.5	5.5	42
R	01ct	6.k	6.0	6.3	6.6	r V
	Pleadr	6 ₀ 3	5•3	5-9	5.9	4
_	Perture Flavor Olor Texture	5.7	5.6	5.7	5.8	4
-	Olor		6.3	6.4	6.8	° 4
	Flence Olor	6.3	6.3	5.8	6.5	
Lana Lana		0	~	*	я	1

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	Vacuum			Storege Time			Vacuum X Storage Tim		
Product	Flavor	<u>Iopo</u>	Texture	Flavor	Ogoz	Texture	Flavor	Odor	rexture
Beef Hash	XX	xx	n. s.	XX	xx	xx	77	XX	n.s.
Beef Stew	жх	xx	x	XX	жх	~	xx	х	n.e.
Beef with Rice	XX	n.8.	ກ.8.	xr	xx	XX	n.s.	n.s.	п.ө.
Chicken and Rice	XX	ж	xx	xx	XX	xx	XX	XX	n.e.
Chicken Stew	xx	хх	n.s.	XX	x #	xx	xx	x	n.s.
Chili Con Carne	xx	хx	x	ХХ	хх	XX	XX	XX	n.e.
Pork with Potatoes	**	жх	n.s.	хх	XX	n.s.	××	XX	n.s.
Spaghetti with Meat Sauce	xx	xx	xx	хх	XX	**	жx	жx	xx

Table 9. Analysis of Variance Results for Eight Combination Meat Items Stored at 100⁹F.

xx Significant at the 1 percent level

x Significant at the 5 percent level

n.s. Not significant at the 5 percent level

Product	Flavor	Odor	Texture
Beef Hesh	0.873 ^{xx}	0.823 ^{xx}	0.578 ^{xx}
Beef Stew	0.852**	0.879 ^{××}	0.732 ^{%X}
Beef with Rice	0.766 ^{XX}	0.657 ^{XX}	0.363 ^{n.s.}
Chicken and Rice	0.876 ^{xx}	0.920 ^{xx}	0.648 ^{XX}
Chicken Stew	0.830 ^{xx}	0.823 ^{xx}	0.193 ^{n.s.}
Chili Con Carne	0.585 ^{xx}	0.667 ^{xx}	0.344 ^{n.s.}
Pork with Potatoes	0.887 ^{××}	0.853 ^{**}	0.499 ^{**}
Spaghetti with Meat Sauce	0.859 ^{xx}	0.889 ^{**}	0.937 ^{xx}

Table 10. Correlation Coefficients (r) for Oxygen Uptake vs. Technological Panel Results

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x Significant at the 5 percent level

xx Significant at the 1 percent level

n.s. Not significant at the 5 percent level

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Beef Hash	y = 5,86 - 0.035x
Beef Stew	y ≈ 6.46 - 0.032x
Beef with Rice	y = 6.36 - 0.035x
Chicken and Rice	y = 6.35 - 0.023x
Chicken Stew	y = 6.17 - 0.030x
Chili Con Carne	y = 6.18 - 0.024x
Pork with Potatoes	y = 5.81 - 0.024x
Spaghetti with Meat Sauce	y = 5.54 - 0.035x

Table 11. Linear Regression Equations for ML. Oxygen Uptake (x) vs. Flavor Rating in a 9-point Scale (y)

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	ſ	Τ	ļ	158.9)		7.	10.9		0,41	26.5	I
	10	UE CO MT	200 1000	iñ.			9.9	:	5.52	131.2 102.7 26.5	
		в 0*		1154.5211	2	*	42.8	2 65		131.2	
		Ę	007	(9.94)			1.3	e r		18.6	i
	204	TH OSSO	1002	(9.94)	2 2 X	1	5.0	8 42		23.9	. 125
		0	10001	(49.2)(46.6)(46.6)	, v , v	;	18.5 5.0 1.3	8 71 2 00		30.4 23.9 18.6	Product - 125 gms.
		ų	e04	(37.7)) «		2.9	, s		15.0	304
0	22"	114 02153	204 1002	(37.7)	0 0		3.2			18.0	•
0		°0	10001	(38.7)(37.7)(37.7)	7.7 2.9 0.8		14.0 3.2 2.9	20.7 13.5 8.7		27.4 18.0 15.0	
t)	srndact) 24 ⁴	0 ₂ 1520 M.	0.04	(28.3)	1.5 1.1		2.3 0.8	2.9		20.3 10.2 12.4	
produc			200 400	(28.3)	1.5		5.3	12.4		10.2	
(m1/125 ges of product)			1000	(30.4) (28.3)(28.3)	8.9		14.6	19.7 12.4 7.9		1 6.02	
(m)/12		2	207	(19.7) (15.5)(18.5)	6.0			9.4 5.6		1 2.01	20.12eaŭ ()
	26"	02 USED ML	207 002	(15.5)	2.0 0.3		2.2	9.6	:	4.UL 12.64	() Å
		02 L	10001	(19.7)	4.1			5.9	;	1 2.07	
		Į	20g	(8.9) 0	0.9		•••	3.6	,		
	28"	H O	1009 709 400	(6°9)	0		-+-				
		°°	10001	(10.6)	2.8	0 1 2 4		0.0 6.6	7 0		
		4	90 4	(3.0)	6	•	+	0.4			5
	307	14 03 20	22	(0°7)	٥	v	1	1.2	0.0		- 756.
		°2	1000	6 o 5	3.3	- 0 V V		5.0 1.2 0.4	2.3 2.0		Bestupace - 756.5
				•	~			Ĩ	24		Han

Table 12. Oxygen Uptake of MILT EASH During Storage (al/125 and of wordact)

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Cargona 1	(ml/125
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Table	

3. 16

			(157.0)	4.1	4.5	8.7	10.9
		400					
5	Ř	202	(157.0)	5.7	7.8	23.0 12.1	48.9 16.3
	02 USED XI	1000	(157.0)	17.8	24.1	23.0	48.9
20"	보	50%	(52.0)(48.3)(43.3) 0 0 0	1.6	8.1 2.1 0.9	3.4	22.5 9.1 5.7
~	2 USED AL	700	(4 8.3) 0	6.4 2.2	2.1	7.9	9.1
	20 0	1000	(52.0)	6.4	8.1	15.5 7.9	
н	¥	400	(39.2)(39.2)	1.1	1.7	3.2	14 6 5 3 2 9 15 1 9 1 5 5 19 5 6 9 5 S
22"	DN CISO	705 205	(39.2) 0	1.1	7.1 4.4	6.5 3.2	6.9
	2 2	10001	(41.9)	2.9	7.4	13.2	19.5
	02 USED AL	007	0.2)(30.2)	2.5 1.3 0.9	1.3	5.6 6.4 3.2	5
24"		700	(30.2) 0	1.3	5.4 1.5	6.4	1.0
		1000	0)(3(3(2.5	5.4		1.21
		101	(119.1)	0	0	4.3 0.9	9.6
26"	0 ₂ USED M.	700 400	(1.91) 0	0.1	0		13
	02 1	1002	(22.6)	2.0	6.1	10.2	14 4
	Ж	400	(9.6)	0	0.3	0	c •
28	1 00 00	200	(9.6)	0	0.5	1.9	
	0.7 0	1000	(13.2)	1.4	5.3	6.8	• •
30"	TH GISD	23	(1.3)	ß	•	•	•
		200	(5.1)	•	•	0.5	. e
	3	1000	(8.1)	0	0.5	0	
ſ	201	2	6	~	*	21	*

Product - 125 gms.

() Avail 02

Beadspace = 747.7 ml

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Table 16. Orygen Uptake of BERF 6 RICE During Storage (al/125 gas. of product) ·

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Tible 15. Curyges Uptake of CELTER & RICE During Storage (m1/115 gros. of product)

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	8	(† • • • 5	4.1	2.3	3.7	7.4	
70	e e	0 (4.84)	0.5	4.5	8.1		
	10001	(154.6)	0.0 7.2 2.2 0.7 8.0 2.2 1.4 10.2 0.7 0.0 49.6	\$0 . 8	137.3	1.5 25.5 7.3 3.7 33.4 6.6 2.9 4.1 8.8 3.6 146.3 14.2	
	100	(47.0)	0.0	1.4	0.0	3.6	125 82
ž	200	(47.0)	0.7	2.3	4.4	<u>s</u> .8	Product ~ 125 gme.
	1000	(47.0) 0	10.2	18.6 2.2 1.4	2.2 39.6 4.4 0.0 137.3	1.4	£
-	808	(38.2)	1.4	2.9	2.2	2.9	
27	1001	(13.4) (27.9) (29.6) (29.4) (37.5) (38.2) (38.2) (47.0) (47.0) (47.0)	2.2	16.3 4.4 2.9	5.1	6.6	
	10000 1001	0.15)	8.0	16.3	30.0	33.4	
	001	(4 . 62) 0	0.7	2.2	1.5	3.7	
244	10.01	(¥-62)	2.2	4.4	5.9 1.5	6.2	1 0 ₂ .
	1000 2001	(27.9)	7.2	0.0 13.1 4.4	23.2	25.5	() Avail 02
	e09	(13.4)	0.0	0.0	0.0 23.2	1.5	Ļ
264	202	(18.4) (18.4)	0.0	2.2	2.2	4.4	
	10001	(20.1)	6.5	11.0	13,2	18.3	
	9	(9.9) (9.9)	0.0	0.0	1.4		
-52	1g	(8.8) (0.8)		1.4	2.2	3.7 2.2	
	100	(1.6)	2.0 0.7	4.5	3.0	6.1	5 ml
Γ	698	(1.5)	0.0 0.0	0.8 0.0 4.5 1.4	0.0 3.0 2.2	3.5 0.8 0.0 6.1	Basdspace Vol 735 ml
5	- Ma	(1.5)	0.0		0.8	0.8	space Vo
	1000	(1.1)	2.0	2.5	•	3.5	Each d
1111		c		*	12	24	

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g Storage	
STBN During	
of CRICERS	f product)
Grygen Uptake	il/125 pm. o
Table 16. Co	3

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5	1700 1 400	0 121.13(1151)	0.1	3.1	0 19.6 4.8 1.6 26.1 8.2 0.9 29.8 9.1 1.0 56.1 12.9 4.1	21.0 5.3 0.1 34.3 3.9 2.3 33.9 10.4 2.4 55.7 12.3 2.6 143.0 24.7 70.0
	1000	(1.121) (1.121)	0 8.8 0.3 0.4 10.3 6.2 0 16.3 1.3 0.4 24.1 0.1	0 15.5 0 0 20.3 0.9 0 19.1 2.1 0 32.8 3.1	26.1	147.0
	, 0,	((45.60) 0	0.4	•	1.0	2
20"	200	(*6.60	1.3	2.1	9.1	12.7
	603 1000 I	(54.4)	16.3	19.1	29.8	55.7
	1 400	0 (36.92) (07.36) (0 (4.42)	0	•	6.0	2.4
724	20/ 	0 (36,50)	6.2	0.9	8.2	10.4
	1000	(46.3)	10.3	50.3 1	26.1	38.9
	400 1000	(27.34) 0	0.4	0	1.6	2.3
240	1000 700	$\left(16.32\right)$ $\left(35.0\right)$ $\left(27.34\right)$ $\left(27.34\right)$ $\left(46.3\right)$ $\left(0$	0.3	٥	8.4	2.2
	1000	(0.35.0)	8.8	16.5	19.6	6.4
	603	(16.32)	0	0	٥	0.1
26"	200	(16.32)	0	8.9 0.2	3.8	5.3
	1000	35) (21.0) 0 0	4.8	8.9	12.7 3.8	21.0
	400	(35.7)	0	0.2	2.0	0.8
28"	700	0 (25.35)	0.2	0.6	3.7	3.7
_	<u>ء</u> ا	(15.6) 0	3.1	11.0	12.5	14.9
	007	(1,47)	0	٥	0.8	0.0
2	200	(L.47) 0	•	0	1.5	0.7
	1000	(8.7) (8.7)	5.6	3.6	8.0	8.7
	100	0	2	*	12	24

Rezdopace - 735 ml

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Product - 125 gad.

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Table 1	

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7106		36"			23"			26"			24"			324			20"		i	5	
SUN	100	1001	00	1000	0.02	0.037	1000	202	202	12000	1 700 1	007	1000	200	700 400 1000		200	400	1852	1002	400
0	(8. 4)	(1.77)	(1.77)	(4.6)	((4.87) 0	((8.8))	.37) (24.9) 0 0	(15.04	(15.04)	(36.3)	(24.43)	(24.48)	(48.7)	(34.22)	22)(34.22) (53.5)	(53.5)	(15.54)	(15.53) 0	(6-451) 0	(156.9 <u>)</u> (0	(154
6	3.8	0	Ö	2.9	0.2	0	3.7	1,0	1.0	9.5	9.5 1.8	0	0.5	0.5 1.3 2.6	3.6	8.5 1.8	1.8		0 21.0	3.9	2.5
4	3.5	0	9	2.3	0.3	0	7.3	1.6	1.3	8.7	2.4		8.7	3.1	2.5	10.3	4.6	0 8.7 3.1 2.5 10.3 4.6 4.3	29.5	6.9	3.3
12	0.9	0.3	0	2.2	1.2	0.5	14.3	8.4	2.5	16.6	12.7	4,6	20.7	16.6 12.7 4.6 20.7 16.5 7.7	7.7		17.8 19.9	9.9	62.1	37.7	25.1
24	4. 5	0	0.3 6.6	6.6	0	1.2	20.9	9.8	7.6 28.0 14.2 14.2 3.0 18.7 18.0 36.7 23.2 21.0 89.7 47.2 45.0	28.0	14.2	14.2	3:-0	18.7	18.0	36.7	23.2	21.0	89.7	47.2	45.1
Bea	depace	Beadspace Vol - 737.4 ml	7.4 ml						0	() Avail 0 ₂	°,						Produc	Product - 125 grame			

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Tabla 18. Orygen Uptake of PORX WITH FWIATORY During Storage (al/125 gme. of product)

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								1176			36			22*			20 "			5	
Ă		30"			287				Tel:	1000		100	$\frac{28}{1000}$ $\frac{1000}{1000}$ $\frac{1000}{1000}$ $\frac{1000}{1000}$ $\frac{1000}{1000}$ $\frac{1000}{1000}$ $\frac{1000}{1000}$ $\frac{1000}{1000}$	240	0.0%	1000	1001	007	1000	200	403
ـــــا دە	10001	200	400	1000	2001	009	1002	202	3	NI	2		3			160 CN	10 57	10 27	115R AV	1158.41	(158.4)
1	(5.5)	(0.8)	(2.9) (0.8) (0.8)	(6.9) (5.3) (5.3)	(2-3)		(17.6)	(12.1)	(1.5.1)	(21.15)	(25.6)	(52-6)		(+.(E)	0 (+- cc)	3(2.36)	0.04	0.0	0	ð	0
+	а ;			> :			9		0	16.2	0.7	0-0		3.0	0.0	22.9	2.3	0.0	42.1	\$2.1 11.4 3.8	3.8
\dagger		2		;												Į					
	5	c c		6.1	5	0.0	14.3	1.5	0.0	31.4	7.5	0.9	14.3 1.5 0.0 31.4 7.5 0.9 39.4 10.5 2.2 47.4 8.4 1.5	10.5	2.2	47.4	8.4	1.5	147.5	147.5 23.4 9.8	9.8
\mathbf{t}						1			•	000			··· ·· ·· ·· ·· ·· ·· ·· ·· ·· ·· ·· ··	28 6		1.05	0.45	3.0	150.1	150.1 122.2	15.1
+		0:0	0.0 0.0	4.0 3.8	2.5	». 0	10.1	•													
	~	0.0	2.1 0.0 0.0 6.1 6.5	6.1	4.5	3.8	16.7	13.6	6.1	30.0	24.1	12.8	16.7 13.6 6.1 30.0 24.1 12.8 40.7 32.4 14.3 50.1 37.7 15.9 157.5 146.3 40.8	32.4	14.3	50.1	37.7	15.9	157.5	146.3	40.8
1	He	adapece	Neadapace Vol - 754.1 ml	154.1 al					-	() Avail 0 ₂	#11 0 ₂					4	roduct	Product - 125 grams	5212 3		

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Table 19. Orygan Uptake of SPACEATTI W/PEAT SAUCE During Stornge (m1/125 gas. of product)

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$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	PACTOR	Beef R	lach (Beef Stev		Beef v/Rice	Rice	Chicken	Chicken and Rice	Chicken Stev	a Stev	Contact Cont	800	Pork with Potatoes		Spechetti vith Meat Sauce	LI WICh
uma-A xz 30.3 xz 40.5 xz 22.1 xz 16.6 xz 11.6 P-B xz 8.4 xz 12.5 xz 22.3 xz 23.4 xz 30.4 P-B xz 15.1 xz 12.5 xz 22.3 xz 23.4 xz 30.4 e-C xz 15.1 xz 16.5 xz 14.6 xz 3.7 xz 8.7 e-C xz 13.1 xz 6.1 xz 13.0.8 xz 30.4 36.1 xz 16.8 xz 30.8 xz 2.7 1.1.6 xz 36.1 xz 16.8 xz 20.8 xz 26.1 xz 26.1 xz 16.8 xz 20.8 xz 26.7 1.1.6 2 xz 6.5 xz 2.1 1.1.6 2 2 1.1.6 2 6.5 xz 2.1 1.1.6 2 2 2 2 6.5 xz 2.1 1.1.6 2 2 2 2 5.2 xz 2.1 1.1.6 2 2 2 <t< th=""><th></th><th>81g (1)</th><th>≰ (2)</th><th>81g (1)</th><th>(3)</th><th>(T)^{\$758}</th><th>(2)</th><th>31g(1)</th><th></th><th>81g(1)</th><th>\$⁽²⁾</th><th>Sig(1) \$(2)</th><th>¢(2)</th><th>818⁽¹⁾</th><th>(2)</th><th>81g(1)</th><th>¥(2)</th></t<>		81g (1)	≰ (2)	81g (1)	(3)	(T) ^{\$758}	(2)	31g(1)		81g(1)	\$ ⁽²⁾	Sig(1) \$(2)	¢(2)	818 ⁽¹⁾	(2)	81g(1)	¥(2)
P - B m 0.4 m 12.5 m 22.3 m 23.4 m 30.4 e - C m 15.1 m 16.5 m 14.6 m 3.7 m 8.7 e - C m 13.1 m 16.5 m 14.6 m 3.7 m 8.7 m 13.1 m 6.1 m 30.8 m 36.1 m 8.7 m 30.8 m 2.7 m. 36.1 m 36.8 m 30.8 m 2.7 n. 56.1 m 6.5 m 30.8 m 2.7 n. 56.1 m 5.2 m 30.8 m 2.7 n. 5.6 5.5 m 20.1 m 2.1 n. 5.6 5.2 m 20.1 m 2.7 n. 5.6 5.2 m 2.1 1.0.6 m 5.6 5.2 m 2.1 1.6.6 1 1.5.4 5.2	Vacuum - A	¥	30•3	Ħ	40.5	X	2.1	×	9 . 91	×	л.6	Ħ	30.1	Ħ	37-3	×	£.14
e - C xz 15.1 xz 16.5 xz 14.6 xz 3.7 xz 8.7 xz 13.1 xz 6.1 xz 30.8 xz 36.1 xz 15.8 xz 30.8 xz 15.1 xz 26.1 xz 56.1 xz 16.8 xz 30.8 xz 15.2 xz 2.7 n.e. - x 5.6 xz 2.1 n.e. - xz 2.7 n.e. - x 5.6 xz 2.1 n.e. - xz 5.6 x 4.6 xz 5.2 xz 2.1 n.e. - 8.2 0.9 - 15.4 - 16.8	Temp - B	×	8.4	X	1 2.5	×	æ.3	Ŕ	23.4	×	30.4	×	14.8	×	14.61	X	2.7
xx 13.1 xx 6.1 xx 30.8 xx 36.1 xx 15.8 xx 30.8 xx 15.2 xx 2.7 p.s. - x 56.5 xx 30.8 xx 15.2 xx 2.7 p.s. - x 5.5 xx 2.1 p.s. - xx 5.6 x 4.6 xx 5.2 xx 2.1 p.s. - xx 6.6 x 4.6 xx 5.2 - 0.2 - 8.2 - 0.9 - 15.4 - 16.8	Time - C	×	15.1	Ħ	16.5	¥	1 4.6	×	3.7	Ħ	8.7	×	¥•82	¥	6.9	X	4.42
xx 30.8 xx 16.2 xx 2.7 n.s. - x 6.5 xx 2.1 n.s. - xx 6.6 x 4.6 xx 5.2 - 0.2 - 8.2 - 0.9 - 15.4 - 16.8	AB	¥	13.1	Ħ	6.1	Ħ	30.8	×	36.1	×	16.8	×	7.2	Ħ	13.2	×	4.0
xx 2.1 m.se. - xx 6.6 x 4.6 xx 5.2 - 0.2 - 8.2 - 0.9 - 15.4 - 16.8	AC	×	30•8	×	2.dI	×	2.7			н	6.5	Ħ	19.0	Ħ	9.8	Ħ	28. Å
- 0.2 - 8.2 - 0.9 - 25.4 - 16.8	8	X	2.1	По Б.	1	X	6.6	ж	4.6	×	5°5	×	5.8	×	o e	8 d	•
	REA	ł	0•2	1	8.2	1	0•9	1	15.Å	•	16.8		2.7	 •	10.2	•	6.2

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Table 20. Ausiysis of variance and components of variance for organ uptake

Significance xx - Significant at the 15 level x - Significant at the 55 level n.s.- Not significant at the 55 level

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(2) Percent of variance

and a state of the second second	A + B + AB	51.8	59.1	75.2	76.3	59.0	52.1	70.1	51.0
A CONTRACTOR OF A CONTRACT	A + C + AC	76.2	73.2	39.4	20.5	26.8	69.5	54.0	87.1
	B + C + BC	25.6	29.0	44.5	31.7	48.3	41.0	24.5	17.1

Table	20A.	Combined	Percentages	Components	of	Variance	
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		Temperature	
Product	100°F.	70°F.	40°F.
Beef Hash	31	10	7
Beef Stew	83	65	17
Beef with Rice	95	53	45
Chicken and Rice	94	11	5
Chicken Stew	95	16	7
Chili Con Carne	57	31	29
Pork with Potatoes	99	92	26
Spaghetti with Meat Sauce	93	94	93

Table 21. Percentage of oxygen available taken up by product packed in air and held 24 weeks

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Table 22.	
	Available, Temperature, and Time as Independent Variables and Oxygen Uptake as the Dependent Variable

A CARACTER AND A CARA

Product	Coefficients R ₁₂₃	Equation*
Beef and Rice	0.7870	$Y = 0.07X_1 + 0.11X_2 + 0.39X_3 - 9.30$
Beef Hash	0.7348	$Y = 0.19X_1 + 0.18X_2 + 0.98X_3 - 19.14$
Beef Stew	0.7878	$Y = 0.26X_1 + 0.22X_2 + 1.33X_3 - 21.14$
Chicken and Rice	0.6123	$Y = 0.18X_1 + 0.32X_2 + 0.64X_3 = 27.00$
Chicken Stew	0.6680	$Y = 0.13X_1 + 0.29X_2 + 0.74X_3 = 23.84$
Chili Con Carne	0.7916	$Y = 0.15X_1 + 0.12X_2 + 0.87X_3 = 14.03$
Pork with Potatoes	0.7295	$Y = 0.36X_1 + 0.39X_2 + 1.20X_3 = 36.13$
Spaghetti with Meat Sauce	0.7599	$Y = 0.38X_1 + 0.17X_2 + 1.45X_3 = 26.68$
* X ₁ = Oxygen available in m X ₂ = Temperature in ^O F. (A X ₃ = Time in weeks (0 to 2 Y = Oxygen uptake in m1/1	40 to 100°E) 24)	uct (O to 160 ml)

Product	100°F.	r 70°F.	40°F.
Beef Hash	0.741	0.672	0.669
Beef Stew	0.916	0.659	0.738
ßeef with Rice	0.680	0.761	0.734
Chicken and Rice	0.855	0.449	0.540
Chicken Stew	0.876	0.761	0.201
Chili Con Carne	0.846	0.624	0.841
Pork with Potatoes	0.541	0.824	0.733
Spaghetti with Meat Sauce	0.863	0.854	0.686

Table 23. Correlation coefficients (r) for time vs. log mol fraction of oxygen remaining at three temperatures

Significance at 5 percent level r = 0.367

Significance at 1 percent level r = 0.470

DF = 27

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· Eight freeze-dried combination meat it					
Packet, Long Range Patrol ware packed with	Packet, Long Range Patrol were packed with different amounts of oxygen in the				
headspace gas and stored at 100 ⁻ , 70 [°] , 40 [°] F. with withdrawals at 0, 2, 4, 12 and 24					
wacks. The eight items were beef hash, bee	f stav, beat	With Tice	and ficken and fice,		
chicken stew, chili con carna, pork with po Oxygen uptake was determined. With the pro	duct stored	et 100 at	the product was also		
evaluated by a 10-member technological pane	i and the re	hydration	ratio determined.		
Regression analysis showed that flavor	and odor co	rrelated 1	nighly with oxygen		
uptake and the slopes of the regression lin	es vore almo	st identic	al for the eight items.		
No correlation was found between rehydratic	n ratio and	oxygen upt	take. Analysis of		
variance indicated that vacuum, temperature	and time ha	d signific	ant effects on oxygen		
uptake, but the relative importance of temp	erature and	rima waa (illigrant lor		
different products. Multiple linear regres available, temperature, and time as indepen	sion aquatio	ns were a	reen untake as the		
dependent variable. The multiple correlati	an confficie	es eux ox; nte rence:	t batwaen 0.61 and		
0.79. Bighly significant linear correlatio	n coafficien	ts were fo	ound with the		
regression of time on log wol fraction of o	xygen remain	ing. This	s indicates that the		
oxygen uptake reactions have attributes of	a first orde	r reaction	۵.		
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