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TECHNICAL REPORT

68-22-FL

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COMPRESSED FOOD COMPONENTS TO MINIMIZE STORAGE SPACE

FACILITY FORM 602

(ACCESSION NUMBER) (THRU)

(PAGES) (CODE)

(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

by

Jack R. Durst

The Pillsbury Company
Minneapolis, Minnesota

Contract No. DA19-129-AMC-860(N)

Acquisitioned Document
SQT

October 1967

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Food Laboratory

FL-64

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MATHEMATICAL EXPRESSION FOR DROP SIZE DISTRIBUTION IN SPRAYS

by

Hiroyuki Hiroyasu

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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TECHNICAL REPORT
68-22-FL

COMPRESSED FOOD COMPONENTS TO MINIMIZE STORAGE SPACE

by

Jack R. Durst

The Pillsbury Company
Minneapolis, Minnesota

Contract No. DA19-129-AMC-860(N)

Project reference:
NASA PR R-22-015-004

Series: FL-64

October 1967

Food Laboratory
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

FOREWORD

Preparation for space flights of increasing duration with enlarged crews requires the development of a feeding system which, along with other requirements, will minimize both the weight and volume of the food inventory. Such requirements, however, must not jeopardize the acceptability and the nutritional quality of the food. In the absence of a reliable method for predicting acceptability under the conditions of actual space flight, it is assumed on the basis of experience with military feeding systems, that familiar foods have a significantly better acceptance than unfamiliar. It is also recognized that the depressing effect of monotony is minimized by providing a variety of food.

Dehydration, specifically freeze drying, combines a reliable method of preservation with the attainment of maximum concentration of natural food nutrients for unit of weight. It has been experimentally established that a number of freeze dried foods, when properly pretreated, can be compressed to approximately 0.8 gram per cubic centimeter without losing the capability of returning during rehydration to precompression size and shape. By the above technology it becomes feasible to achieve a major reduction in both the weight and volume of many familiar foods without sacrifice of nutritional function or irreversible damage to acceptability.

In an earlier contract (DA 19-129-AMC-2103, All Purpose Matrices for Compressed Food Bars) The Pillsbury Company demonstrated the effectiveness of a bland, high-caloric binding material to provide a desirable level of cohesion in bars prepared from a large variety of dehydrated components. Incorporation of predetermined amounts of this binding material provides a basis for compressing a variety of foods into bars of uniform size and equal caloric content. In another contract (DA 19-129-AMC-1, Food Adjuncts Stabilized as Thin Sheets or Laminates) The Pillsbury Company prepared more than thirty sauces, spreads, relishes and the like in the form of flexible, sheets suitable for direct consumption in conjunction with a bland carrier.

By combining the technologies cited above it appears possible to prepare a large number of common meal items by hydrating and mixing combinations of selected compressed food bars with appropriate stabilized sauces and condiments. Furthermore the regular geometry of the above components would permit maximum packing efficiency in a rectangular container. Thus a relatively small packing box would provide a high caloric density on both a weight and volume basis, and, at the same time provide components for the preparation of a large number of different familiar foods.

This contract seeks to demonstrate the feasibility of combining these concepts in the development of compressed food bars and stabilized adjuncts which can be packed into a box with maximum

efficiency and from which can be prepared a great variety of familiar foods of uniformly high acceptability.

The experimental effort described herein was performed at the Research Laboratories of The Pillsbury Company, 311 Second Street S. E., Minneapolis, Minnesota 55414 under contract DA 19-129-AMC-860. Funds were provided by Project: NASA-DPR R-22-015-004. Dr. Jack R. Durst served as the Official Investigator; his collaborators were John D. Ringstrom, Gary W. Hall, Ronald J. Gauthier, William C. Winters and James C. Blodgett. Project Officer and Alternate Project Officer for the U. S. Army Natick Laboratories were Dr. Maxwell C. Brockmann and Mrs. Mary V. Klicka, respectively.

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ABSTRACT

This study was originated to design, develop, and demonstrate an integrated feeding system based on a specified number of stable food components which can be stored in a limited space and from which can be prepared a variety of nutritious food items.

Information is presented for the preparation of 10 food bars, 4 food sheets and 13 food adjunct cubes. Data are given on these components packed in flexible pouches, some under vacuum, after a thirteen week storage study. Evaluations were carried out on microbiological, physical and organoleptic considerations. Hedonic ratings are shown for 45 meals prepared from these components before and after thirteen weeks' storage at 38°C using both a nine point 5 neutral scale and a nine point 3 neutral scale. Nutritional values of ingredients used are listed.

COMPRESSED FOOD COMPONENTS TO MINIMIZE STORAGE SPACE

SCOPE OF CONTRACT

1. The purpose of this project shall be to design, develop and demonstrate an integrated feeding system based on a specified number of stable food components which can be stored in a limited space and from which can be prepared a variety of nutritionally defined meal items. Specific parameters for this contract shall be met by a maximum of ten (10) different compact dehydrated food bars and not more than fifteen (15) different stabilized modules of sauces, seasonings and other food adjuncts. When hydrated and mixed in defined combinations, these components shall permit preparation of at least thirty (30) familiar meal items in servings of approximately 600 calories each. Components for thirty (30) servings, equivalent to 18,000 calories shall be capable of storage in a rectangular container having an internal volume of 7,000 cubic centimeters or less.

2. The following requirements shall apply to both compacted bars and stabilized adjuncts.

a. Ingredients shall conform to current regulations of the Food and Drug Administration.

b. Components for any meal item shall hydrate to an acceptable level within twenty minutes after addition of a prescribed amount of room temperature water. To facilitate disintegration hydration and mixing, gentle, intermittent agitation may be applied.

c. Geometry shall favor efficient and orderly packing in the above-mentioned rectangular container.

d. Pressure and shear arising from normal handling at temperatures between 0 and 38°C shall produce no fracture, fragmentation or dimensional

change in excess of two percent.

e. Surfaces shall not become sticky when exposed for two hours at room temperature to a relative humidity of 75 percent.

f. Components sealed in laminated pouches and stored for three months at 38°C shall undergo no significant physical, chemical or microbiological changes and shall remain acceptable for preparation of meal items.

3. Each of the thirty or more meal items shall be rated as acceptable for human consumption by a panel under the direction of Contractor's technologist trained in the management of panels and the interpretation of results therefrom. These meal items shall remain acceptable when prepared from components stored three months at 38°C in accordance with 2f above.

4. Prior to the completion of this contract, four packed units conforming to this Scope, together with instructions for use, shall be submitted to the Project Officer.

INTRODUCTION

From experience gained "in house" and during work on Contract No. DA19-129-QM-1970(01-6063) "Formulation and Fabrication of Food Bars," Contract No. DA19-129-AMC-2103(X) "All Purpose Matrix for Compressed Food Bars," and Contract No. DA19-129-AMC-1(X) "Food Adjuncts Stabilized as Thin Sheets or Laminates" and in the interest of fabricating food bars from foods familiar to the greatest number of potential users, the ten following foods were chosen as the base for the ten bars.

(1) Ground Beef
(2) Diced Beef
(3) Diced Pork
(4) Diced Chicken
(5) Diced Turkey
(6) Tuna
(7) Rice
(8) Potato
(9) Mixed Vegetables (Peas and Corn)
(10) Milk Solids

We decided to fabricate the bars 1/2-inch thick instead of 1-inch thick because we could combine bars of two varieties for a given meal. This would allow a greater menu variety than if each meal were restricted to one 1-inch bar of one variety. All of the above bars were retained in the final menu.

As adjuncts to the ten basic bars, the following fifteen were chosen for preliminary study.

(1) Beef Gravy
(2) Pork Gravy
(3) Chicken Gravy
(4) Turkey Gravy
(5) Creaming Adjunct
(6) Barbecue Adjunct
(7) Mayonnaise Adjunct
(8) Bacon Adjunct
(9) White Sauce
(10) Chocolate Sauce
(11) Vanilla Sauce
(12) Tomato Sauce
(13) Cheese Sauce
(14) Starch Adjunct
(15) Onion Sauce

The following twelve adjuncts were selected for the final menu. All adjuncts used in the final menu were fabricated as 11/16 inch cubes.

(1)	Brown Gravy	(7)	Bacon
(2)	Home Style Gravy	(8)	White Sauce
(3)	Chicken Gravy	(9)	Cheese Sauce
(4)	Barbecue Sauce	(10)	Onion Sauce
(5)	Tomato Sauce	(11)	Chocolate Sauce
(6)	Mayonnaise	(12)	Butterscotch

The final menu is as follows:

	Meal Item	Components and Quantity
(1)	Beef, Rice and Gravy	Ground Beef Bar (1), Rice Bar (1), Brown Gravy Cube (2 or more)
(2)	Beef and Gravy	Diced Beef Bar (2), Brown Gravy Cube (2 or more)
(3)	Beef Stew	Diced Beef Bar (1), Vegetable Bar (1), Brown Gravy Cube (2 or more) (Combine all components.)
(4)	Beef, Potatoes and Gravy	Diced Beef Bar (1), Potato Bar (1), Brown Gravy Cube (2 or more)
(5)	Beef and Vegetables	Diced Beef Bar (1), Vegetable Bar (1) (Serve separately.)
(6)	Creamed Beef	Ground Beef Bar (2), White Sauce Cube (3 or more)
(7)	Barbecued Beef	Ground Beef Bar (2), Barbecue Cube (1-3)
(8)	Chicken, Rice and Gravy	Chicken Bar (1), Rice Bar (1), Chicken Gravy Cube (1 or more)
(9)	Chicken and Gravy	Chicken Bar (2), Chicken Gravy Cube (2 or more)

Meal Item	Components and Quantity
(10) Chicken Stew	Chicken Bar (1), Vegetable Bar (1), Chicken Gravy Cube (2 or more) (Combine.)
(11) Chicken, Potatoes and Gravy	Chicken Bar (1), Potato Bar (1), Chicken Gravy Cube (2 or more)
(12) Chicken and Vegetables	Chicken Bar (1), Vegetable Bar (1) (Serve separately.)
(13) Chicken Salad	Chicken Bar (2), Bacon Cube (4), Mayonnaise Cube (5)
(14) Barbecued Chicken	Chicken Bar (2), Barbecue Adjunct (2 or more)
(15) Turkey, Rice and Gravy	Turkey Bar (1), Rice Bar (1), Home Style Gravy Cube (2 or more)
(16) Turkey and Gravy	Turkey Bar (2), Home Style Gravy Cube (2 or more)
(17) Turkey Stew	Turkey Bar (1), Vegetable Bar (1), Home Style Gravy Cube (2 or more) (Combine.)
(18) Turkey, Potatoes and Gravy	Turkey Bar (1), Potato Bar (1), Home Style Gravy Cube (2 or more)
(19) Turkey and Vegetables	Turkey Bar (1), Vegetable Bar (1) (Serve separately.)
(20) Turkey Salad	Turkey Bar (2), Bacon Cube (4), Mayonnaise Cube (5)
(21) Barbecued Turkey	Turkey Bar (2), Barbecue Cube (2-3)
(22) Tuna and Rice	Tuna Bar (1), Rice Bar (1)
(23) Tuna and Potatoes	Tuna Bar (1), Potato Bar (1), White Sauce Cube (1 or more)
(24) Tuna Salad	Tuna Bar (2), Bacon Cube (4), Mayonnaise Cube (5)
(25) Tuna and Vegetables	Tuna Bar (1), Vegetable Bar (1) (Serve separately.)

Meal Item	Components and Quantity
(26) Creamed Tuna	Tuna Bar (2), White Sauce Cube (3 or more)
(27) Pork, Rice and Gravy	Pork Bar (1), Rice Bar (1), Home Style Gravy Cube (2 or more)
(28) Pork and Gravy	Pork Bar (2), Home Style Gravy Cube (2 or more)
(29) Pork Stew	Pork Bar (1), Vegetable Bar (1), Home Style Gravy Cube (2 or more)
(30) Pork, Potatoes and Gravy	Pork Bar (1), Potato Bar (1), Home Style Gravy Cube (2 or more)
(31) Pork and Vegetables	Pork Bar (1), Vegetable Bar (1) (Serve separately.)
(32) Barbecued Pork	Pork Bar (2), Barbecue Cube (3 or more)
(33) Beef in Tomato Sauce	Diced Beef Bar (2), Tomato Cubes (3 or more)
(34) Pork in Cheese Sauce	Pork Bar (2), Cheese Cube (3 or more)
(35) Pork in Tomato Sauce	Pork Bar (2), Tomato Cube (3 or more)
(36) Tuna in Tomato Sauce	Tuna Bar (2), Tomato Cube (3 or more)
(37) Tuna in Cheese Sauce	Tuna Bar (2), Cheese Cube (3 or more)
(38) Beef in Cheese Sauce	Diced Beef Bar (2), Cheese Cube (3 or more)
(39) Vegetables with Cheese & Bacon	Vegetable Bar (2), Bacon Cube (3), Cheese Cube (3 or more)
(40) Chocolate Pudding	Milk Solids Bar (2), Chocolate Cubes (4 or more)
(41) Chocolate Drink	Milk Solids Bar (2), Chocolate Cubes (4 or more)

Meal Item	Components and Quantity
(42) Butterscotch Pudding	Milk Solids Bar (2), Butterscotch Cubes (4 or more)
(43) Butterscotch Drink	Milk Solids Bar (2), Butterscotch Cubes (4 or more)
(44) Cream of Potato Soup	Potato Bar (2), Onion Cube (4)
(45) Cream of Tomato Soup	Milk Solids Bar (2), Tomato Cubes (3-4)

From the results of the study of "Food Adjuncts Stabilized as Thin Sheets or Laminates" we knew it was possible to form flexible sheets from a wide variety of food stuffs. We felt this approach would be quite compatible with the parameters of the contract. Therefore, eight varieties of sheets were fabricated and on the whole were found successful but difficulty was encountered in hydrating a few types. This fact in conjunction with the number of operations necessary to produce the finished sheet prompted us to investigate another method of producing the stabilized adjunct. We decided to apply the technique of the bars to the adjuncts and obtained very good results.

A Denison ten ton hydraulic press was used for all compaction work. Pressures given are those upon the surface of the compacted material.

All items were packed in aluminized PVC pouches (pouch stock: 0.5 mil Mylar; 0.00035" aluminum foil, 3 mil polyvinyl chloride).

The bars were packed under 29" of vacuum with very good results. But packaging the adjuncts in this manner caused some of them to become very hard. Subsequent storage without the vacuum of these items showed a marked decrease in their tendency to harden. This is explained fully in the section on interpretation of storage study results.

EXPERIMENTAL

I. Use of Matrices A_3 and B_2 as Binders

Matrices A_3 and B_2 were formulated and found very successful as binders for dry foodstuffs during the course of research on the "All Purpose Matrix for Compressed Food Bars" contract. They are easy to handle, have high caloric values (4.9 and 6.3 calories per gram, respectively), good stability, mild flavor and good rehydration properties. Matrix A_3 has better binding power than B_2 in the same application but due to a higher percentage of sugars may in some cases be too sweet.

We felt Matrices A_3 and B_2 would more than adequately fill our requirements as binders in the applications called for in this contract.

A. Preparation of Matrix A_3

1. Formula

	% Dry	Typical Quantities (lb)
Sodium Caseinate, Edible, Land-O-Lakes	27.00	54.0
Water	-----	216.0
Sucrose, Granulated	10.00	20.00
Dextrose	15.00	30.00
Durkex 500 Oil, Durkee Co.	20.00	40.0
Starch	10.00	20.0
Lactose, Foremost Dairies	18.00	36.0
Water (for lactose make-up)	-----	36.0
		452.0 total 200.0 dry

2. Procedure

a. Make up 20% sodium caseinate solution using Schnellkutter or similar high speed mixer.

b. Pass to make up tank and raise temperature to 130°F.

c. Add sucrose and dextrose to sodium caseinate solution and mix until dissolved.

d. Suspend starch in Durkex oil and pass to make up tank, and mix with the sodium caseinate solution by passing through an Oakes mixer. Check stability at this point by placing a drop or two of the mixture in about 250 ml of 130°F water in a clean container and stirring. If, after the swirling motion of the water has ceased, no oil globules are visible upon the surface, the dispersion is stable. If globules are visible continue mixing the batch until it checks stable.

e. Make up lactose in an equal weight of water. Add to make up tank and mix.

f. Recirculate this completed dispersion through an Oakes mixer.

g. Pass to surge tank and spray dry at 2400 psi with an outlet temperature of 170-175°F and an inlet temperature of 265°F, using a #67 orifice and #17 core.

3. Results

A free flowing white powder of the following composition results.

Protein	23.4%	Ash	1.1%
Fat	20.0%	Carbohydrate	51.1% (by diff.)
Moisture	3.6%	Calories	4.9 per gram

Bacteriological data:

Standard plate count per gram	< 10.0
Coliform colonies per gram	< 5.0
E. Coli per gram	Negative
Fecal Streptococci per gram	< 1.8 MPN
Salmonella	Negative
Staphylococci per gram	Negative

B. Preparation of Matrix B_2

1. Formula

	% Dry	Typical Quantities (lb)
Sodium Caseinate, edible, Land-O-Lakes	19.2	38.4
Water (for Sodium Caseinate solution)	----	153.6
Sucrose, Granulated	7.0	14.0
Durkex 500 Oil, Durkee Co.	47.1	94.2
Starch	10.0	20.0
Lactose, Foremost Dairies	16.7	33.4
Water (for lactose make up)	----	33.4
		387.0 total
		200.0 dry wt

2. Procedure

a. Make up 20% sodium caseinate solution using a Schnellkutter or similar high speed mixer.

b. Pass to make up tank and raise temperature to 130°F.

c. Add sucrose to the sodium caseinate and mix until dissolved.

d. Slurry the starch in the Durkex 500 (temperature 145°F.) oil and pass to the make up tank. Mix with the sodium caseinate solution by passing through an Oakes mixer. Check stability as outlined in Section I, A, 2, d.

e. Dissolve the lactose in an equal weight of water. Add to the make up tank and mix.

f. Recirculate the completed dispersion through an Oakes mixer.

g. Pass to surge tank and spray dry at 2000 psi with an outlet temperature of 263-270°F. using a #67 orifice and a #17 core.

3. Results

The product was a white, free flowing powder of the following composition:

Protein	16.8%	Carbohydrate	32.5% (by diff.)
Fat	47.7%	Ash	0.8%
Moisture	2.2%	Calories	6.3 per gram

Bacteriological Data:

Standard plate count per gram	< 10.0
Coliform colonies per gram	< 5.0
E. Coli per gram	Negative
Fecal Streptococci per gram	< 1.8 MPN
Salmonella	Negative
Staphylococci	Negative

C. Use of Matrix B_2 to Make Diced Beef Food Bars

1. Formula

Beef, diced 3/8", freeze dried (Wilson & Co.)	50.0%
Matrix B_2	36.8%
Pillsbury Brown Gravy Mix	9.95%
Beefatone (Henry H. Ottens, Mfg. Co.)	0.05%
Monosodium Glutamate	1.00%
Salt	2.00%
Caramel Color	0.20%

Add 4 ml water per 100 gms of solids while mixing to increase cohesion.

2. Procedure

Combine all dry ingredients in a Hobart A-200 mixer bowl and mix at speed #1 until homogenous. Continue mixing while adding the water by use of

an atomizer. The depth of fill on the Denison hydraulic press was adjusted to give a finished bar weighing 60 gms. Pressing conditions were: 940 psi with a dwell time of 30% of one second.

3. Results

The finished bar measured 2" x 4" x 1/2". When dropped from 6 feet to a hard flat surface, it did not break but tended to disintegrate around the edge on successive drops.

When crumbled and placed in 90 ml of 80°F. water the bar rehydrated readily within 20 minutes. The calculated calorie value was 4.9 calories per gram resulting in 297 calories per bar.

Some loss of piece identity was noted, possibly caused by the mixing procedure.

D. Use of Matrix B_2 to Make Ground Beef Food Bars

1. Formula

Beef, ground 3/16", freeze dried (Wilson & Co.)	72%
Matrix B_2	25%
Monosodium Glutamate	1%
Salt	2%

Add 4 ml water per 100 gms of solids while mixing to increase cohesion.

2. Procedure

Combine all dry ingredients in an A-200 Hobart bowl. Mix until homogeneous using speed #1 on the mixer, then spray on the water with continued mixing. Depth of fill on the Denison press was adjusted to yield a 60 gm bar. Pressing conditions were 1060 psi with a dwell of 40% of 1 second.

3. Results

The finished bar had the following dimensions: 2" x 4" x 1/2". When dropped from six feet to a hard flat surface, it broke into two pieces (3/4 1/4).

The bar rehydrated readily in 20 minutes when crumbled and added to 60 ml of 80°F. water.

The computed caloric value was 5.4 calories per gram resulting in 324 calories per bar.

E. Use of Matrix B_2 to Make Diced Pork Food Bars

1. Formula

Pork, diced 3/8", freeze dried (Wilson & Co.)	50%
Matrix B_2	37%
Pillsbury Home Style Gravy Mix	10%
Monosodium Glutamate	1%
Salt	2%

Add 4 ml per 100 gms of solids of water while mixing to increase cohesion.

2. Procedure

Add all dry ingredients with the exception of the pork to an A-200 Hobart bowl. Mix at speed #1 until homogeneous, then spray on the water. Add the pork pieces and mix only long enough to obtain homogeneity. Over-mixing will result in excess distribution of the pork fat making good cohesion extremely difficult. The depth of fill on the Denison press was set to give a 60 gm bar. Pressing conditions were 900 psi and a dwell time of 30% of one second.

3. Results

The finished bar measured 2" x 4" x 1/2".

When dropped from six feet to a hard flat surface, it did not break but tended to disintegrate on successive drops. It rehydrated readily in 20 minutes when crumbled and added to 90 ml of 80°F. water.

Computed caloric value was 5.5 calories per gram resulting in 330 calories per bar.

F. Use of Matrix B_2 to Make Diced Chicken Bars

1. Formula

Chicken, diced 3/8", freeze dried (Wilson & Co.)	50%
Matrix B_2	37%
Pillsbury Chicken Gravy Mix	9.95%
Chickatone (Henry H. Ottens Mfg. Co.)	0.05%
Monosodium Glutamate	1.0%
Salt	2.0%

Add 4 ml of water per 100 gms of solids during mixing to increase cohesion.

2. Procedure

Combine all dry ingredients except the chicken in a Hobart A-200 using speed #1 until homogeneous. Continue mixing while spraying on the water, then add the chicken and mix only until homogeneous. Over-mixing will result in loss of particle identity. Depth of fill on the Denison press was adjusted to give a 60 gm bar. Pressing conditions were 950 psi with a dwell time of 40% of one second.

3. Results

The finished bar had the following dimensions: 2" x 4" x 1/2". When dropped from six feet to a hard flat surface the bar had not broken after four drops.

Hydration was readily accomplished in less than 20 minutes by adding the crumbled bar to 90 ml of 80°F. water and stirring intermittently. Computed caloric values were 5.2 calories per gram resulting in a 312 calorie bar.

G. Use of Matrix B_2 to Make a Diced Turkey Food Bar

1. Formula

Turkey, diced 3/8", freeze dried, Wilson & Co.	50.0%
Matrix B_2	37.0%
Pillsbury Home Style Gravy Mix	10.0%
Monosodium Glutamate	1.0%
Salt	2.0%

Add 4 ml of water per 100 grams of solids while mixing to increase cohesion.

2. Procedure

Mix all dry ingredients except the turkey until homogeneous using a Hobart A-200 mixer at speed #1. Spray on the water with continued mixing, then add the turkey pieces and mix only until homogeneous. Overmixing will result in loss of piece identity. Depth of fill on the Denison press was adjusted to give a bar weighing 60 grams. Pressing conditions were 950 psi with a dwell time of 40% of one second.

3. Results

The resulting bars measured 2" x 4" x 1/2". They rehydrated readily in 20 minutes when crumbled and added to 90 ml of 80°F. water and exhibited good strength in that they did not break when dropped a number of times from six feet to a hard flat surface but tended to slowly disintegrate around the edges. Computed caloric values were 5.2 calories per gram giving a 312 calorie bar.

H. Use of Matrix B_2 to Make a Rice Food Bar

1. Formula

Rice, freeze dried (California Vegetable Concentrates)	80%
Matrix B_2	20%

Add 4 ml water per 100 grams solids to increase cohesion.

2. Procedure

a. Place rice in Hobart A-200 mixer. Spray on the water while mixing at speed #1. Immediately add the matrix and continue mixing only until the matrix is distributed on the rice. Depth of fill on the Denison press was adjusted to give a bar weighing 60 grams. Pressing conditions were 950 psi with a dwell time of 40% of one second.

b. Place matrix in Hobart A-200 bowl. Spray on water while mixing at speed #1. Add rice and mix until homogeneous. Depth of fill was adjusted to yield a 60 gram bar. Pressing conditions were 950 psi with a dwell time of 40% of one second.

3. Results

a. The resulting bar measured 2" x 4" x 13/16" and broke into four pieces on the first drop from six feet to a hard flat surface (1/5, 1/5, 1/5, 2/5). When crumbled and added to 85 ml of 80°F. water, the bar rehydrated readily within 20 minutes.

b. This procedure produced a bar 2" x 4" x 25/32" which when dropped as above broke into three pieces (1/4, 1/4, 2/4). This bar also rehydrated readily within 20 minutes when crumbled and added to 85 ml of 80°F. water. This method was used to produce the bars for storage study because of superior strength.

Computed caloric values are 4.42 calories per gram resulting in a 266 calorie bar.

I. Use of Matrix B_2 to Make a Milk Solids Food Bar

1. Formula

Red Owl Instant Nonfat Dry Milk Solids	50%
Matrix B_2	50%

Add 3 ml water per 100 grams of solids while mixing to increase cohesion.

2. Procedure

Thoroughly blend the matrix and milk solids using a Hobart A-200 mixer. Continue mixing while spraying on the water, using an atomizer. Depth of fill was adjusted on the Denison press to yield a 60 gram bar. Optimum pressure anddwell time were 380 psi and 20% of one second respectively.

3. Results

The resulting bar was 2" x 4" x 19/32" thick and when dropped from a height of six feet to a hard flat surface broke into four pieces on the first drop. When thoroughly crumbled and added to 600 ml of 80°F. water it readily dissolved within 20 minutes resulting in a beverage tasting very much like reconstituted milk solids.

The computed caloric values were 4.95 calories per gram and 297 calories per 60 gram bar.

J. Use of Matrix B_2 to Make a Mashed Potato Food Bar

1. Formula

a. Pillsbury Instant Mashed Potato Flakes 80%

Matrix B_2 20%

When blended and hydrated with 90 ml of 80°F. water the above formulation tended to be lumpy and had a distinct flavor from the matrix. We then decided to investigate the possibility of using Pillsbury Sour Cream Mashed Potato Mix because the dehydrated sour cream solids have a composition similar to the matrix.

b. Pillsbury Sour Cream with Bleu Cheese Mashed Potato Mix 100%

4 ml of water per 100 gms of solids

2. Procedure

Add the water to the potato mix by spraying on with an atomizer while mixing at speed #1 using a Hobart A-200 mixer. Depth of fill on the Denison press was adjusted to yield a bar weighing 60 grams. Optimum pressing conditions for this material were 750 psi with a dwell time of 40% of one second.

3. Results

The compacted bar measured 2" x 4" x 15/32" and when dropped from a height of six feet to a hard flat surface did not break but tended to disintegrate along the edges with successive drops. Rehydration was readily accomplished within 20 minutes by crumbling the bar and adding to 230 ml of 80°F. water.

Caloric values are 5 calories per gram or 300 calories per bar.

K. Use of Matrix B_2 to Make a Mixed Vegetable Bar

1. Formula

Corn, freeze-dried (California Vegetable Concentrates)	30.0%
Peas, freeze-dried (California Vegetable Concentrates)	20.0%
Matrix B_2	44.43%
Salt	2.9%
Sugar	1.1%

Corn Syrup Solids	0.6%
Onion Powder	0.17%
Monosodium Glutamate	0.30%
White Pepper	0.20%
Celery Salt	0.20%
Butter Flavor	0.10%

Add 10 ml of water per 100 grams of solids while mixing to increase cohesion.

2. Procedure

Combine all dry ingredients with the exception of the corn and peas using a Hobart A-200 mixer set at speed #1. Continue mixing while spraying on the water. Add the vegetables and mix only long enough to obtain homogeneity. Over-mixing results in loss of piece identity. Depth of fill on the Denison press was adjusted to yield a bar weighing 60 grams. The mixture was compacted under a pressure of 315 psi with a dwell period of 20% of 1 second. The bars were then placed in an air circulating oven set at 140°F. for 4 hours.

3. Results

The resulting bar measured 2" x 4" x 17/32" and when dropped from six feet to a hard flat surface broke into three pieces on the first drop (1/4, 1/4, 1/2). When crumbled and added to 100 ml of 80°F. water, the bar readily rehydrated within 20 minutes. A green color was predominate from the crushed peas. Calculated caloric values were 4.6 per gram or 276 calories per bar.

L. Use of Matrix B_2 to Make a Tuna Food Bar

1. Formula

Tuna, Freeze-Dried (see procedure)	60.0%
Matrix B_2	35.5%
Salt	2.4%
Monosodium Glutamate	1.39%
Sugar	0.40%

Corn Syrup Solids	0.20%
Onion Powder	0.08%
White Pepper	0.01%
Celery Salt	0.01%
Butter Flavor	0.01%

Add 4 ml of water per 100 grams of solids while mixing to increase cohesion.

2. Procedure

Giesha brand water-packed tuna was used. Prior to freeze drying, it was drained, broken into pieces having a cross section no greater than 1/2" and frozen. Freeze drying was done with a Stokes freeze drier; model 2003F2, serial number P65699.

Combine all ingredients using a Hobart A-200 mixer set at speed #1. The water should be sprayed on while mixing. Depth of fill on the Denison press was adjusted to give a 60 gram bar. Compaction was done at a pressure of 1,250 psi with a dwell time of 30% of 1 second.

3. Results

The resulting bar measured 2" x 4" x 9/16". It broke in half on being dropped from six feet to a hard flat surface. Rehydration was readily accomplished within 20 minutes when the bar was crumbled and added to 90 ml of 80°F. water. The calculated caloric values were 5.2 per gram giving 312 calories per bar.

II. Production of Flexible Food Adjuncts Using Hydrocolloids As A Structure Matrix

A. Flexible Barbecue Sauce Adjuncts

1. Formula

Barbecue Sauce (Kraft)	99%
Carboxymethylcellulose	1%

2. Procedure

The carboxymethylcellulose and barbecue sauce were combined by mixing at high speed using a Waring Blendor. Mixing was continued to ensure thorough dispersion of the carboxymethylcellulose (approximately 5 minutes). The mixture was then poured into 2" x 2" x 7" paperboard molds which had been sprayed inside with Dow Corning Slipicone, an aerosol dispensed silicone release agent which is F.D.A. approved for food use as long as the resulting silicone content of the food is no greater than 10 ppm. The filled molds were then placed in a freezer at 0°F. When the mixture was frozen, the mold was peeled away and the mixture sliced into 2" x 2" x 3/32" sheets using a Hobart meat slicer. These sheets were placed on silicone release paper, then put in an air circulating oven set at 70°C. and dried for three hours. They were then turned over and further dried for 45 minutes, allowed to cool, dusted with rice flour to avoid sticking and packaged.

3. Results

The resulting sheets were flexible, measured 2" x 2" x 1/16" thick, weighed approximately 5 grams and when cut into small pieces (1/4" x 1/8") and added to 80°F. water rehydrated readily in 20 minutes. Computed caloric value was 5.4 per gram.

B. Flexible Tomato Sauce Adjuncts

1. Formula

Tomato Sauce	99%
Carboxymethylcellulose	1%

2. Procedure

Mixing, freezing and slicing procedures were the same as for barbecue adjuncts. The sliced sheets were placed on silicone release paper, put in the air circulating oven set at 140°F. for 2 hours, cooled, turned over and left to dry in the laboratory (72°F.) for 24 hours.

3. Results

The resulting sheets were flexible, measured approximately 2" x

2" x 1/32", and weighed approximately 2.5 grams. They rehydrated readily in 20 minutes when cut into 1/8" x 1/4" pieces and added to 80°F. water and stirred intermittently. Caloric values were 2.6 per gram giving 6.5 calories per sheet.

C. Flexible Chicken Gravy Adjuncts

1. Formula

Pillsbury Chicken Gravy Mix	7.5%
Carboxymethylcellulose	1.0%
Water (100°C.)	91.5%

2. Procedure

The carboxymethylcellulose and gravy mix were thoroughly blended by mixing in a Hobart N-50 mixer. The powder was added to the boiling water using a Lightning mixer to disperse the mixture. This was brought to a boil with constant stirring to avoid scorching, then placed in a Waring Blender and mixed at high speed for 2-1/2 to 3 minutes. The mixture was cooled and placed in 3" x 3" x 12" molds prepared as for the barbecue adjunct. The filled molds were placed in the freezer and when thoroughly frozen, the mold was peeled off and the mixture sliced into 3" x 3" x 1/4" sheets which were placed on polyethylene sheets and dried at ambient laboratory conditions (72°F.) for 36 to 48 hours, turning every 8 to 12 hours. A 2" x 2" template was then used to trim the resulting sheet to the proper size.

3. Results

The adjunct was flexible, measured 2" x 2" x 1/64" - 1/32" thick, weighed approximately 1.5 grams and rehydrated readily within 20 minutes when cut into 1/4" x 1/8" pieces and added to 80°F. water and stirred.

Caloric value was 3.2 per gram.

Time and space considerations prohibited production of quantities large enough for storage studies although physical characteristics were very good.

D. Flexible Brown Gravy Adjuncts

1. Formula

Pillsbury Brown Gravy Mix	7.5%

Carboxymethylcellulose	1.0%
Water	91.5% (100°C.)

2. Procedure

The procedure was exactly the same as that used for the chicken gravy adjunct, section II, C.

3. Results

Results were identical to those obtained for the chicken gravy adjunct. Computed caloric value was 2.5 per gram. Time and space considerations prevented production of quantities large enough for storage study although the product was very acceptable in all other respects.

III. Incorporation of Food Adjuncts into Stable Dispersions

We knew from the results of Contract No. DA19-129-AMC-1(N)(OI9000) "Food Sheets Stabilized as Thin Sheets or Laminates" that it was possible to incorporate food adjuncts into stable dispersions and then dry the dispersions as thin sheets. The stable dispersion or encapsulation process is simply two immiscible systems, a film former in the continuous phase surrounding a liquid or once liquid discontinuous phase. The following are needed to form the stable dispersion: (1) Film former, something that is capable of forming a film around something, (2) a liquid which is immiscible in this film former, (3) a plasticizer which actually makes the film former able to form a film, and (4) proper mixing.

It has been found that other materials can be carried in the stable dispersions without breaking the dispersions and thus when the dispersions are dried into sheets, the materials are also incorporated into the sheets.

A. Dispersions Technique for Making White Sauce Adjuncts

1. Formula

Durkex 500 Oil (Durkee Co.)	12.5%
Nonfat Dry Milk Solids (Red Owl Instant)	23.5%
Dextrin (American Maize ARD 1606)	12.0%
Gelatin (Knox)	1.8%

Paprika	0.2%
Water	50.0%

2. Procedure

a. Slurry the oil NFMS, dextrin and paprika using a Waring Blender.

b. Dissolve the gelatin in the water and add this to the slurry with high speed mixing. Continue mixing until a stable dispersion is formed. Check stability as described in section I, A, 2, d. "Make-up of Matrix A3".

c. Place in 2" x 2" x 7" molds prepared as in II, A, 2 and freeze.

d. Slice 1/8" thick using a Hobart meat slicer and place on release paper.

e. Dry 40 minutes at 140°F. in an air circulating oven, then 16 hours at room temperature. Some case hardening was evident so the sheets were placed in polyethylene bags for 24 hours to equilibrate.

3. Results

The resulting sheets were flexible, measured 2" x 2" x 1/8", weighed 8 grams and tasted like white sauce but unfortunately did not rehydrate acceptably within 20 minutes when cut into 1/8" x 1/4" pieces and added to an excess of 80°F. water. These adjuncts were not storage tested.

B. Dispersion Technique for Making Mayonnaise Adjuncts

1. Formula

Durkex 500 Oil (Durkee Co.)	30.0%
Gelatin (Knox)	5.0%
Sodium Caseinate	7.5%
Salt	1.6%
Dry Mustard (Durkee)	1.0%
White Pepper (Red Owl)	0.2%
Sucrose	4.7%
Vinegar (Red Owl)	10.0%
Water	40.0%

2. Procedure

a. Heat the Durkex oil to 150°F., place in a Waring Blender and slurry with the sodium caseinate, sucrose, salt, pepper and mustard.

b. Dissolve the gelatin in the water, heat to 150°F., add this solution to the slurry and mix at high speed until a stable dispersion forms. Check stability as outlined in Section I, A, 2, d. "Make-up of Matrix A_3".

c. Add the vinegar with continued mixing.

d. Place in molds prepared as in Section II, A, 2 and freeze.

e. When thoroughly frozen remove the mold and slice into 3/32" thick sheets using a Hobart electric meat slicer and place on silicone release paper to dry for 24 hours at ambient conditions, turning three times.

3. Results

The adjuncts were flexible, measured 2" x 2" x 1/8", weighed 7.5 grams and tasted like mayonnaise but did not rehydrate well enough in 20 minutes to be acceptable, when cut into 1/8" x 1/4" pieces and added to 80°F. water. This adjunct was not storage tested.

C. Dispersion Technique for Making Vanilla Flavored Adjuncts

1. Formula

Durkex 500 Oil (The Durkee Co.)	20.0%
Sodium Caseinate	7.0%
Gelatin (Knox)	3.0%
Vanilla Concentrate	1.0%
Sucrose	32.0%
Water	37.0%

2. Procedure

a. Heat the oil to 150°F. Place it in a Waring Blender with the sodium caseinate and slurry.

b. Dissolve the gelatin in the water, heat to 150°F. and add to the slurry along with the sucrose.

c. Mix at high speed until a stable dispersion is formed. Check stability as outlined in Section I, A, 2, d. "Make-up of Matrix A_3".

d. Add the vanilla concentrate and mix to distribute.

e. Place in molds prepared as in Section II, A, 2 and freeze.

f. When thoroughly frozen remove the mold, slice 3/32" thick, place on silicone release paper and dry at ambient conditions for 24 hours turning three times.

3. Results

The resulting sheets were flexible, measured 2" x 2" x 1/8", weighed 7.5 grams and rehydrated to an acceptable level within twenty minutes when cut into 1/4" x 1/4" pieces and added to an excess of 80°F. water. They had a calculated caloric value of 4.85 calories per gram. These adjuncts were storage tested.

D. Dispersion Technique for Making Chocolate Flavored Adjuncts

1. Formula

Durkex 500 Oil (The Durkee Co.)	19.0%
Sodium Caseinate	7.0%
Gelatin (Knox)	2.0%
Gelatinized Cocoa	5.0%
Vanilla Concentrate	0.5%
Sucrose	32.0%
Citric Acid (anhydrous)	0.15%
Water	34.35%

2. Procedure

To help keep the bacteria count down and to make the product smoother and more palatable, the cocoa was gelatinized before addition to the product.

Procedure for Gelatinized Cocoa

Mix cocoa and water (approximately 20% solids) into a slurry and place into a Groen vacuum or pressure mixer. Set temperature of the outside steam jacket to 170°F. Set mixing speed at No. 10 and mix for 10 minutes. Next

cut temperature to 150°F. and mix for an additional 1-1/2 hours. Make sure that the lid is fastened tightly while the gelatinizing is being carried on. This gelatinized cocoa is then used in the formula allowing for the moisture in the cocoa. The stable dispersion was made as follows: The Durkex 500 was heated to 150°F. and the sodium caseinate added and mixed until coated with oil. The sucrose was added and mixing continued until all the ingredients were well dispersed. The water, heated to 150°F. in which the gelatin had previously been dissolved, was added with continued mixing until a stable dispersion was formed (approximately 2 minutes). To this stable dispersion was added the pregelatinized cocoa, vanilla concentrate, citric acid and mixing was continued until all ingredients were thoroughly distributed. This product was then poured into molds prepared as in Section II, A, 2 and placed in the freezer. The frozen blocks were then sliced at a No. 10 setting on a Hobart slicer and dried on release paper for 24 hours.

3. Results

The resulting sheets were flexible, measured 2" x 2" x 1/8", weighed 7.8 grams and readily rehydrated when cut into 1/4" x 1/4" pieces and added to an excess of 80°F. water. Calculated caloric value was 4.08 calories per gram. These adjuncts were storage tested.

IV. Production of Stabilized Food Adjuncts By Compression

By using the same technique employed for forming the food bars we found we were able to produce adjuncts stabilized as 11/16" cubes. We chose the cubes shape to conform to the requirements of the contract for maximum space utilization within a rectangular container and because the cube would have almost equal resistance to physical damage on all sides.

To fabricate the cubes we used a trial and error method of placing a weighed amount of material into the press cavity and pressing. Varying amounts were used until we obtained a good cube. This usually necessitated three to six trials. No pressure determinations were made as in compressing to a specified height the stops of the top ram rested on the stop blocks of the lower ram

preventing determination of the pressure upon the compacted material. Pressures used were those sufficient to compact the material to the 11/16 height.

A. Compressed Brown Gravy Adjuncts

1. Formula

Pillsbury Brown Gravy Mix	61.0%
Starch	31.8%
Kelset (Kelco Co.)	3.2%
Water	4.0%

2. Procedure

Thoroughly dry blend all of the dry ingredients using a Hobart N-50 mixer. Add the water by spraying on with continued mixing. Best results were obtained when depth of fill on the Denison press was set to yield a cube weighing 5.8 to 6 grams. Dwell time was 40% of one second.

3. Results

When the cube was thoroughly crushed between the thumb and forefinger and added to 33 ml of 80°F. water, it rehydrated in less than 20 minutes to a product which had the appearance, taste and consistency of gravy. Each cube contained approximately 18 calories at 3.0 calories per gram. It broke into two pieces on the second drop from six feet to a hard flat surface.

B. Compressed Chicken Gravy Adjuncts

1. Formula

Pillsbury Chicken Gravy Mix	61.0%
Starch	31.8%
Kelset (Kelco Co.)	3.2%
Water	4.0%

2. Procedure

The procedure was identical to that in section IV, A, "Compressed Brown Gravy Adjuncts."

3. Results

When the cube was thoroughly crushed between the thumb and forefinger and added to 33 ml of 80°F. water, it rehydrated to a product which had the appearance, taste and consistency of gravy in less than 20 minutes. Each cube contained approximately 21 calories at 3.6 calories per gram. It broke into two pieces on the second drop from six feet to a hard flat surface.

C. Compressed Home Style Gravy Adjuncts

1. Formula

Pillsbury Home Style Gravy Mix	61.0%
Starch	31.8%
Kelset (Kelco Co.)	3.2%
Water	4.0%

2. Procedure

The procedure used was identical to that in section IV, A, "Compressed Brown Gravy Adjuncts."

3. Results

When the cube was thoroughly crushed between the thumb and forefinger and added to 33 ml of 80°F. water, it rehydrated to a product which had the appearance, taste and consistency of gravy within 20 minutes. Each cube contained approximately 18 calories at 3.0 calories per gram. It broke into two pieces on the second drop from six feet to a hard flat surface.

D. Compressed Mayonnaise Adjuncts

1. Formula

Matrix B_2	84.37%
Dried Egg Yolk	3.85%
Salt	3.08%
Dry Mustard (Durkee)	2.88%
Vinstant (Delaware Food Prod., Inc.)	1.44%
White Pepper	0.38%
Water	4.00%

2. Procedure

Thoroughly blend the dry ingredients using a Hobart N-50 mixer set at speed #1. Continue mixing while spraying on the water. Best results were obtained when the depth of fill on the Denison press was set to yield a cube weighing about 5 grams, with a dwell time of 20% of one second.

3. Results

When the cube was thoroughly crushed between the thumb and forefinger and added to 6 ml of 80°F. water with stirring, it rehydrated to a product resembling mayonnaise in less than 20 minutes. Calculated caloric value was 5.7 per gram or 28.5 per cube. It broke into two pieces on the fifth drop from six feet to a hard flat surface.

E. Compressed White Sauce Adjunct

1. Formula

Matrix B_2	48.0%
Nonfat Dry Milk Solids (Red Owl)	44.0%
White Pepper	0.1%
Salt	3.7%
Paprika	0.2%
Water	4.0%

2. Procedure

Thoroughly blend all dry ingredients using a Hobart N-50 mixer set at speed #1. Continue mixing while spraying on the water. Best results were obtained when depth of fill on the Denison press was set to yield a cube weighing about 5 grams. Dwell time was 12% of one second.

3. Results

When thoroughly crumbled between the thumb and forefinger and added to 6 ml of 80°F. water with stirring, this material rehydrated to a product very much like white sauce within twenty minutes. Calculated caloric values are 4.6 per gram and 23 per 5 gram cube. It broke into three equal pieces on the fifth drop from six feet to a hard flat surface.

F. Compressed Cheese Sauce Adjunct

1. Formula

Uncolored Cheese Tang (Kraft)	86.5%
Colored Cheese Tang (Kraft)	9.5%
Water	4.0%

2. Procedure

Thoroughly dry blend the cheese tang using a Hobart N-50 mixer. Spray on the water with continued mixing. Best results were obtained when the depth of fill on the Denison press was adjusted to yield a 4.8 gram cube. Dwell time was 20% of one second.

3. Results

When the cube was thoroughly crushed between the thumb and forefinger and added to 8 ml of 80°F. water, it rehydrated to a cheese sauce product in less than 20 minutes. Calculated caloric values were 5.4 calories per gram or about 26 calories per cube. When dropped from a height of six feet to a hard flat surface, this cube broke into four pieces on the second drop.

G. Compressed Chocolate Sauce Adjuncts

1. Formula

Sugar	37.55%
Cocoa	30.30%
Matrix A3	24.00%
Vanilla	2.00%
Pillsbury Sweet*30 Artificial Sweetener	1.15%
Water	5.00%

2. Procedure

Thoroughly blend all of the dry ingredients using a Hobart N-50 mixer at speed #1. Continue the mixing while spraying on the water. The best results were obtained when the depth of fill on the press was set to yield a cube weighing approximately 6 grams and dwell time was 80% of one second. In this case

the high pressure was held on the bottom ram until just before the top ram cleared the cavity during the ejection stroke. Failure to do this always resulted in cubes split horizontally.

3. Results

When thoroughly crumbled between the thumb and forefinger and added to 5 ml of 80°F. water the material hydrated to a chocolate sauce consistency within twenty minutes. When dropped from six feet to a hard flat surface, it broke into two pieces on the fourth drop. Calculated caloric values were 3.6 per gram or 21 per cube.

H. Compressed Butterscotch Adjuncts

1. Formula

FD&C Yellow Color #5 & #6 (equal parts)	0.016%
Butterscotch Flavor (Florasynth)	0.016%
Caramel Color	1.20 %
Vanilla Flavor	0.40 %
Sucrose (Granulated)	76.768%
Matrix A3	19.60 %
Water	2.00 %

2. Procedure

Combine all dry ingredients in a Hobart N-50 mixer. Spray on the water while continuing the mixing. The best results were obtained when the depth of fill was adjusted to yield a cube weighing about 6.3 grams and using a dwell time of one second.

3. Results

When crushed thoroughly between the thumb and forefinger and added to 6 ml of 80°F. water the material rehydrated to a sauce-like consistency. The cube broke into three pieces on the third drop from six feet to a hard flat surface. Calculated caloric value was 4 per gram or 25 per cube.

I. Compressed Onion Adjuncts

1. Formula

Onion Powder	4.1%
Onion Pieces	23.8%
Salt	35.3%
Black Pepper	0.7%
Matrix B_2	33.1%
Water	3.0%

2. Procedure

Combine all dry ingredients in the Hobart N-50 mixer. Spray on the water while mixing. The best cubes were obtained when the depth of fill was adjusted to yield a cube weighing 5.75 - 6.0 grams with a dwell time of 40% of one second.

3. Results

When thoroughly crushed between the thumb and forefinger and added to 7 ml of 80°F. water the material rehydrated to an onion sauce consistency within twenty minutes. The cube broke into three pieces on the sixth drop from 6 feet to a hard flat surface. The approximate caloric value is 3.4 per gram or 20 calories per cube.

J. Compressed Barbecue Adjunct

1. Formula

Onion Powder	0.17%
Celery Seed (whole)	0.06%
Paprika	0.19%
Cayenne Pepper	0.06%
Cinnamon	0.03%
Allspice	0.045%
Salt	3.30 %
Sugar (Granulated)	26.00 %
Tomato Powder	51.345%

Sodium Diacetate	8.40%
Smoked Yeast (Florasynth)	8.40%
Water	2.00%

2. Procedure

Sift and then thoroughly blend the dry ingredients. Continue the mixing while adding the water by use of an atomizer. The best cubes were produced when the depth of fill was adjusted so as to yield a 5.5 gram cube and the dwell time was 60% of one second.

3. Results

When thoroughly crushed between the thumb and forefinger and added to 10 ml of 80°F. water, a barbecue type sauce resulted almost immediately. This cube did not break when dropped ten times from a height of six feet to a hard flat surface although some flattening of the edges and corners did occur. Calculated caloric value is 3.6 per gram ~~or~~ 20 per cube.

K. Compressed Tomato Sauce Adjuncts

1. Formula

Tomato Powder	59%
Matrix B_2	39%
Water	2%

2. Procedure

Thoroughly dry blend the ingredients. Then spray on the water with continued mixing using an atomizer. The best cubes were obtained by adjusting the depth of fill to produce a 5.5 gram cube and the dwell time was set for 60% of one second.

3. Results

When thoroughly crushed between the thumb and forefinger and added to 10 ml of 80°F. water, a tomato sauce-like product resulted in about five minutes. Drop test results were identical to those for the barbecue cube above. Calculated caloric values were 4.5 per gram or 25 per cube.

L. Compressed Bacon Adjuncts

1. Formula

Bacon (Wilson's Prefried)	58%
Matrix B_2	38%
Water	4%

2. Procedure

Prefry the bacon until quite crisp and then while still hot spread between sheets of absorbent toweling and blot to remove as much fat as possible. Place the matrix in a Hobart N-50 mixer and add the water by spraying on while mixing. Add the bacon and mix only until homogeneous. The best cubes were obtained when the depth of fill was adjusted to yield cubes weighing 5 grams and the dwell set at 40% of ten seconds.

3. Results

The finished cubes had a caloric value of 5.6 per gram or 28 per cube. They crushed easily between the thumb and forefinger and rehydrated within 20 minutes in 6 ml of 80°F. water.

M. Compressed Cream Sauce Adjunct

1. Formula

Coffeemate	96.9%
Sour Cream Flavor (I.F.F. V-9418)	0.1%
Water	3.0%

2. Procedure

Thoroughly dry blend the dry ingredients using a Hobart N-50 mixer. Continue mixing while spraying on the water. The best results were obtained when the depth of fill was adjusted to yield a 4.2 - 4.6 gram cube and the dwell set at 20% of one second.

3. Results

The finished cube broke into three pieces when dropped from six feet to a hard flat surface. It also crushed easily between the thumb and

forefinger and rehydrated almost instantly in 5 ml of 80°F. water. Caloric values are 5. per gram or 26 per cube.

V. Physical Data

As called for in the Scope of the Contract, tests were conducted to determine the amount of fracture, fragmentation and dimensional change resulting from normal handling at temperatures between 0 and 38°C. In addition to the above determinations, the bulk densities of the compacted items were measured and all items checked for stickiness. The determinations were made after the item had been inspected, weighed, measured and packaged in the flexible pouch stock (0.5 mil mylar, 0.00035" aluminum foil, 3 mil polyvinyl chloride), coded and stored four weeks at 38°C. This, we felt, would simulate normal handling.

The procedures for the determinations were the following:

Fracture: Fracture in this application was defined as a complete cleavage which, if separated, would yield two or more pieces each weighing 10% or more of the initial weight of the item. Particles weighing less than 10% of the initial item were termed fragments. All items were inspected before packaging for fractures. No item was packaged for storage if any fracture was present. After storage the same items were again inspected as before to determine if handling and storage had produced any fractures.

Fragmentation: The percent of fragmentation was determined by removing the item from the pouch and then collectively weighing those particles remaining in the pouch which individually weighed less than 10% of the total weight of the item. The collective weight of the particles was divided by the total weight of the item and this figure multiplied by 100.

Dimensional Change: The percent dimensional change was determined by measuring the item with calipers before storage, then again after four weeks storage at 38°C, dividing the difference by the original dimension and multiplying this by 100. The percents which were negative denoted a decrease in size probably due to vacuum packaging.

Stickiness: Stickiness was determined by placing the items on a porcelain support above the liquid level in a glass desiccator containing a saturated solution of sodium chloride. A saturated solution of sodium chloride will maintain a relative humidity of 75% at 20°C. in an enclosed container. The items were then checked for stickiness two hours after the humidity had stabilized at 75% ± two percent as indicated by a dial hygrometer by touching the item and by pressing two identical items together to see if any sticking occurred.

Bulk Density: The bulk density of the compressed items was determined by dividing the weight of the item by the volume. The volume of the compacted bars was measured by use of a National Loaf Volume Meter. The volume of the compressed adjuncts was found by observing the displacement when the adjunct was placed in a

graduated 100 cc cylinder and 25 cc of fine granulated non-caking NaCl was added.

VI. Microbiological, Moisture and Organoleptic Storage Study Results

The following microbiological determinations were made on all items before storage and after eight and thirteen weeks storage, except for Escherichia Coliform which was inadvertently not determined on the Turkey, Pork, Chicken, Diced Beef, or Potato and Milk Solids bars and Chocolate, Vanilla, Barbecue and Tomato Sheets after eight weeks storage: standard plate count per gram, Coliform colonies per gram, Fecal Streptococci per gram, Coagulase positive staphylococci and Escherichia Coliform colonies per gram.

Procedures used for the determination were those specified in the "Microbiological Requirements for Spacefood Prototypes", Addendum No. 1B, dated 30 December 1966, published by the U.S. Army Natick Laboratories, Natick, Massachusetts.

Moisture determinations were made by breaking up the bar or compacted adjunct in an Osterizer, weighing a sample and placing it in a vacuum oven set at 70°C. for 16 hours, then reweighing to determine moisture loss. The flexible sheets were put through a food chopper and then samples weighed and placed in the vacuum oven.

Odor was checked immediately after opening the pouch.

To check hydration of the bars they were crumbled in the hand into pieces no larger than 3/8", placed in a container and the required amount of 80°F. water added with stirring.

Rehydration of the compacted adjuncts was accomplished by crushing the cube to a powder between the thumb and forefinger and adding to the required amount of 80°F. water with stirring.

The sheets were rehydrated by cutting into 1/8" x 1/8" pieces and adding to an excess of 80°F. water with intermittent stirring. Flavor of all the items was checked after complete hydration was attained.

TABLE I

PHYSICAL DATA AFTER 4 WEEKS STORAGE AT 38°C.

Item	% Fragmentation **	Fractures	Dimensional Stability % Change		Bulk Density
			Length	Width	
° Diced Beef Bar I.C.	3.9	None	0	+ 1.54	.73
° Ground Beef Bar I.A.	0	None	+ .77	+ 1.54	.84
° Pork Bar I.E.	0.17	None	+ 1.54	+ 3	.70
° Chicken Bar I.F.	0.0	None	+ 2.34	+ 1.54	.73
° Turkey Bar I.G.	2.0	None	+ 1.54	+ 3	.76
Rice Bar I.H.	.16	None	+ 1.54	+ 1.17	.40
° Milk Solids Bar I.I.	0.83	None	+ .78	0	.95
° Mashed Potato Bar I.J.	0.34	None	+ 1.54	+ 1.54	.67
° Vegetable Bar I.K.	0	None	0	+ .77	.69
° Tuna Bar I.L.	0	None	+ .77	+ 1.54	.69
° Barbecue Sheet II.A.	0	None	-	-	-
° Tomato Sheet II.B.	0	None	-	-	-
° Vanilla Sheet III.C.	0	None	-	-	-
° Chocolate Sheet III.D.	0	None	-	-	-
			Height *	Width	
° Brown Gravy Cube IV.A.	0	None	+ 2.27	+ 2.27	1.18
Chicken Gravy Cube IV.B.	0	None	+13	+ 2.27	1.1
Home Style Gravy Cube IV.C.	0	None	+ 9	+ 2.27	.93
° Mayonnaise Cube IV.D.	0	None	- 4.54	- 2.27	1.09
° White Sauce Cube IV.E.	0	None	0	0	.94
° Cheese Sauce Cube IV.F.	0	None	- 2.27	- 4.54	1.03
° Chocolate Sauce Cub IV.G.	0	None	0	0	1.16
° Butterscotch Cube IV.H.	0	None	+ 2.27	+ 2.27	1.30
° Onion Sauce Cube IV.I.	0	None	0	0	1.53
Barbecue Sauce Cube IV.J.	0	None	+ 6.6	+ 2.27	1.1
Tomato Sauce Cube IV.K.	0	None	+ 4.5	+ 2.27	1.1
° Bacon Cube IV.L.	0	None	+ 9	0	1.1
° Creaming Cube IV.M.	0	None	- 9.0	- 4.54	1.30

* Refers to orientation in the die when pressed

** By Weight

° Vacuum Packed

The creaming cube was the only item to exhibit any stickiness when exposed to a relative humidity of 75% for 2 hours at 72°F.

TABLE II

MICROBIOLOGICAL, MOISTURE AND ORGANOLEPTIC STORAGE STUDY DATA FOR COMPRESSED FOOD BARS

STORAGE AT 100°F. FOR 13 WEEKS

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Turkey Bar							
0	4.92	2840	< 10/gm	Neg.	70 MPN	Neg.	Rehydration: good. Crumbles easily. Flavor, odor & appearance: good.
2	4.99						Rehydration, flavor & odor: typical.
4	5.15						Rehydration: good. Flavor & odor: typical.
8	5.14	1360	40/gm	Neg.	62 MPN		Rehydration: fair. Odor: typical. Some flavor loss.
13	5.13	900	< 3 MPN	Neg.	24 MPN	Neg.	Rehydration: fair. Odor: typical. Some flavor loss.
Pork Bar							
0	4.37	1880	< 10/gm	Neg.	> 140 MPN	Neg.	Rehydration: good. Crumbles easily. Flavor, odor & appearance: good.
2	4.26						Rehydration: good. Flavor & odor: typical.
4	4.27						Rehydration: good. Flavor & odor: typical.
8	4.32	1230	< 10/gm	Neg.	36 MPN	-	Rehydration: fair. Odor: typical. Some flavor loss.
13	4.20	480	< 3 MPN	Neg.	< 110 MPN	Neg.	Rehydration: fair. Odor: typical. Some flavor loss.
Mashed Potato Bar							
0	4.65	840	< 10/gm	Neg.	0.6 MPN	Neg.	Rehydration: excellent. Crumbles easily. Flavor, odor & appearance: good.
2	4.69						Rehydration: excellent. Odor & flavor: typical. Some chipping on edges.

* Standard total plate count per gram

TABLE II - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
4	4.68						Rehydration: excellent. Odor & flavor: typical. Some chipping on edges.
8	4.57	4740	< 10/gm	Neg.	2.3 MPN	-	Rehydration: excellent. Odor & flavor: typical. Some chipping on edges.
13	4.66	1020	< 3/MPN	Neg.	2.3 MPN	Neg.	Rehydration: very good. Odor & flavor: typical. Some chipping on edges.
Milk Solids Bar							
0	4.37	2570	< 10/gm	Neg.	< 140 MPN	Neg.	Rehydration: good. Crumbles readily. Flavor, odor & appearance: good.
2	4.41						Rehydration: fair. Flavor & odor: typical.
4	4.38						Rehydration: poor. Bar too hard to break up easily. Flavor & odor: typical.
8	4.35	820	< 10/gm	Neg.	110 MPN	-	Rehydration: poor. Some fat globules present. Bar too hard to break up easily. Flavor & odor: typical.
13	4.32	1140	< 3 MPN	Neg.	< 110 MPN	Neg.	Rehydration: poor. Many lumps. Bar too hard to break up easily. Flavor & odor: typical.
Ground Beef Bar							
0	5.42	800	< 0.23 MPN	Neg.	24 MPN	Neg.	Rehydration: good. Crumbles easily. Flavor & appearance: good. Odor: strong.
2	5.29						Rehydration: good. Flavor & odor: typical.
4	5.33						Rehydration: good. Flavor & odor: typical.
8	5.41	1240	< 3 MPN	Neg.	24 MPN	Neg.	Rehydration: good. Flavor & odor: typical.
13	5.57	2500	< 3 MPN	Neg.	24 MPN	Neg.	Rehydration: good. Flavor & odor: typical.

TABLE II - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Tuna Bar							
0	4.85	1250	< 0.23 MPN	Neg.	16 MPN	Neg.	Rehydration: good. Crumbles easily. Flavor & appearance: good. Odor: strong.
2	5.01						Rehydration: good. Flavor & odor: typical.
4	4.90						Rehydration: good. Flavor & odor: typical.
8	4.99	1380	< 3 MPN	Neg.	110 MPN	Neg.	Rehydration: good. Flavor & odor: typical.
13	5.08	2050	< 3 MPN	Neg.	4.3 MPN	Neg.	Rehydration: good. Flavor & odor: typical.
Diced Beef Bar							
0	4.80	1400	< 10/gm	Neg.	> 140 MPN	Neg.	Rehydration: good. Crumbles easily. Flavor, odor & appearance: good.
2	4.66						Rehydration: good. Flavor & odor: typical.
4	4.63						Rehydration: good. Flavor & odor: typical.
8	4.67	400	< 10/gm	Neg.	240 MPN	-	Rehydration: fair. Flavor & odor: typical.
13	4.58	710	< 3 MPN	Neg.	7110 MPN	Neg.	Rehydration: good. Odor: typical. Very little flavor loss.
Mixed Vegetable Bar							
0	4.17	640	< 0.23 MPN	Neg.	140 MPN	Neg.	Rehydration: good. Crumbles easily. Flavor, odor & appearance: good.
2	4.44						Rehydration: good. Flavor & odor: typical.
4	4.49						Rehydration: good. Flavor & odor: normal.
8	4.36	1160	< 3 MPN	Neg.	9.3 MPN	Neg.	Rehydration: fair. Flavor & odor: normal.
13	4.68	1700	< 3 MPN	Neg.	7.5 MPN	Neg.	Rehydration: fair. Flavor & odor: normal

TABLE II - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Rice Bar							
0	3.75	550	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: very good. Crumbles easily. Flavor, odor & appearance: good.
2	3.46						Rehydration: very good. Flavor & odor: normal.
4	3.36						Rehydration: very good. Flavor & odor: normal.
8	3.68	150	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: very good. Flavor & odor: normal.
11	3.76	770	< 3 MPN	Neg.	21.0 MPN	Neg.	Rehydration: very good. Flavor & odor: normal
Viced Beef Bar							
0	5.66	640	< 10/gm	Neg.	> 140 MPN	Neg.	Rehydration: good. Crumbles easily. Flavor, odor & appearance: good.
2	4.66						Rehydration: good. Flavor & odor: typical.
4	4.63						Rehydration: good. Flavor & odor: typical.
8	4.67	400	< 10/gm	Neg.	240 MPN	-	Rehydration: fair. Odor: typical. Some flavor loss.
13	4.58	710	< 3 MPN	Neg.	> 110 MPN	Neg.	Rehydration: good. Odor: typical. Some flavor loss.

TABLE III

MICROBIOLOGICAL, MOISTURE AND ORGANOLEPTIC STORAGE STUDY DATA FOR FOOD ADJUNCT SHEETS

STORAGE AT 100°F. FOR 13 WEEKS

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Chocolate Sauce Sheets							
0	15.24	120	< 10/gm	Pos.	< .23 MPN	Neg.	Rehydration: fair. Flavor, odor & appearance: good.
2	15.59						Rehydration: poor. Sticking together. Flavor & odor: normal. Flexible.
4	15.25						Rehydration: poor. Sticking together. Flavor & odor: normal. Flexible.
8	15.09	160	< 10/gm	Neg.	2.3 MPN	-	Same as 4 weeks.
13	15.89	260	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: poor. Sticking together. Bloom. Flavor & odor: normal.
Vanilla Sauce Sheets							
0	12.06	50	< 10/gm	Neg.	.26 MPN	Neg.	Rehydration: fair. Flavor, odor & appearance: good.
2	12.41						Rehydration: poor. Sticking together. Oily surface. Flavor & odor: normal. Flexible.
4	12.07						Rehydration: poor. Sticking together. Flexible. Oily surface. Odor & flavor: normal.
8	11.83	200	< 10/gm	Neg.	62 MPN	-	Same as 4 weeks.
13	12.60	380	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: poor. Sticking together. Surface oily & motted. Flavor & odor: normal.

* Standard total plate count per gram

TABLE III - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Tomato Sauce Sheets							
0	14.83	1000	10/gm	Neg.	< .23 MPN	Neg.	Rehydration: fair. Flavor, odor & appearance: good.
2	16.13						Rehydration: poor. Stuck together. Flavor & odor: normal.
4	15.34						Same as 2 weeks.
8	15.62	910	< 10/gm	Neg.	2.3 MPN	-	Rehydration: poor. Stuck together. Flavor & odor: normal. Somewhat darker appearance.
13	15.39	1170	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: very poor. Burned odor. Very dark color. Not tasted.
Barbecue Sauce Sheets							
0	12.48	750	< 10/gm	Neg.	24 MPN	Neg.	Rehydration: good. Flavor, odor & appearance: good.
2	12.71						Rehydration: fair. Stuck together. Flavor & odor: normal.
4	13.71						Same as 2 weeks.
8	12.88	10	< 10/gm	Neg.	2.3 MPN	-	Rehydration: fair. Stuck together. Flavor & odor: normal.
13	14.23	780	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: poor. Stuck together. Flavor & odor: normal.

TABLE IV

MICROBIOLOGICAL, MOISTURE AND ORGANOLEPTIC STORAGE STUDY DATA FOR COMPRESSED FOOD ADJUNCT CUBES

STORAGE AT 100°F. FOR 13 WEEKS

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Brown Gravy Cubes							
0	4.10	700	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: excellent. Crushes easily. Flavor, odor & appearance: good.
2	3.75						Rehydration: excellent. Flavor & odor: normal.
4	4.12						Rehydration: excellent. Flavor & odor: normal.
8	4.20	310	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: excellent. Flavor & odor: normal.
13	3.96	690	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: excellent. Flavor, odor & appearance: normal.
Onion Sauce Cubes							
0	4.60	3000	3.6 MPN	Neg.	> 110 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	4.46						Rehydration: good. Hard to crush. Flavor & odor: normal.
4	4.42						Rehydration: fair. Very hard to crush. Somewhat darker. Flavor & odor: normal.
8	4.49	≯ 3000	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: fair. Very hard to crush. Color darker. Flavor & odor: normal.
13	4.24	> 3000 <10,000	< 3 MPN	Neg.	0.3 MPN	Neg.	Rehydration: fair. Very hard. Flavor & odor: normal. Darkening.

* Standard total plate count per gram

TABLE IV - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
				Chocolate Cubes			
0	4.95	1150	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	3.98						Rehydration: good. Crushes easily. Flavor, odor & appearance: normal.
4	5.19						Rehydration: good. Very difficult to crush. Flavor, odor & appearance: normal.
8	5.14	1000	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Hard to crush. Flavor, odor & appearance: normal.
13	5.09	925	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Hard to crush. Flavor, odor & appearance: normal.
				Butterscotch Cubes			
0	1.99	100	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	2.24						Rehydration: good. Slightly hard to crush. Flavor, odor & appearance: normal.
4	2.24						Rehydration: good. Impossible to crush with fingers. Flavor, odor & appearance: normal.
8	2.28	45	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Very hard to crush. Flavor, odor & appearance: normal.
13	2.20	15	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Impossible to crush with fingers. Flavor, odor & appearance; Normal.

TABLE IV - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Cheese Cubes							
0	4.83	1420	9.1 MPN	Neg.	4.3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	4.92						Rehydration: fair. Hard to crush. Flavor, odor & appearance: normal.
4	4.93						Rehydration: good. Very difficult to crush with fingers. Flavor, odor & appearance: normal.
8	4.88	45	< 3 MPN	Neg.	2.3 MPN	Neg.	Rehydration: good. Very difficult to crush with fingers. Flavor, odor & appearance: normal.
13	4.99	220	< 3 MPN	Neg.	2.3 MPN	Neg.	Rehydration: good. Hard to crush with fingers. Flavor, odor & appearance: normal.
Creaming Adjunct Cubes							
0	4.59	2690	< 3 MPN	Neg.	9.3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	4.68						Hard to crush. Rehydration: fair. Flavor, odor & appearance: normal.
4	4.68						Rehydration: good. Impossible to crush by hand. Flavor, odor & appearance: normal.
8	4.64	20	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: fair. Impossible to crush by hand. Flavor, odor & appearance: normal.
13	4.71	50	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: fair. Very hard & brittle. Flavor & odor: normal. Darker color.

TABLE IV - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Mayonnaise Cubes							
0	4.18	780	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	4.27						Rehydration: poor. Hard to crush. Flavor, odor & appearance: normal.
4	4.26						Rehydration: good. Impossible to crush with fingers. Flavor, odor & appearance: normal.
8	4.14	60	9.1 MPN	Neg.	2.3 MPN	Neg.	Rehydration: good. Impossible to crush with fingers. Flavor, odor & appearance: normal.
13	4.21	240	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Impossible to crush with fingers. Flavor, odor: normal. Color: darker.
White Sauce Cubes							
0	2.02	> 3000 < 10,000	< 3 MPN	Neg.	< 3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	2.74						Rehydration: fair. Hard to crush. Flavor, odor & appearance: normal.
4	2.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rehydration: good. Hard to crush. Flavor, odor & appearance: normal.
8	2.72	> 3000 < 10,000	23 MPN	Neg.	.91 MPN	Neg.	Rehydration: good. Impossible to crush with fingers. Flavor, odor & appearance: normal.
13	2.88	> 3000 < 10,000	< 3.0 MPN	Neg.	0.73 MPN	Neg.	Rehydration: good. Impossible to crush with fingers. Flavor, odor & appearance: normal.

TABLE IV - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Chicken Gravy Cubes							
0	2.39	240	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	2.54						Rehydration: good. Crushes easily. Flavor, odor & appearance: normal.
4	2.41						Rehydration: good. Crushes easily. Flavor, odor & appearance: normal.
8	2.64	520	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: normal.
11*	2.73	280	< 3 MPN	Neg.	.91 MPN	Neg.	Rehydration: good. Crushes readily. Flavor, odor & appearance: normal.
Home Style Gravy Cubes							
0	2.53	180	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	2.61						Rehydration: good. Crushes easily. Flavor, odor & appearance: normal.
4	2.82						Rehydration: good. Crushes easily. Flavor, odor & appearance: normal.
8	2.75	1280	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: normal.
11*	2.76	190	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Flavor, odor & appearance: normal.

* See page 55

TABLE IV - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
Bacon Cubes							
0	5.32	250	< 3 MPN	Neg.	.91 MPN	Neg.	Rehydration: very good. Crushes easily. Flavor, odor & appearance: good.
2	4.64						Rehydration: very good. Easy to crush. Flavor, odor & appearance: normal.
4	5.02						Rehydration: good. Slightly hard to crush. Flavor, odor & appearance: normal.
8	4.65	300	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Slightly hard to crush. Flavor & odor: normal. Some darkening.
11*	4.75	400	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Somewhat hard to crush. Flavor & odor: normal. Some darkening.
Tomato Cubes							
0	1.73	25	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Crushes easily. Flavor, odor & appearance: good.
2	1.97						Rehydration: good. Easy to crush. Flavor, odor & appearance: normal.
4	2.18						Rehydration: good. Fairly easy to crush. Flavor, odor & appearance: normal.
8	1.98	20	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: fair. Some lumps. Slightly hard to crush. Flavor & odor: normal. Some darkening.
11*	1.79	109	< 3 MPN	Neg.	< 0.3 MPN	-	Rehydration: fair. Some lumps. Somewhat hard to crush. Flavor & odor: normal. Somewhat darker.

* See page 55

TABLE IV - (cont'd)

Weeks In Storage	Moisture %	TPC*	Coliforms	Staph.	Strep.	E. Coli.	Organoleptic
			Barbecue Cubes				
0	2.60	810	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: very good. Crushes easily. Flavor, odor & appearance: good.
2	2.72						Rehydration: very good. Crushes readily. Flavor, odor & appearance: normal.
4	2.92						Rehydration: very good. Crushes readily. Flavor, odor & appearance: normal.
8	2.76	1580	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Somewhat firm. Slightly difficult to crush. Flavor & odor: normal. Some darkening.
11 *	2.57	10	< 3 MPN	Neg.	< 0.3 MPN	Neg.	Rehydration: good. Somewhat hard. Difficult to crush. Flavor & odor: normal. Color : darker.

* See page 55

TABLE V

HEDONIC RATING OF THE 45 MEAL ITEMS BEFORE & AFTER THIRTEEN WEEKS STORAGE AT 100°F. USING A NINE POINT 5 NEUTRAL HEDONIC SCALE

5 Neutral Hedonic Scale

9 Like extremely	5 Neither like nor dislike
8 Like very much	4 Dislike slightly
7 Like moderately	3 Dislike moderately
6 Like slightly	2 Dislike very much
	1 Dislike extremely

Meal Item	Rating: * Before	*After
Beef, Rice & Gravy	7	6.0
Beef & Gravy	7.5	6.1
Beef Stew	7	5.4
Beef, Potatoes & Gravy	7.5	5.8
Beef & Vegetables	6	5.7
Creamed Beef	5	5.2
Barbecued Beef	7.1	6.5
Chicken, Rice & Gravy	6	5.0
Chicken & Gravy	6.5	5.6
Chicken Stew	6.2	5.5
Chicken, Potatoes & Gravy	6.6	3.9
Chicken & Vegetables	6.2	6.3
Chicken Salad	5.1	4.5
Barbecued Chicken	6.0	5.7
Turkey, Rice & Gravy	6.5	4.3
Turkey & Gravy	7.1	6.9
Turkey Stew	7.0	5.3
Turkey, Potatoes & Gravy	7.5	6.5
Turkey & Vegetables	6.2	5.7
Tuna & Rice	5.0	4.0

Meal Item	Rating: * Before	*After
Tuna & Potatoes	6.0	5.4
Tuna Salad	5.0	3.9
Tuna & Vegetables	5.2	5.4
Creamed Tuna	6.0	5.5
Pork, Rice & Gravy	7.2	6.5
Pork Stew	7.0	3.5
Pork, Potatoes & Gravy	8.0	5.0
Pork & Gravy	8.0	6.3
Pork & Vegetables	7.1	6.8
Barbecued Pork	7.0	6.5
Beef in Tomato Sauce	6.0	5.8
Pork in Cheese Sauce	5.9	5.0
Pork in Tomato Sauce	6.0	6.2
Tuna in Tomato Sauce	5.0	3.7
Tuna in Cheese Sauce	6.0	6.1
Beef in Cheese Sauce	6.1	4.8
Vegetables with Bacon in Cheese Sauce	5.2	5.3
Chocolate Pudding	7.5	5.7
Turkey Salad	6.0	5.8
Barbecued Turkey	7.0	5.6
Butterscotch Drink	6.1	5.6
Cream of Tomato Soup	6.0	4.7
Chocolate Drink	7.0	6.8
Butterscotch Pudding	6.5	5.8
Cream of Potato Soup	7	7.1

*Before storage the items were rated by an expert panel. After storage the items were rated by a random sample panel.

TABLE VI

HEDONIC RATING OF THE 45 MEAL ITEMS AFTER THIRTEEN WEEKS STORAGE AT 100°F. USING A NINE POINT 3 NEUTRAL SCALE

Nine Point Hedonic Scale

9 Like extremely
8 Like strongly
7 Like very well
6 Like fairly well
5 Like moderately
4 Like mildly
3 Neutral
2 Dislike moderately
1 Dislike intensely

Meal Item	Rating	Meal Item	Rating
Beef, Rice & Gravy	4.0	Tuna & Rice	1.3
Beef & Gravy	4.0	Tuna & Potato	4.0
Beef Stew	5.0	Tuna Salad	3.0
Beef, Potatoes & Gravy	5.0	Tuna & Vegetables	2.7
Beef & Vegetables	4.3	Creamed Tuna	4.0
Creamed Beef	3.7	Pork, Rice & Gravy	4.0
Barbecued Beef	5.3	Pork Stew	2.0
Chicken, Rice & Gravy	2.7	Pork, Potatoes & Gravy	2.7
Chicken & Gravy	3.3	Pork & Gravy	4.3
Chicken Stew	3.0	Pork & Vegetables	5.3
Chicken, Potatoes & Gravy	1.7	Barbecued Pork	4.3
Chicken & Vegetables	3.7	Beef In Tomato Sauce	5.0
Chicken Salad	3.3	Pork In Cheese Sauce	3.3
Barbecued Chicken	3.7	Pork In Tomato Sauce	4.7
Turkey, Rice & Gravy	3.0	Tuna In Tomato Sauce	3.0
Turkey & Gravy	6.3	Tuna In Cheese Sauce	4.3
Turkey Stew	4.7	Beef In Cheese Sauce	4.7
Turkey, Potatoes & Gravy	5.0	Vegetables with Bacon In Cheese	3.3
Turkey & Vegetables	4.7	Chocolate Pudding	4.0
Turkey Salad	3.7	Chocolate Drink	5.3

Meal Item	Rating	Meal Item	Rating
Barbecued Turkey	2.7	Butterscotch Pudding	3.7
Butterscotch Drink	3.0	Cream of Potato Soup	7.0
Cream of Tomato Soup	4.0		

VII. Interpretation of Storage Study Results

A. Microbiological

No significant growth patterns were observed. This is an agreement with our past experiences with these materials in which we found that if the moisture level is held at 5% or below, little or no growth occurs and in some cases a decrease in viable organisms is observed.

It should be noted that although the method for determining coliform colonies was changed from a plate to a tube method after evaluating the eight week samples of the turkey, pork, chicken, diced beef, mashed potatoes, and milk solids bars, chocolate, vanilla, barbecue and tomato sheets, the results correspond in that the counts were the lowest possible for the method used. All of the remaining products were checked for coliform colonies using the tube method throughout the storage study.

The final evaluation of bacon cubes, tomato cubes, chicken gravy cubes, home style gravy cubes, barbecue cubes and rice bar was done after 11 weeks instead of 13 weeks in order to finish within the contract period.

B. Physical

Excessive dimensional changes were observed in three of the bar items (diced beef, turkey and pork). The maximum change was +3% in width. All changes were increases. It should be stressed that the turkey and pork bar both gained 1/16 inch in length and width but because the original width was only one-half the original length, an identical change in length and width resulted in a percentage change twice as great for the width as for the length.

Eleven of the cubes showed dimensional changes in excess of 2% of the original dimension. Some increased in size while others decreased. The vacuum packaging in the flexible pouches was probably the cause of the size decreases noted in some items.

No problems were encountered in packing the items into the 7000 cc volume because of the dimensional changes noted and in fact a minimum of 33 meal items (66 bars) complete with cubes (110 may be packed in a box 12 x 8.5 x 4 inches.

Excessive fragmentation was observed in the diced beef only. This was caused by overmixing of the ingredients resulting in shredding of the beef and distribution of excess beef fat which hindered cohesion.

A number of the adjunct cubes became very hard and therefore difficult to break up before rehydration was attempted. This problem is discussed in the section "Effects of Vacuum Packaging versus Atmospheric Packaging in Flexible Pouches on Food Adjunct Cubes.

C. Organoleptic

On the whole most items were in good condition after the 13 week storage period. Some items darkened; others had some noticeable flavor loss (all items probably lost or changed flavor to some extent) and others became very hard. All of the above undesirable characteristics could either be eliminated or lessened so as not to be objectionable by formulation changes. As stated before, the hardening of many of the cubes was due to their being packed in the flexible pouches under a vacuum.

Of the 45 meal items which were evaluated by a panel after 13 weeks storage only 7 items or 15.6% received a rating lower than 3 (neither like nor dislike) on a 9 point hedonic scale. The lowest value was 1.3, the highest 7. Using the 5 neutral 9 point hedonic scale, eight items or 17.8% received a rating lower than 5. The lowest value was 3.5, the highest 7.1. The ratings are good considering the storage conditions and in addition, the items had not been optimized for flavor but rather formulated to meet the caloric, volume and physical requirements of the contract.

VIII. Effect of Vacuum Packaging as Opposed to Atmospheric Packaging in Flexible Pouches on Food Adjunct Cubes

We found that some of the food adjunct cubes became very hard or impossible to crush between the thumb and forefinger after two weeks storage at 100°F. when packed in flexible laminated foil pouches under a vacuum. The cubes must be crushed to facilitate rehydration.

We decided to find out if substituting a pregelatinized starch for the matrix would alleviate the problem. The following cubes were manufactured with the

starch completely replacing the matrix: chocolate, onion, mayonnaise, *cheese and white sauce. Half of each type was packaged under vacuum in the flexible pouches, the other half in air in the same type of pouches. In addition, the following cubes made from the B_2 formulations were packaged in the pouches with no vacuum: chocolate, onion, white sauce and butterscotch to determine if use of the vacuum was primarily responsible for the hardening observed in those in the storage study.

All of the samples were placed in a temperature controlled oven set at 100°F. and observed after 2 weeks, 4 weeks, etc.

The following results were obtained.

TABLE VII

CRUSHABILITY

Item	2 wks		4 wks		8 wks	
	Air	Vac	Air	Vac	Air	Vac
Starch Formulations						
Chocolate	good	good	good	good	good	good
Onion	good	good	good	hard	good	hard
Mayonnaise	good	good	good	good	good	good
White sauce	good	difficult	good	good	good	good
Cheese	good	good	very easy		very easy	good
B_2 Formulation						
Chocolate	good		good		good	
Onion	hard		fair		fair	
White sauce	very hard		very hard		very hard	
Butterscotch	good		fair		good	

By comparing the above results and those of the storage study, it can be seen that both formulation and packaging were factors in causing the excessive hardness of some cubes. Formulations will have to be adjusted to yield cubes which will remain crushable to facilitate rehydration.

IX. Nutritional Values of Ingredients

The nutritional values used to calculate the caloric content of the bars and food adjuncts are given in Table VIII.

*Starch replaced 60% of Cheese Tang.

TABLE VIII

NUTRITIONAL VALUES OF INGREDIENTS USED

Ingredient	Calculated K cal/gm	% Protein	% Fat
*Beef, diced 3/8", Wilson & Co.	4.6	85.	14.5
*Beef, ground 3/16", Wilson & Co.	5.3	72.	29.2
*Chicken, diced 3/8", Wilson & Co.	4.9	81.1	18.4
*Turkey, diced 3/8", Wilson & Co.	5.1	76	23.5
*Pork, diced 3/8", Wilson & Co.	5.8	61.	38.
*Tuna, pcs.	4.1	96.5	2.8
°Matrix B_2	6.3		
°Matrix A_3	4.9		
*Rice F.D., Calif. Veg. Concentrates	3.95		
*Corn F.D., Calif. Veg. Concentrates	3.5		
*Peas F.D., Calif. Veg. Concentrates	3.8		
°Brown Gravy Mix, Pillsbury	2.8		
°Home Style Gravy, Pillsbury	2.8		
°Chicken Gravy Mix, Pillsbury	3.38		
*Sugar	3.85		
*Corn Syrup Solids	3.4		
°Sour Cream Mashed Potato Mix, Pillsbury	5.0		
*Milk Solids, Red Owl	3.6		
*Dry Mustard, Durkee	4.1		
*Dried Egg Yolk	6.6		
*Cocoa	2.95		
*Onion Pcs. & Powder	3.5		
*Starch	3.7		
*Cheese Tang, Kraft (both)	5.8		
*Bacon Bits, Wilson	6.1		
*Tomato Powder	3.5		
*Smoked Yeast	3.1		

Ingredient	Calculated K cal/gm	% Protein	% Fat
*Durkex 500 Oil, The Durkee Co.	8.8		
[z]Gelatin (Knox)	4.0		
[c]Sodium Caseinate (Land-O-Lakes)	4.2		
[z]Coffeemate (The Carnation Co.)	5.9		

*Calculated from data contained in "Composition of Foods", Agriculture Handbook No.8, United States Department of Agriculture, Rev. 1963.

[c]Land O'Lakes Technical Bulletin No. 101.

[o]Values obtained from the manufacturer.

[z]Label value.

X. Label Declarations of Commercially Available Proprietary Ingredients

The label declaration of commercially available proprietary ingredients is given in Table IX.

TABLE IX

LABEL DECLARATION OF COMMERCIALLY AVAILABLE PROPRIETARY INGREDIENTS

1. Mashed Potato Mix, Sour Cream with Bleu Cheese
   The Pillsbury Company

   Potato flakes, sour cream solids, dehydrated Bleu Cheese, vegetable greens, sodium phosphates, monoglycerides, citric acid, and artificial flavor. Potato flakes and sour cream solids preserved with sodium sulfites, BHA, BHT and propyl gallate.

2. Home Style Gravy Mix
   The Pillsbury Company

   Modified food starch, hydrolyzed plant proteins, bleached flour, corn syrup solids, salt, monosodium glutamate, dried onions, vegetable shortening with mono- and diglycerides, flavoring, spices, and caramel coloring.

3. Chicken Gravy Mix
   The Pillsbury Company

   Modified food starch, dehydrated chicken chunks with BHA perservative, hydrolyzed plant protein, bleached flour, corn syrup solids, salt, monosodium glutamate, vegetable shortening with mono- and diglycerides, artificial coloring and flavoring.

4. Brown Gravy Mix
   The Pillsbury Company

   Modified food starch, hydrolyzed plant proteins, bleached flour, salt, corn syrup solids, dried onions, monosodium glutamate, vegetable shortening with mono- and diglycerides, citric acid, flavoring, spices and caramel coloring.

5. Coffee-mate
   The Carnation Co.

   Corn syrup solids, vegetable fat, sodium caseinate, dipotassium phosphate, emulsifier, sodium silico-aluminate, artificial flavor and artificial colors.

Use of the above materials does not constitute an official endorsement or approval.

XI. Comments

The four packed units sent to the U.S. Army Natick Laboratories for their evaluation contained 66 bars (enough for 33 meal items) and 110 cubes in a volume 12" x 8.5" x 4". This more than fulfilled the requirements of the contract as it called for 30 meal items in a 7000 cc volume. A container with the above interior dimensions contains approximately 6,700 cc.

In packing the units for evaluation, it was necessary to use a packaging material on the different varieties of bars and cubes to prevent odor, flavor and fat transfer. Also the milk solids bar and rice bar were 19/32" and 25/32" thick respectively. These two factors prevented us from packing the units as full as desired.

If all bars selected were 1/2 inch or less in thickness and no packaging material were used, a maximum of 86 bars (43 meal items) and 152 cubes could be packed in one unit with dimensions of 12" x 8.5" x 4". Approximately 3.2 cubes should be allowed per meal item, consistent with space available, to permit some variation from the given menu in adjuncts used per meal item.

XII. Areas of Future Work

Future work on this system should include flavor optimization, improving rehydration after extended storage, prevention of hardening of the components and evaluation of a low volume non-toxic, vapor barrier, easily removable packaging material.

XIII. Summary

The results of the study indicate that the concept of a compacted stable feeding system with ratio of 2.57 calories per cc is definitely possible and that a ratio as high as 3.5 calories is feasible.

The components are physically and microbiologically stable and organoleptically acceptable for a period of at least 13 weeks when stored at 100°F. in foil pouches, some of which were under a vacuum. From a system comprised of 10 bars

and 12 adjuncts, 45 different meal items may be prepared, each meal item yielding approximately 600 calories.

The system should be optimized by improving flavor, rehydration characteristics and development of a suitable packaging material or coating to separate the various components.

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13. ABSTRACT

This study was originated to design, develop, and demonstrate an integrated feeding system based on a specified number of stable food components which can be stored in a limited space and from which can be prepared a variety of nutritious food items.

Information is presented for the preparation of 10 food bars, 4 food sheets and 13 food adjunct cubes. Data are given on these components packed in flexible pouches, some under vacuum, after a thirteen week storage study. Evaluations were carried out on microbiological, physical and organoleptic considerations. Hedonic ratings are shown for 45 meals prepared from these components before and after thirteen weeks' storage at 38 C using both a nine point 5 neutral scale and a nine point 3 neutral scale. Nutritional values of ingredients used are listed.

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Acceptability	8		7			
Food adjuncts	2,9		9			
Food bars	2,9		9			
Food sheets	2,9		9			
Dehydrated	0		0			
Military rations	4		4			