AD

TECHNICAL REPORT

74-53-FEL

INVESTIGATION OF REHYDRATION CHARACTERISTICS OF COMPRESSED COMMINUTED MEATS

by

Arvind S. Ranadive

Emil A. Huang

Edward Seltzer

Food Science Department, Cook College
Rutgers University
New Brunswick, New Jersey 08903

DAAG17-73-C-0015

FEL-33

June 1974

Approved for public release; distribution unlimited.

UNITED STATES ARMY
NATICK DEVELOPMENT CENTER
NATICK, MASSACHUSETTS 01760

U.S. ARMY MATERIEL COMMAND

Food Engineering Laboratory

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 74-53-FL
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): INVESTIGATION OF REHYDRATION CHARACTERISTICS OF COMPRESSED COMMINUTED MEATS
5. TYPE OF REPORT & PERIOD COVERED: Final, Sept 1972 - Dec 1973
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s):

Arvind S. Ranadive
Emil A. Huang
Edward Seltzer

8. CONTRACT OR GRANT NUMBER(s): DAAG17-73-C-0015
9. PERFORMING ORGANIZATION NAME AND ADDRESS:

Food Science Department, Cook College
Rutgers University
New Brunswick, New Jersey 08903

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 6.2, 1T762713A034, 01-007
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Natick Development Center, Natick, Massachusetts 01760
12. REPORT DATE: June 1974
13. NUMBER OF PAGES:
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

	Link A		Link B		Link C	
	Role	WT	Role	WT	Role	WT
Rehydration	8		4		6	
Freeze Dried Foods	9		9		9	
Compressed Foods	9				9	

(Cont.)

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

This report presents formulations of dehydrated compressed comminuted meat products with controlled rehydration properties.

Meatballs and pork sausages are deep-fat fried, freeze dried, slightly remoistened, compressed into blocks and then redried. Selection of suitable binder systems is vital for insuring adequate rehydration without overimbibition.

19. Key Words (Continued)

	Link A Role	Link A WT	Link B Role	Link B WT	Link C Role	Link C WT
Pork	9		9		9	
Sausages	9		9		9	
Meat Balls	9		9		9	
Precooked	0		0		0	
Compressing			8			
Plasticizing			10			
Weight					7	
Volume					7	
Size					7	
Shape					7	

20. Abstract (Continued)

Combinations of certain cross-linked and/or pregelatinized modified starches with small amounts of isolated wheat gluten were found to impart desired characteristics.

FOREWORD

In the freeze drying of foods moisture is removed, but the volume remains essentially unchanged. Thus, there is a substantial saving in weight, but no saving in volume. However, it has been shown that freeze dried foods can be compressed to save volume with the use of plasticizing agents so that they will rehydrate to their original size and shape.

Work at NLABS has shown that freeze dried precooked pork sausage and meat balls can be compressed using approximately 10 percent moisture as a plasticizer and will rehydrate very rapidly. However, they tend to over rehydrate when placed in an excess of water, becoming larger than originally and containing water like a sponge. This contract was designed to investigate the rehydration characteristics of compressed freeze dried precooked pork sausage and meat balls and to determine ways in which the rehydration could be controlled.

The study was conducted under Project Number 1J662713A034. Prof. Edward Seltzer was the Principal Investigator and Mr. J.M. Tuomy the NLABS Project Officer. Mr. Richard Helmer was the alternate Project Officer.

Acknowledgments

The prosecution of a product and process project in a university requires the services of students who may work part-time during the academic season and full-time during the summer. Their skills, interest and initiative (and often a certain amount of creativity) are indispensible to the workmanlike performance of such research and development. The following graduate students deserve identification with this effort:

Miss Anne Elizabeth Sloan (bacteriology, analytical methods);

Miss Ann E. Huang (browning analysis methods, rehydration tests, peroxide tests);

Mr. Richard Stier (product formulation and preparation);

Miss Cathy Ann Schafer (panel test supervision).

Mr. Robert Killops, engineer of the Food Science building and facilities, faithfully and conscientiously participated in installing and tuning up a complex pilot plant freeze dryer system. This had been contributed by Best Foods Co., Division of C.P.C. International with funds for rehabilitating and installing.

TABLE OF CONTENTS

List of Tables

List of Figures

Figure		Page No.

INVESTIGATION OF REHYDRATION CHARACTERISTICS OF COMPRESSED COMMINUTED MEATS

I. Introduction:

A. General:

Freeze dried foods often have the advantages of good shelf stability, good color of rehydrated product, good flavor and light weight. Also in freeze dehydrated foods volume reduction is negligible and hence density of these products is very low. Science and technology are not being utilized to profit potentially from simultaneous weight and volume reduction of the freeze dried food, and consequently, a new class of foods, compressed foods, is being developed. Although compressed foods can be classified into two categories, reversible and nonreversible, we are dealing here only with reversible type compressed foods (namely, those capable of being restored to their pre-compression volume when rehydrated).

The overall objective of this study is to improve the formulation and/or process for the manufacture of compressed freeze dried meatballs and pork sausage links. Hamdy (1960) has reviewed literature on compression of mostly air dried foods. Hamdy (1962) also worked on the development of freeze-dried compressed spinach and ground beef. He reported the importance of remoistening of the products before compression. Ishler (1968) also worked on a wide range of compressed freeze dried products from fruits and vegetables to chicken, fish and rice.

Buscemi et al. (1964) have done some work on fried, freeze-dried meatballs and pork sausages, and Fitzmaurice et al. (1969) continued the work on the development of compressed freeze-dried meatballs and pork sausages. Further formulation and methods of preparation are in the Military Specifications MIL-M43506, 23 June 1967 and MIL-P-43383A, 30 September 1969. These specifications emphasize 2% moisture content being required in the freeze-dried non-compressed foods, formerly a common goal for assuring uniformly or completely dried products when freeze dehydrated.

Both product formulations relied on the combination of the appropriate meats with the added mixture of salt, spices and pregelatinized corn meal. The latter binder used at the level of 2.5 to 5.4% of formula weight is critical to the matrix formation during the various processing steps, especially the final rehydration. After mixing all ingredients, the steps consist of forming into balls or links, respectively, deep fat frying, and then freeze drying. The freeze dried products were then remoistened adequately to permit compression for volume reduction. Shelf life, rehydratability, texture, and panel acceptability have all been reported as being satisfactory.

The products thus prepared, however, have a tendency to overimbibe water when rehydrated with an excess of water. Our major objective in this research project has been to retain existing capability for rehydration of the formulated, deep-fat fried, freeze dried and compressed meat products into cooked form having close to the original moisture content, shape, and volume of the predried, precompression units of food while avoiding over-rehydration by too much water imbibition.

B. Theoretical Considerations and Practical Approach:

Carbohydrates, proteins, and gums may alone or in combination serve to form matrices binding together the meat pieces and permitting access of water between and into the comminuted meat pieces. This matrix network with water ingress made favorable, as well, by the nature of freeze dehydration (i.e., voids left by water removal) can, in addition to the skin effect, control critically the degree of rehydration as well as texture.

A typical alternative to the use of gelatinized corn meal might be a combination of gelatinized starch and isolated protein such as wheat gluten. Wheat gluten would impart structure to the products which in compressed state can store the memory of the original shape allowing the product to rehydrate within limits and to restore its original size and shape.

Other isolated proteins such as soy or cottonseed protein and egg white solids also looked promising in this research.

Freeze Drying: Heldman et al. (1972) in their work on the energetics of water binding in dehydrated foods, the effect of platen temperatures during freeze drying, and the water sorption capacity of freeze dehydrated foods, found that products freeze dried with a platen temperature of 105°F (40.5°C) had consistently higher water sorption capacity than products freeze dried at 140°F (60°C). In addition, at higher platen temperatures the products tended to darken. Platen temperature of 130°F has been specified for this present project, and it has been adhered to carefully (e.g., 130 $\pm$ 3°F or 54.5 $\pm$ 1.5°C).

Remoistening: Since freeze-dried products with 2% moisture are fragile, they cannot be compressed as such. It is, therefore, very important that these products attain a certain plasticity before they can be compressed without fragmentation. Hamdy (1962) found that spinach can be successfully compressed at 9% moisture content and ground beef at 13%. Ishler (1965) studied the use of water, glycerine and propylene glycol as plasticizing agents. He reported that water in the range of 5-20% and propylene glycol or glycerine in the range of 5-15% can be used successfully to compress the foods. One should, however, recognize the need to optimize the proper moisture level for each food since the properties of individual foods vary to a large extent*. Consequently, too high moisture or too low moisture could deteriorate product quality. This added moisture is removed from foods after compression by a secondary drying. This further drying step also poses many other problems since it involves one more major step in handling and processing.

Redrying: If compressed foods are to have final moisture content of about 2% (as in regular freeze-dried foods), they have to undergo redrying after compression. Since compression needs from 5-15% moisture in foods, redrying involves removal of the excess 3-12% moisture from foods. From drying rate curves, it is apparent that removal of part of this moisture from monomolecular moisture (BET) layer and second molecular layer needs more drastic drying conditions. Ishler and Knipper (1968) have found redrying in a vacuum oven at temperatures ranging from 40-60°C for approximately 5 hours was needed to reduce the moisture content to less than 2%. This also means that products during this redrying step would undergo additional cooking. Such additional processing inevitably would result in some lowering of the product quality achieved by the initial freeze drying.

Shelf-life Stabilities: Any convenience food system is of little use if the system has poor shelf-stability. Dehydrated foods usually have good shelf or storage stability if prepared with a good technique and if appropriately packaged. However, more complex dry food systems such as compressed redried foods have to undergo some drastic processes. These treatments could, and in fact do, alter the shelf-stability of these foods.

Lipid oxidation is a function of a_w (Labuza, et al. 1969). It was shown that water was protective for dehydrated

---

*For the two products with which this project is concerned, a range of 10 to 13% moisture was found to be optimum for compression.

food, and as water activity increased, the oxidation rate decreased (an optimum range for protection against oxidation being $a_w = 0.2 - 0.5$). This is characteristically true in low water activity range (Fig. 1) (Labuza, 1973). Freeze-dried foods at a_w near 0.05 are susceptible to the classic type of rancidity involving unsaturated neutral lipids.

If one is looking for shelf-stable products, he should question the prudence of redrying the food to 2% ($a_w \sim 0.05$) moisture content. One way to cope with this problem would be to find an optimum moisture level at which products would be least susceptible to fat oxidation, non-enzymatic browning and microbial deterioration.

The relationships between a_w or RH at equilibrium moisture concentration in a system are summarized by a moisture sorption isotherm. The physical-chemical mechanism underlying water activity as revealed by moisture sorption isotherms is discussed elsewhere (Labuza, 1968). Fig. 1 shows the relationship between a_w and lipid oxidation, moisture isotherms, non-enzymatic browning, and microbial spoilage.

Non-enzymatic browning is another type of chemical change to which freeze-dried foods are quite susceptible. Brockmann (1966) has discussed extensively the effects of non-enzymic browning on the deterioration in stored, freeze-dried meats. Browning causes the development of a bitter off-flavor and also leads to a loss of protein solubility. The latter reaction decreases the nutritional quality of protein. Mizrahi, et al. (1970) working on non-enzymatic browning of dehydrated cabbage, have found that rate and the extent of browning increased as the moisture content increased from 1.2% to 17.9%. Not much work has been published on the browning of redried food products. As discussed in our results and discussion part of this report, the effect of redrying appears to be a major factor in the non-enzymatic browning of foods at low moisture levels.

Microbial stability is another factor that should be considered while studying the shelf-stability of foods. However, since most dehydrated foods have water activities much below 0.7, microbial spoilage is almost impossible, as can be seen in Fig. 1. Surface condensations can give rise to high water activity areas on dry foods which can support microbial growth. This possibility necessitates the monitoring of microbial stability of dry foods in storage. In this present project, microbiological examinations have been a scrupulously careful part of our research, especially in order to show the acceptability of moisture levels much higher than 2% (i.e., 4.5% and 10 + % moisture).

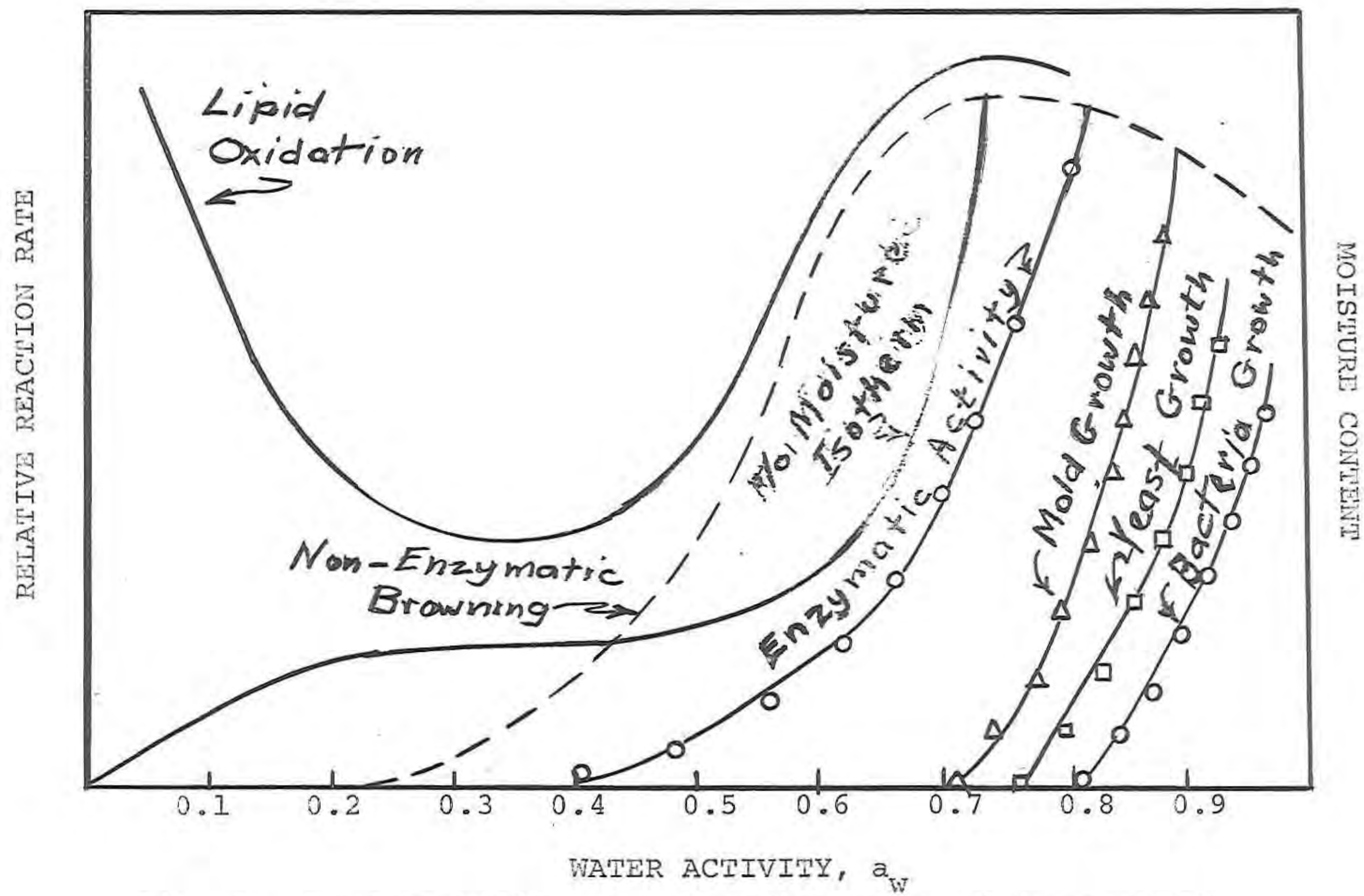


Fig. 1. Food Stability as a Function of a_w (Labuza, 1973)

II. Product Development

1. Formulations:

1.1. Preliminary Work on Product Formulation and Techniques:

1.1.1. Pork Sausages.

Pork sausages were made according to the following general formula:

Ingredient	As Percentage of Raw Pork
Pork, raw	100
Binder(s)	Variable (typically 2.5)
Salt	2.07
Pepper	0.107
Rosemary	0.08
Sugar	0.321

Various binders and their combinations used are listed in Table 1.

The dry ingredients were weighed and mixed. The boneless pork loin (Swift Co., New Brunswick, N.J.) containing about 15-20% fat was then ground through a Hobart auger mill plate having 1/2 in. diameter holes. Then the mixed ingredients were sprinkled evenly on the pork and the whole mixture ground through a plate having 3/16 in. diameter holes. Alternatively, in later formulation work a Hobart rotary food cutter was used for the first comminution during which the mixed ingredients were sprinkled into the meat.

In some batches, pork was ground through a plate having 1/2 in. diameter holes. Then it was mixed with the required amount of salt for 30 minutes. At the end of this period, other ingredients were added and the total mix ground through the plate having 3/16 in. diameter holes.

The salt level shown above is considered high for consumption in freshly made sausages. Much of this salt (and some spices) is leached out during the final cooking when the dehydrated product is reconstituted.

In a few batches, pork was treated with papain. Controlled treatment of meat with a proteolytic enzyme like papain partially hydrolyzes the long protein chain and helps tenderize the structure. Water holding capacity of the meat also increases owing to increased number of both $-NH_2$ and -COOH groups. Thirdly, protein solubilized due to this treatment acts as self binder providing structural network.

The pork was ground through a plate having 1/2 in. diameter holes, mixed with enzyme solution (papain 0.0005%) and let react at room temperature for 30 minutes. At the end of this period, other ingredients were mixed in and the combined material was ground through a plate having 3/16 in. diameter holes.

Sausage mixes were prepared and shaped into "links" using a 2 1/2 in. x 1/4 in. x 1/2 in. die (a plastic slab with cylindrical cut-outs, Fig. 2). Sausages were immersion fried at 375°F in cottonseed oil (Wesson Oil) for 2.5 minutes, or until internal temperature reached 160°F. Sausages were then immediately placed in a cold room, -22°F, to be frozen. Freeze drying of the frozen links was accomplished by using a laboratory model VirTis freeze dryer during this early formulation work.

TABLE 1

Sausage Formulations: Tests of Binder Types and Combinations

Formula No.	Binder(s)	Amount of Binder (% of Raw Meat)
1[1]	Corn Meal, pregelatinized	4.3
2[1]	Corn Meal, pregelatinized	3.4
3[1]	Egg Albumin	3.4
4[1]	Modified Starch Soy Protein	2.6 1.3
5[1]	Modified Starch	1.25
6	Modified Starch Soy Protein	1.0 1.0
7	Modified Starch Wheat Gluten[2]	1.0 1.0
8	Modified Starch Wheat Gluten	2.0 0.25
9	Egg Albumin Wheat Gluten	1.0 0.25
10	Modified Starch Wheat Gluten	2.0 0.1
11	Egg Albumin Wheat Gluten	2.0 0.1
12	Modified Starch Egg Albumin Wheat Gluten	1.0 1.0 0.1
13	Modified Starch Locust Bean Gum	2.0 0.25
14	Modified Starch Soy Protein Locust Bean Gum	1.0 1.0 0.5
15	Modified Starch Soy Protein Wheat Gluten	1.0 1.0 0.025
16	Modified Starch Wheat Gluten	2.0 0.05
17	Gelatinized Durum Flour	0.28

[1]These sausages were stuffed into collagen casings provided by Devro Co., Somerville, N.J. (Div. of Johnson & Johnson Co., Inc.).

[2]Wheat Gluten was supplied by Paniplus Co., Div. of ITT, Kansas City, Mo.

TABLE 1 (continued)

Formula No.	Binder(s)	Amount of Binder (% of Raw Meat)
18	Gelatinized Durum Flour	1.0
	Modified Starch	1.0
19	Modified Starch	2.0
	Wheat Gluten	0.025
20	Modified Starch	1.0
	Gelatinized Corn Meal	1.0
	Wheat Gluten	0.025
21	Modified Starch	2.0
	Wheat Gluten	0.025
	Pork treated with papain for 30 min.	
22	Modified Starch	2.0
	Wheat Gluten	0.05
	Pork treated with papain prior to making sausage	
23	Egg Albumin	2.0
	Wheat Gluten	0.05
24	Modified Starch (National 10)[3]	2.0
	Gelatinized Corn Meal	0.4
	Wheat Gluten	0.15
25	Modified Starch (Supergel 30)[5]	2.0
	Gelatinized Corn Meal	0.4
	Wheat Gluten	0.15
26	Modified Starch (Supergel 40)[5]	2.0
	Gelatinized Corn Meal	0.4
	Wheat Gluten	0.15
27	Modified Starch (National 10)	2.25
	Wheat Gluten	0.1
28	Starch (National 10)	2.25
	Gelatinized Starch (National 711)[4]	0.2
	Wheat Gluten (Paniplus)	0.15

[3&4] National 10 and 711 starch which were supplied by National Starch & Chemical Corporation, Plainfield, New Jersey.

[5] Modified starches - Supergel 30 and Supergel 40 were supplied by Stein Hall, New York.

1.1.2. Beef Meatballs.

Meatballs were prepared according to the following general formula:

Formula	Amounts As Percentage of Raw Meat
Beef	100
Binder(s)	Variable
Salt	1.26
Pepper	0.08
Onion Powder	0.92
Water	20.

Various binders and their combinations are listed in Table 2. (Results of this are tabulated in Table 2 of the Results Section).

The dry ingredients were weighed and mixed. Fresh beef (square and cross-cut chuck, lean) was ground through a plate having 1/2 in. diameter holes. Then the rest of the ingredients were evenly spread over the meat and the combined material was ground through a plate having 3/16 in. diameter holes.

In some batches, beef was ground through a plate having 1/2 in. diameter holes. Then it was mixed with required amount of salt for 30 seconds. At the end of this period, other ingredients were added and the combined material ground through the plate having 3/16 in. diameter holes.

In a few other batches, beef was treated with papain. Beef was ground through a plate having 1/2 in. diameter holes, mixed with enzyme solution when enzyme was being tested (papain 0.0005%) and let react at room temperature for 30 minutes. At the end of this period, other ingredients were added and the mix was ground through a plate having 3/16 in. diameter holes.

Meatballs were then prepared by shaping batch-wise either using a die (Fig. 3) (1 in. d. x 1/2 in. thick) or made manually. Meatballs were deep fat fried at 375°F for 2.5 minutes or to internal temperature of 150°F. Polyunsaturated Wesson pure vegetable oil was used for deep frying in a Sears cooker fryer.

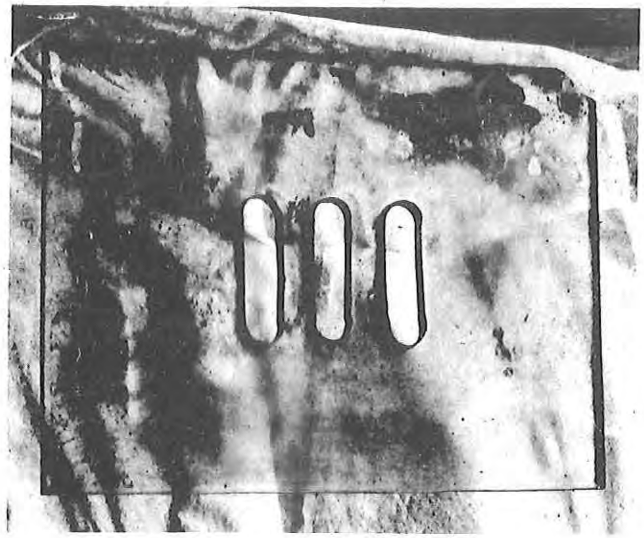


Fig. 2 Plastic slab with cylindrical cut-out for making sausage links (6.3 cm x 1.3 cm x 1.3 cm dia.)

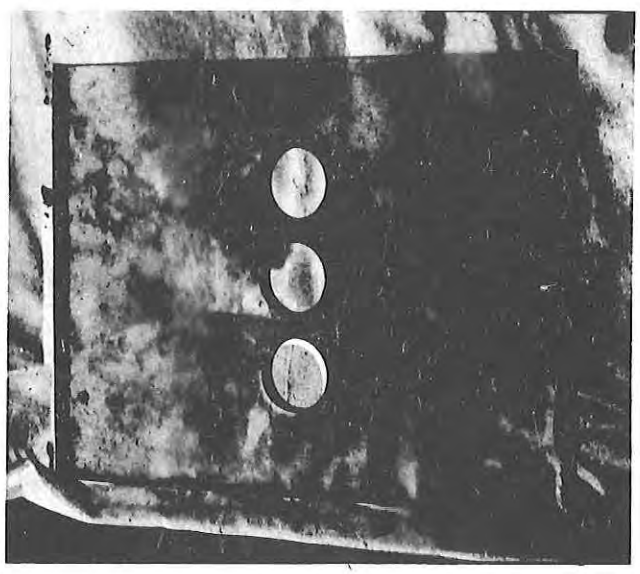


Fig. 3 Plastic die for making meat balls (2.5 cm dia. x 1.3 cm thick)

TABLE 2

Evaluation of Binders for Meatball Formulations

Tests of Binder Types

Formula No.	Binder(s)	Amount of Binder (% of Raw Meat)
1	Corn Meal	3.16
2	Modified Starch Soy Protein	1.0 1.0
3	Modified Starch Wheat Gluten	2.0 0.25
4	Egg Albumin Wheat Gluten	1.0 0.25
5	Modified Starch Wheat Gluten	2.0 0.1
6	Modified Starch Wheat Gluten	2.0 0.05
7	Modified Starch Locust Bean Gum	2.0 0.5
8	Modified Starch Wheat Gluten	2.0 0.025
9	Modified Starch Egg Albumin Wheat Gluten	1.0 1.0 0.025
10	Modified Starch Soy Protein	1.0 1.0
11	Modified Starch Gelatin Wheat Gluten	1.0 1.0 0.025
12	Modified Starch Gelatinized Durum Flour	1.0 0.28
13	Modified Starch Durum Flour (ungelatinized)	1.0 0.29

National 10 and 711 starches were provided by National Starch & Chemical Corporation, Plainfield, N.J.

Supergel 40 starch was provided by Stein Hall Company.

Wheat Gluten was supplied by Paniplus Company.

TABLE 2 (continued)

Formula No.	Binder(s)	Amount of Binder (% of Raw Meat)
14	Modified Starch	1.0
	Gelatinized Durum Flour	1.0
15	Modified Starch	2.0
	Wheat Gluten (meat treated with papain)	0.250
16	Modified Starch (National 10)	2.5
	Pregelatinized Starch (National 711)	0.2
	Wheat Gluten	0.1
17	Modified Starch (National 10)	2.5
	Pregelatinized Starch (National 711)	0.2
	Wheat Gluten	0.125
18	Modified Starch (National 10)	2.5
	Pregelatinized Starch	0.2
	Wheat Gluten (Amylomaize VII*)	0.15
19	Starch (Amylomaize VII)	2.5
	Wheat Gluten	0.1
20	Modified Starch (Supergel 40)	2.5
	Wheat Gluten	0.1
21	Modified Starch (National 10)	2.5
	Wheat Gluten	0.1

*Amylomaize VII was upplied by American Maize Co., Hammond, Ind.

2. Formulation of the Products - Accepted by Panel and Approved for Storage Studies

Fresh and freeze-dried compressed products accepted by the panel were studied for their storage stability. These were prepared for 100 pounds of raw mixture according to the following formulas:

2.1. Pork Sausages:

Final Formulation Used for Pork Sausage

Ingredients	Pounds	Ounces
Pork	94	--
Starch (National No. 10)	2	1.92
Pregelatinized Starch (National No. 711)		3.04
Wheat Gluten (Paniplus)		2.24
Salt	1	11.2
Pepper (black)		1.63
Sugar		4.86
Ginger (powder)		0.45
Rosemary		1.22
Sage		1.76
Thyme		0.91
Mace		0.91
Potassium Sorbate		1.44

All the ingredients (except pork) were weighed and mixed. The boneless pork loin containing about 14-17% fat was then cut into pieces. The pieces were then put into a rotary Hobart Food Cutter (Model T215 GA) and the mixed ingredients were then sprinkled evenly on them. The food cutter was then switched on until the pan containing pork went 5-6 full turns under the rotating scimitar knives. The chopped spice-binder mixed pork was then ground through a plate having 3/16 inch diameter holes.

Then the links were formed (in the plastic cut-out die) and fried at 375°F. for 2 min. and 30 seconds.

2.2. Meatballs:

Ingredients	Pounds	Ounces
Beef	86	8
Starch (National No. 10)	2	2.72
Wheat Gluten (Paniplus)		1.39
Salt	1	3.52
Pepper (black)		2.27
Ginger (powder)		0.32
Onion Powder	1	2.18
K - sorbate		1.39
Water	8	10.56

Meatballs were then prepared as described in 1.1.1.

3. Freezing:

All the products were frozen slowly by storing them enclosed in an aluminum foil cover in still air at -22°C for 18 to 48 hours prior to freeze drying.

4. Freeze Drying:

Freeze drying of the products was carried out both in the laboratory and in the pilot plant.

4.1. Freeze-drying at room temperature (Lab. scale dryer). Products for compression were prepared by using a VirTis Laboratory model freeze dryer.

Products frozen by the method described previously (II-3) were placed in precooled sample chambers. The latter were then quickly attached to the apparatus, evacuated and allowed to warm with the progression of drying to the room temperature (22-25°C). The vacuum was maintained at the highest level possible (usually 1 mm. pressure). In this process product was never warmed above room temperature.

4.2. Freeze Drying in Pilot Plant:

Freeze drying of large batches of products was done in an F.J. Stokes 42 sq. ft. (shelf area) freeze dryer. This enabled us to prepare large quantities of samples at one time. Table 3 shows the log record of a typical freeze drying run. Freeze drying was usually carried out at platen temperatures at 130°F (not rising above 135°F) and was stopped when geometrical centers of the product reached 125-130°F. The product temperatures, plate temperatures and condenser temperatures were monitored by thermocouples attached to a continuous recorder. Vacuum in the drying chamber was maintained at 75-200 microns of mercury (positive pressure). Typical freeze drying operations lasted for 8 - 9 hrs. in which products were dried to 2 - 3% moisture levels.

5. Humidification and Compression:

Meatballs and sausages prepared by the formulations described earlier (2.1 and 2.2) were found to be suitable for further studies in detail. After freeze drying, the products needed to be remoistened before compression. The following agents were tried for successful remoistening for compression:

5.1. Propylene glycol by itself as well as with water was tried for remoistening of the product.

5.2. Glycerine was used by itself and in combination with water for remoistening of the product.

5.3. Pure distilled water was used as remoistening agent.

5.4. Steam was used as remoistening agent.

Products were remoistened with the above agents in the range of 3 to 17 percent by weight (on dry basis) by use of a Crown-Spra-tool (No. 8011 Power Pak*). This is a can containing water and a propellant which atomizes the water to give a fine mist spray and permits efficient, uniform moistening by the two-fluid nozzle principle. After remoistening the surfaces, the products were held under vacuum in order to effect the equilibration of moisture in product. This system proved to be simple and highly effective. Addition of moisture was virtually quantitative, since the added liquid was drawn or displaced from a graduated 8 ounce transparent bottle attached by a bridge-holder with the propellant can and the trigger-operated two-fluid atomizer device. An extremely fine and uniform water mist is nebulized thereby.

*Crown Industrial Products Co., Hebron, Illinois 60034

Products were compressed in cylindrical (1 in. or 2.53 cm inside diameter) or rectangular cells (5 in. x 3/4 in. x 3 in., or 12.7 cm x 1.91 cm x 7.62 cm) in a Carver hydraulic press. Compression pressures were in the range of 1,500-2,000 lbs. (or 68.2-90.9Kg) and temperatures maintained were either 20-22°C (ambient) or 5°C (cold room).

A new compression cell (5 in. x 3/4 in., or 12.7 cm x 1.91 cm) was designed so that three to four sausages could be piled one on top of another in two rows. This minimized the breakage of sausages during compression which occurred when a 3 in. x 1 in. (or 7.62 cm x 2.54 cm) cell was used to compress four sausages at a time.

6. Final Drying:

Compressed products were finally vacuum oven dried at 50-70°C to various moisture levels from 8 to 2%. Typical drying time was 4-5 hrs. at vacuum of 29 in. Hg.

7. Use of Gelatin for Stacking Sausage and Meatballs:

Stacking of the pressed products can facilitate packaging efficiently without disorientation, thereby assuming best volumetric space saving. Dry Knox unflavored gelatin U.S.P., in solutions at 10% and 25% concentration, were used. Drops of 10% or 25% of gelatin solutions were used between each sausage or meatball during compression. After compression, the stacked product was tested for their rehydration performance as indicated in Section III B-2.

The method of causing the unit products to adhere as stacks was developed in response to an oral request by Natick Project Officers. It appeares simple and effective, especially since the gelatin bond can be expected to dissolve during the reconstitution in hot water thereby releasing the unit products as separate pieces.

An outline or preparation of the products is given in the following Fig. 4.

Fig. 4. Flow Diagram for Preparation of Freeze Dried and Compressed Beef Meatballs and Pork Sausages.

Raw Meat
(Beef) (Pork)

↓

Coarse Grinding
5/8" (1.59 cm) r.p. plate

Pork Food Cutter
(Hobart)

↓

Mixing with
Spices & Binders

↓

Fine Grinding thru
3/18 in. (0.42 cm) r.p. plate

↓

Temperature
at 0-4°C for 1/2 hr.

↓

Molding
in Plastic Die Plate

↓

Deep Fat Frying
375°F (190.6°C), 2½ min.

↓

Weighing & Labeling, etc.

↓

Freezing, covered
-22°C, for 24-48 hrs.

↓

Freeze Drying in Stokes
42 sq. ft. Freeze Dryer

↓

Remoistening to 11%
Moisture for Compression

↓

Moisture Equilibration
Under Vacuum for 24 hrs.

↓

Compression
at 1,500-2,000 lbs.
(68.2-90.0 Kg)

↓

Storage with 10-12% Moisture	Redrying in Vacuum Oven	Redrying in Vacuum Oven
	↓	↓
	Stored with 4.5% Moisture	Stored with 2% Moisture

III. Experimental Methods

A. Chemical Studies

1. Moisture Content: AOAC

The product was pulverized with a cold mortar and pestle. Five grams of the sample were accurately weighed on an analytical balance and dried in either:

a. Vacuum oven - 65^{O} for 18 hrs.

b. Air oven - 100^{O} to $105^{O}C$ or 105^{O} to $110^{O}C$ for 24 hrs.

Percent of moisture was then calculated as follows:

$$\text{Moisture \%} = \frac{\text{Dry Wt.}}{\text{Sample Wt.}} \times 100\%.$$

c. Toluene Distillation Method: (AOAC)

2. Moisture Content - Measurement by GLC.

Moisture content of sample was measured by a Gas-Liquid Chromatograph technique after extraction with anhydrous methanöl.

A sample of ten grams of pulverized product was extracted by refluxing at 70°C for 2 hrs. with anhydrous methanol. The extract was then collected and made up to 100 ml using an air-tight moisture free chamber. The moisture content was then measured by injecting 5 $\mu\ell$ of extract into a GLC.

A standard curve was prepared at the same time by injecting methanol solution of known water concentrations. The conditions for the GLC technique were as follows:

Chromatograph: Varian TC Gas Chromatograph Aerograph-1520
Column: A 3' x 1/4" Column was used packed with Porapack Q.
Column Temperature: 120°C
Detector Temperature: 225°C
Injector Temperature: 240°C
Carrier Gas: 38 ml/min.
TC Cell at 150 m Amps.

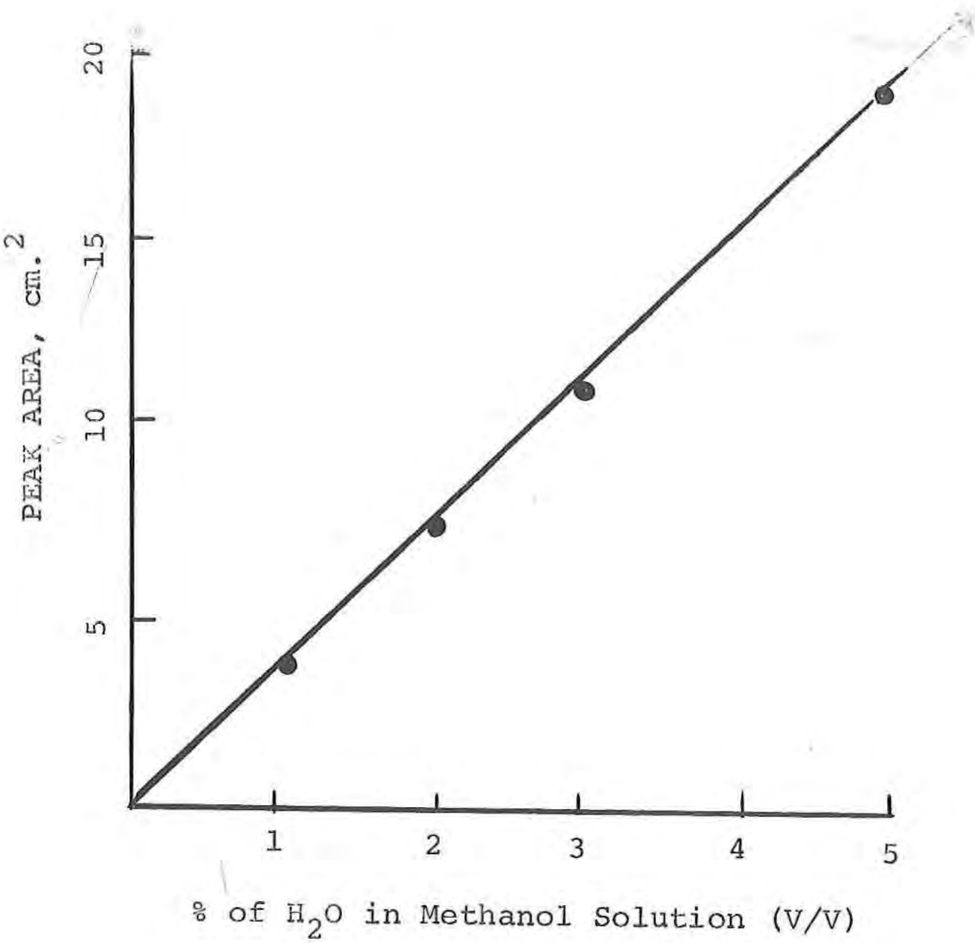


Fig. 5 Typical standard curve for moisture determination by GLC method

Figure 5 shows a standard curve for one of the representative runs.

One important point should be mentioned, the precaution being that one hour before the methanol extract and standard solutions were injected, 10 $\mu\ell$ of pure distilled water were injected into the GLC. This aided in saturating the column and consequently gave very consistent peak area values.

3. Fat Determination: By Soxhlet Method

The fat is extracted in previously weighed round bottom flask (W_2). A sample of 10 grams of dry product was extracted with 125 ml of $CC\ell_4$ for 6 hrs. using the Soxhlet extraction apparatus. At the end of extraction period, the flask was cooled and $CC\ell_4$ was removed by distillation assembly. After distillation was completed, the flask was kept in a vacuum desiccator and vacuum was pulled continuously for 4-6 hrs. to remove the last traces of solvent; the flask was weighed (W_1). All weighing operations were carried out using an analytical balance. Percent fat in the product can be calculated as follows:

$$\% \text{ Fat} = \frac{(W_1 - W_2) \times 100}{\text{Sample Weight}} \%.$$

In the case of raw meat and pork, a representative sample of about 100-150 grams was first freeze dried and the percentage of moisture in the raw product was determined. Then 10 grams of this dry product were used for fat determination. The amount of fat was expressed in terms of raw fresh weight.

4. Peroxide Value: (A.O.C.S. Method 8:53)

Representative samples of sausages and meatballs containing between 0.5-1.0 g lipid were weighed into 125 ml Erlenmeyer flask and 40 ml of chloroform:methanol 3.1(V/V) were added, the flasks shaken for 1/2 hr. and their contents filtered under vacuum on a Buchner Funnel using 40 ml of solvent to wash the residue. The filtrate was collected into a tared flask and solvent evaporated. The weight of the lipid was then calculated by weighing the flask.

The lipid in the flask was dissolved with 10 ml of a mixture of glacial acetic acid:chloroform (3:2). Then 0.5 ml of freshly prepared potassium iodide (saturated solution) was added and after exactly 2 min., 15 ml of distilled water were added to stop the reaction. The mixture was then titrated with 0.001N $Na_2S_2O_3$ using 1 ml 5% starch solution as an indicator. The thiosulfate was standardized periodically against potassium dichromate. The peroxide value was given below:

$$\frac{\text{meq } O_2}{\text{Kg fat}} = \frac{(\text{Ml. } Na_2S_2O_3) \times (\text{Normality of } Na_2S_2O_3) \times 1000}{\text{grams fat}} .$$

5. Non-Enzymatic Browning

a. Hot water extraction method: (Pearson, et al., 1962)

Four grams of pulverized product were accurately weighed on an analytical balance and put into a 250 ml Erlenmeyer flask. Then 75 ml of distilled water were added to the flask and contents heated to 80-90°C for 1 hr. At the end of this period, 0.5 ml of 40°C acetic acid was added and pH adjusted to 5.5. The contents were then made up to 100 ml. using distilled water, shaken vigorously and filtered through Whatman No. 41 filter paper. A portion of 25 ml of this filtrate was then centrifuged at 2,500 rpm for 1/2 hr. The aliquots were then collected and O.D. (optical density) read in a Varian recording spectrophotometer at 375 nm and 420 nm. Distilled water was used as the blank.

b. Enzymatic extraction method (for browning)

(Modified Choi, et al. (1949) by Labuza)

0.5 to 2.0 grams pulverized sample was suspended in 22.5 ml. of 0.125 to 0.5% trypsin solution (0.031-0.125 grams trypsin in 22.5 ml H_2O). The system was then incubated in 45°C water shaker for 2 hrs. at 120 cpm (cycles per min.).

Following a 2 hr. incubation period, trypsin was denatured with 2 ml 50% (wt./vol.) trichloroacetic acid, and 0.1 g Celite (filter aid) was added.

The system was filtered with Whatman #3 filter paper and O.D. of filtrate read at 420 nm with Varian recording spectrophotometer.

Blank (0.00 O.D.) had no sample added to trypsin solution, but treated otherwise as regular samples.

B. Physical and Physico-Chemical Studies

1. Determination of O_2 in Headspace by GLC Method

Varian Aerograph, A90-p3, was used to determine oxygen content in the headspace of the storage jars. 0.3 ml of samples were injected. The peak height was measured and expressed as percent of O_2 using a volume of 0.3 ml of air as a standard.

The conditions of Varian Aerograph A90-p3 used for headspace O_2 determination were as follows:

Column:	Molecular Sieve A-5, 80/100, 6' x 1/4"
Injector Temperature:	46°C
Column Temperature:	50°C
Detector Temperature:	115°C
Filament Current:	150 m.a.
Helium Pressure:	60 psi
Flow Rate:	30 ml/in.

2. Rehydration

Products were rehydrated for 10 min. in excess of hot water maintained at 75-85°C. The products were then taken out of the water, blotted with filter paper and weighed. The rehydration ratio is expressed as:

$$R = \frac{\text{Rehydrated Weight (= Wet Wt.)}}{\text{Dry Wt. of One Product Unit}} .$$

3. Density of the Products

Density of the products before compression, after compression and after rehydration were determined according to the following equation:

$$d(g/cm^3) = \frac{\text{Weight of Product (g)}}{\text{Volume of Product (cm}^3)}$$

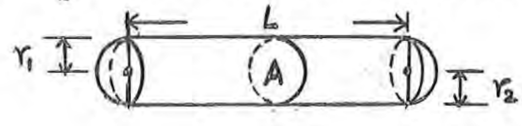
The volume of these products was calculated as follows:

(a) An average diameter of meatball, before compression and after rehydration, was measured with caliper and the volume was then calculated;

$$V_{MB}(cm^3) = \frac{4}{3}\pi r^3$$

in which V_{MB} is the volume of meatball (cm^3) and r is the averaged radius of meatball (cm).

(b) For sausage, before compression and after rehydration, the volume V_s was calculated as follows:



$$V_s\ (cm^3) = AL + \frac{2}{3}\pi(r_1^3 + r_2^3)$$

in which A is the average cross section area of sausage (cm^2)

L is the length of sausage (cm)

r_1 is the radius of one end of sausage

r_2 is the radius of another end of sausage.

(c) For compressed meatball and sausage, the volume was obtained by multiplying one major surface by the thickness.

4. Adsorption and Desorption Isotherms of Freeze Dried Meatballs and Sausages

Moisture adsorption and desorption isotherms were determined for freeze dried meatballs and sausages at 20°C and 30°C using the weight equilibrium (Wink) method. Since meatballs and sausages are heterogeneous materials larger samples were necessary for this study. Accordingly, one freeze-dried meatball or sausage (weighing about 4 to 5 grams) was used per humidity chamber in each run. A_w (R.H.) values from 0.11 to 0.96 for different R.H. chambers were obtained by using saturated salt solutions of various salts (Table 4). The values of a_w (R.H.) of these salt solutions at different temperatures were taken from literature. Sometimes the a_w values were actually determined in the lab. Periodically, the samples were weighed on an analytical balance until equilibrium was reached (usually within 2-3 weeks). Afterwards, equilibrium moisture content of the samples was determined using the G.L.C. method.

For the determination of desorption isotherms, the products following adsorption isotherms determination were sprayed with H_2O and placed in a chamber with 100% R.H. and allowed to take up water in order to equilibrate to a constant weight in this chamber; products (meatball or sausage) were returned to their respective chambers and allowed to equilibrate at their respective a_w value chambers. Weights were again measured periodically until constant weights were obtained.

For determination of monomolecular moisture content of freeze dried beef meatballs and pork sausages, BET isotherm (Brunauer-Emmett-Teller) is employed. A modified BET Equation by Salwin (equation) is used for determining the BET isotherm.

$$\frac{R}{m(I-R)} = \frac{1}{m_1 C} + \frac{C-1}{m_1 C}\ (R)$$

in which R denotes relative humidity P/P_o and a_w

m = equilibrium moisture content, dry basis at R

m_1 = moisture content corresponding to monomolecular adsorption

C = a constant at a given temperature

$\cong e^{(E_1-L)/rT}$

E_1 = heat of sorption of first layer

L = heat of condensation of water

r = gas constant

T = absolute temperature

Plotting $R/m(1-R)$ vs R, gives a linear relationship. From the slope and intercept of this line, the monolayer coverage value can be calculated (Labuza, 1968). Results for our products are given in a later section of this report.

TABLE 4

Equilibrium Relative Humidities for Saturated Salt Solutions*

		% Relative Humidity at Stated Temperature	
Saturated Salt Solution		68°F (20°C)	86°F (30°C)
Lithum Chloride	$LiCl \cdot H_2O$	12.4	11.8
Potassium Acetate	$KC_2H_3O_2$	23.3	22.0
Magnesium Chloride	$MgCl_2 \cdot 6H_2O$	33.6	32.8
Potassium Carbonate	$K_2CO_3 \cdot 2H_2O$	44.0	43.5
Potassium Nitrite	KNO_2	49.0	47.2
Magnesium Nitrate	$Mg(NO_3)_2 \cdot 6H_2O$	54.9	52.0
Sodium Chloride	NaCl	75.5	75.6
Ammonium Sulfate	$(NH_4)_2SO_4$	80.6	80.0
Potassium Nitrate	KNO_3	93.2	90.7
Potassium Sulfate	K_2SO_4	97.2	96.6

*Ref. Hygrodynamics Technical Bulletin No. 5, Hygrodynamics, Inc., 949 Selim Road, Silver Spring, Maryland 20910

5. Texture of the Products

The initial and final textures of meat products were determined using the Kramer "shear cell", and peak force measured from the analog recording was expressed as peak deformation force in lbs.

Freeze dried compressed products stored at different temperature and periods were run by this test.

C. Microbiological Examination:

Microbial examinations to determine the total organism count and the number of Escherichia coli, molds and yeast per gram of sample were conducted on both fresh meat samples prior to the preparation of meatballs and sausages and on freeze dried compressed meatballs and sausages stored for varying periods of time at 50°C and 22°C. Subsamples were taken from the fresh meat used for the preparation of meatballs and sausages and analyzed immediately. Freeze dried and compressed samples were analyzed immediately after removal from storage.

1. Preparation of Homogenate:

Ten grams of the meat sample, representative of the food specimens, were aseptically weighed into a sterile blender jar. In a sterile Waring Blender, this 10.0 g meat sample and 90 ml of sterile peptone dilution fluid (0.1% were homogenized at a high speed for 1½ minutes. Dilutions of the slurry were made with sterile peptone dilution fluid to cover the range of 10^{-1} to 10^{-5} organisms/ml.

2. Aerobic Plate Count:

Decimal dilutions of 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4} and 10^{-5} of food homogenate were prepared. All dilutions were shaken 25 times in 1 foot arc in 7 seconds. One ml of each dilution was pipetted into each of appropriately marked duplicate petri dishes. Twelve to 15 ml of PCA agar (Difco) standard methods Agar or plate count Agar were sterilized at 121°C for 15 min., adjusted final pH to 7.3 ± 0.2, and cooled to 44°-46°C; and poured into each dish within 15 minutes of time of original dilution. Before pouring the agar was cooled to ∿ 45°C so as not to kill any organisms. Plates were immediately rotated to insure mixing of the sample dilution and agar medium. Dilution water and agar control plates were also prepared for each series of samples. The petri dishes were inverted and incubated promptly at 35 ± 1°C for 48 ± 2 hrs. After incubation, plates containing 30-300 colonies were counted using a colony counter. Average counts were obtained and reported as aerobic plate count/gram.

3. E. Coli Determination:

A three tube Most Probable Number (MPN) Procedure which uses the multiple tube fermentation technique for enumeration of coliforms was employed to determine most probable numbers.

3.1. Presumptive Test:

Decimal dilutions of 10^{-1} to 10^{-5} were prepared (same dilutions used in Aerobic Plate Count). All dilutions were shaken 25 times in a 1 foot arc in 7 seconds. Each of three lauryl tryptose 2% broth fermentation tubes were inoculated with 1 ml volume (Difco-pH 6.8, autoclaved 15 min. at $121^{o}C$) of each dilution. These tubes were incubated for 48 ± 2 hours at $35^{o}C$. Tubes were examined at 24 ± 2 hours for gas formation. Displacement of liquid in fermentation tube (gas formation) and/or vigorous effervescence were looked for when tubes were shaken gently. (This denotes a positive presumptive test.) After the first 24 hour period, negative tubes were reincubated for an additional 24 hours. Gas in any quantity within 48 ± 2 hours denotes a positive presumptive test for coliform organisms. Confirmatory tests were done on all positive presumptive tests.

A schematic procedure for presumptive test of MPN method is shown as follows:

Presumptive Test

Incubation

(Lauryl tryptose broth fermentation tubes)

↓ $0.5^{o}C$, 24 hours

(+) ↓ gas formation ↓ confirmed test

(−) ↓ no gas formation ↓ reincubation

↓ $35 \pm 0.5^{o}C$, 24 hrs.

(+) ↓ gas formation ↓ confirmed test

(−) ↓ no gas formation ↓ discard

3.2. Confirmed Test:

Transfer a sterile 3 mm diameter loopful from each positive tube of Lauryl tryptose broth to a separate tube of Brilliant Green Lactose Bile Broth 2% fermentation tubes. When transferring, insert loop in such a manner as to avoid any pellicle. Incubate for 48 $\pm$ 3 hours at 32 $\pm$ 0.5°C. Read positive tubes same as in presumptive tests.

From each positive Brilliant Green Lactose Bile Broth fermentation tube, streak 1 plate of Eosin Methylene Blue agar. Insert needle into fermentation tube approximately 5 mm into broth, taking care to avoid the pellicle. Streak the plate in a manner which will obtain discrete colonies separated by at least 0.5 cm. Incubate plates at 35 $\pm$ .5°C for 24 $\pm$ 2 hrs. Examine plates for typical nucleated with or without green sheen colonies. Pick two of these colonies from every plate by touching the needle to the center of the colony. Inoculate a lauryl tryptose broth fermentation tube with one of the typical colonies chosen. Incubate the completed test of fermentation tubes at 35 $\pm$ 0.5°C for 48 $\pm$ 3 hours. Gas formation denotes a positive result. A positive result indicates that these bacteria can be considered coliforms (using three tubes -MPN tables to determine the MPN on a number of positive completed fermentation tubes). Results are reported as most probable number of E. coli per gram of sample.

A schematic procedure for confirmed test is shown as follows:

<u>Confirmed Test</u>

Brilliant Green Lactose Bile Broth

Incubation

↓ 35 ± 0.5°C

48 ± 3 hours

(+) ↓ gas formation ↓ incubation

(Eosin-methylene blue Agar Plates)

↓ 35 ± 0.5°C, 24 ± 2 hrs.

(−) ↓ other non-nucleated green sheen colonies present

(+) ↓ Nucleated green sheen typical colonies ↓

(−) ↓ no gas formation ↓ discard

<u>Completed Test</u>

Incubation

(Secondary Lauryl Tryptose Broth Fermentation Tubes)

↓ 35 ± 0.5°C, 48 hrs.

(+) ↓ gas formation ↓ bacteria tested can be considered coliforms

(−) ↓ no gas formation

4. Yeast and Mold:

Prepare decimal dilutions of 10^{-1} to 10^{-5} of sample homogenate. Shake all dilutions 25 times in one-foot arc in 7 seconds. One ml of each dilution is pipetted into each of the appropriately marked duplicate petri dishes. Pour plates with 15-20 ml of Potato Dextrose Agar (Difco - autoclave at 121°C for 15 min.) acidified to pH 3.5. Immediately rotate plates to mix dilutions and agar medium. Incubate at 21°C for 5 days, observing plates after 3 days for possible mold overgrowth. Report average counts as number of yeast and mold colonies per gram of sample.

D. Sensory Evaluation:

Freshly prepared meatballs and sausages and freeze dried compressed meatballs and sausages (dehydrated) at various moisture content levels (2%, 4.5%, and 10%) were submitted to a taste panel at various intervals during the course of this project. During the shelf life studies, samples withdrawn from storage were evaluated by the panel every 2 or 4 weeks.

The panel consisted of 20 members, all graduate students or faculty members in the Department of Food Science, Rutgers University. All panel members were familiar with sensory evaluation techniques. It should be mentioned that the modern booth-type facilities located in the new Food Science Building were used. The air conditioned individual panel rooms can accommodate 12 people at one sitting. Samples were served into the panel booths from an adjoining preparation kitchen. All testing sessions were scheduled for 11:00 A.M. or 2:00 to 3:00 P.M.

Freshly prepared meatballs and sausages were submitted to the panel immediately after preparation.

In preparation for each panel session involving freeze dried compressed products, tap water was heated to a temperature of 75-85°C in 4 quart cooking pots. Separate pots of water were prepared for each set of samples. Twenty meatballs (or sausages) were soaked in each pot for exactly ten minutes. At the end of the ten minute period, samples were removed with a straining spoon and transferred to cooking pans; excess water was drained off. These pans were placed in a low temperature oven (150°F) for approximately 10 minutes prior to paneling. This warming period aided in keeping the samples warm while paneling and in removing excess water; yet did not over-dry the sample. Samples were removed from the oven and submitted to the panel for evaluation, one sausage or one meatball per disposable cup (with plastic spoon or fork).

Depending on the day of paneling, a maximum of three samples was served to the judge per session. Samples were placed in separate paper cups, labeled (A. B. C., etc.) and served to the evaluator on a plate. One score sheet per sample and a preference sheet and/or a description of the intended use of the product were provided to the judges with samples.

One Product Evaluation Score Sheet per sample tested was distributed to each panelist (Table 5). This score sheet rated several parameters of the product (appearance, aroma/flavor, texture, consistency) on a 9 point hedonic scale (6 acceptable). Additional comments were encouraged. These numerical values were listed on the chart following its collection by the test supervisor-judge. However, these values were not shown to the panelists. An overall product rating are determined by the judge and marked in the final column. Mean values of scores were calculated for each column and reported comments were recorded with the results. Comparisons were made between products (by the supervisor-judge) using the values computed for each of these categories.

When original formulations were being tested, Product Evaluation Score Sheets and a preference sheet reading, "Do you prefer sample A or B? Why?" were distributed; answers were tabulated, and comments, recorded with the results. Formula elimination or modification were often based on these data.

A description of the intended use of the freeze dried and compressed products accompanied the score sheet for all freeze dried and compressed samples; they read:

> These sausages and meatballs are intended to be used by Army and Navy personnel in situations where bulk food storage may present a problem; e.g., submarine voyages.

TABLE 5

PRODUCT EVALUATION SCORE SHEET

Name: ____________________ Brand: ____________________

Date: ____________________ Product Flavor: ____________

Descriptive Product Rating

	Appearance	Aroma/Flavor	Texture Consistency	Overall
Excellent				
Good				
Poor				
Unacceptable				

COMMENTS: (Use other side if needed).

IV. Results.

1. Sausage Formulation - Tests of Binder Types.

The general formula used for sausage formulation was indicated in Section II-1.1.1. It was necessary to find a suitable binder for a successful product. Various types of binders were tested for their performance on rehydration and overall taste panel acceptance. Results are shown in Tables 6 and 7.

The tests clearly indicated that pork sausage made with 2.25% modified cross-linked amylose starch, National No. 10, (National Starch and Chemical Corp.), 0.15% wheat gluten and 0.20% pregelatinized amylose starch (National No. 711), produced a good final product - products C and D in the above table. This product(s) did not fragment on compression. The rehydration (of the product containing ~ 10% moisture content initially) and textural qualities were also very good. Water imbibition gave good rehydration within the meat as well as between the meat particles without sloppy overimbibition. When using only National No. 10 starch, the above product tended to resist inbibition through the exterior crust, and the imbibed water tended to reside sponge-like between the meat particles instead of penetrating and moistening the meat particles. By adding the appropriate amount of pregelatinized high-amylose starch, National No. 711, the barriers of the other starch were opened sufficiently to accomplish the desired crust porosity and meat piece moistening without the sponge-like wetness effect. The kinds and amounts of these binders constitute a major breakthrough in accomplishing the proper remoistening without over- or under-imbibition of any or all parts of the product. Additionally, this system successfully replaces pregelatinized corn meal and fulfills the needed "fat pocket control" in high fat sausages.

2. Beef Meatballs Formulation - Tests of Binder Types

Tests of binders used for meatball formulation were conducted by mixing binders with raw material and other ingredients as indicated in section II-1.1.2. The results of screening tests are given in Table 8.

Effect of Binders on Rehydration Performance and Overall Taste Panel Acceptance

TABLE 6

Formula No.	Binder(s), % of Raw Meat		Rehydration	Overall Qualifications[3]	Comments
1[1]	Corn Meal	3.4	Poor	4	Excessive water uptake and became soggy.
2[1]	Corn Meal	3.4	Poor	4	Casing inhibited the rehydration.
3[1]	Egg Albumin	3.4	Poor	4	Casing hindered drying as well as rehydration process.
4[1]	Modified[2] Starch Soy Protein	2.6 1.3	Poor	4	Product stayed dry in the center. Also a tough cover formed may be due to combination of collagen casing and soy protein.
5[1]	Modified Starch Soy Protein	1.25 1.25	Poor	4	
6[1]	Modified Starch Soy Protein	1.0 1.0	Fair	3	Some dry spots remained in the sausage. Also, sausage did not recover its original form.
7	Modified Starch Wheat Gluten	1.0 1.0	Poor	4	Hard covering formed on sausages probably due to high levels of wheat gluten.

[1]These sausages were stuffed into collagen casings provided by Devro Co., Somerville, N.J. (Div. of Johnson and Johnson Co., Inc.)

[2]Modified Starch = National Starch No. 10 was supplied by National Starch & Chemical Corporation, Plainfield, N.J.

[3]Qualification Scoring: 1 = Excellent; 2 = Promising; 3 = Fair - questionable; 4 = Poor.

TABLE 6 (cont'd)

Formula No.	Binder(s)	% of Raw Meat	Rehydration	Overall Qualifications[3]	Comments
8	Modified Starch Wheat Gluten	2.0 0.25	Poor	4	Rehydration was poor due to hard covering formation.
9	Egg Albumin Wheat Gluten	1.0 0.25	Good	3	Texture very bad, rubber-like and very difficult to bite.
10	Modified Starch Wheat Gluten	2.0 0.1	Fair	3	Rehydration was slow. Also, product did not return to the original shape but rather stayed rectangular and compressed.
11	Egg Albumin Wheat Gluten	2.0 0.1	Fair	3	Rehydration was slow. Product did not regain its original shape.
12	Modified Starch Egg Albumin Wheat Gluten	1.0 1.0 0.1	Poor	4	Hard casing formed. Also, center remained dry.
13	Modified Starch Locust Bean Gum	2.0 0.25	Fair	2-3	Product rehydrated completely in about 3-4 minutes. Had good texture and color. Product had gummy feeling.
14	Modified Starch Soy Protein Locust Bean Gum	1.0 1.0 0.5	Fair	3	Few dry spots in the sausages after 1 min. rehydration. Product did not regain the original shape and size. Attributable to soy protein effect.

TABLE 6 (cont'd)

Formula No.	Binder(s) (% of Raw Meat)		Rehydration	Overall Qualifications[3]	Comments
15	Modified Starch Soy Protein Wheat Gluten	1.0 1.0 0.025	Poor	4	Did not rehydrate completely even after 10 min. Also, product had undesirable grey color.
16	Modified Starch Wheat Gluten	2.0 0.05	Poor	4	Product showed dry spots even after 10 min. rehydration.
17	Gel. Durum Flour Modified Starch	0.28 1.0		4	Very poor cohesive properties.
18	Gel. Durum Flour Modified Starch	1.0 1.0		4	Product had very poor cohesive properties and was very crumbly in dry state.
19	Modified Starch Wheat Gluten	2.0 0.025	Poor	3	Product did not regain its original shape and size. (Good for meatballs, however).
20	Modified Starch Gel. Corn Meal Wheat Gluten	1.0 1.0 0.025	Poor	4	Product did not completely rehydrate in 10 min. Final drying temperature did not improve product quality (kept at 50°C).
21	Modified Starch Wheat Gluten (Pork treated with papain for 30min.)	2.0 0.025	Fair	2-3	Rehydration almost complete. Product did not regain original shape and size.

TABLE 6 (cont'd)

Formula No.	Binder(s)	% of Raw Meat	Rehydration	Overall Qualifications[3]	Comments
22	Modified Starch Wheat Gluten (Pork treated with papain prior to making sausage)	2.0 0.05	Poor	4	Tough casing was formed on the surface of the sausage.
23	Egg Albumin Wheat Gluten	2.0 0.05	Poor	4	Tough casing formed on the sausage. Rehydration very slow.
24	Modified Starch (Nat'l.) Gel. Corn Meal Wheat Gluten	2.0 0.4 0.15	Poor	3	Tough casing formed on the sausage. Rehydration slow.
25	Modified Starch (Supergel 30) Gel. Corn Meal Wheat Gluten	2.0 0.4 0.15	Poor	4	Did not rehydrate well, very tough.
26	Modified Starch (Supergel 40) Wheat Gluten	2.0 0.15	Poor	4	Tough casing formed on the sausage. Rehydration very slow.

TABLE 6 (cont'd)

Formula No.	Binder(s)	% of Raw Meat	Rehydration	Overall Qualifications[3]	Comments
27	Modified Starch (Nat'l. No.10)	2.25	Fair	3	Rehydrated well but loss in structure.
	Wheat Gluten	0.1			
28	Starch (Nat'l. No. 10)	2.25	Good	1-2	Rehydration good. Nice appearance.
	Pregelatinized Starch (Nat'l. No. 711)	0.2			
	Wheat Gluten (Paniplus)	0.15			

All of the above "overall qualifications" represent organoleptic screening opinions usually only of the researchers rather than of formal panel testers.

Table 6 indicates that none of the single or combined binders is suitable for building up a good texture and proper rehydratability for sausage. Therefore, additional study on binders was done on overall panel rating. The results are shown in Table 7.

TABLE 7

Effect of Binder Combination on Overall Panel Rating for Pork Sausages

	Binders	%	Overall Panel Score (1)	Remarks
A	Gelatinized Corn Meal (original Natick Labs formulation)	2.50	6.4	Deep-fat fried but undehydrated
B	Starch (National 10) Gelatinized Corn Meal Wheat Gluten	2.00 0.40 0.15	6.8	"
C	Starch (National 10) Pregelatinized Starch (National 711) Wheat Gluten	2.25 0.20 0.15	7.6	"
D	Same as C		7.5;6.3;6.5	Fried as above, then freeze dried, compressed (2)
E	Same as B		6.2;5.2	"
F	Starch (Stein Hall Supergel 30) Gelatinized Corn Meal Gluten	2.00 0.40 0.15	5.8	"
G	Starch (Stein Hall Supergel 40) Pregelatinized Starch (National No. 711) Gelatinized Corn Meal Gluten	2.00 0.20 0.40 0.15	6.1	"

(1) Overall panel score is based on hedonic scale from 1 to 9. Scores of 6.0 or above for meat products indicate an acceptable product.

(2) All the compressed products were compressed with 10-12% moisture and panel tested in 24 to 48 hrs.

TABLE 8

Meatballs Formulations; Tests of Binder Types

Formula No.	Binder	% of Raw Meat	Rehydration	Overall Qualifications[1]	Comments
1	Corn Meal	3.16	Poor	4	Over-imbibition of water
2	Modified Starch (Nat'l. No. 10)	1.0	Poor	4	Very low water uptake
	Soy Protein	1.0			
3	Modified[2] Starch	2.0	Poor	4	Very slow water uptake due to hard casing
	Wheat Gluten	0.25			
4	Egg Albumin	1.0	Fair	4	Slow water uptake, tough texture, rubbery
	Wheat Gluten	0.25			
5	Modified Starch	2.0	Fair	3	Slow water uptake, dry feeling
	Wheat Gluten	0.1			
6	Modified Starch	2.0	Fair	3	Complete rehydration in 2-3 min.
	Wheat Gluten	0.05			

[1] Overall Qualifications (i.e., preliminary screening)
1 = Excellent; 2 = Promising; 3 = Fair - questionable; 4 = Poor.

[2] Modified starch used in these is National No. 10, which was supplied by National Starch and Chemical Corporation.

TABLE 8 (Cont'd)

Formula No.	Binder	% of Raw Meat	Rehydration	Overall Qualifications[1]	Comments
7	Modified Starch Locust Bean Gum	2.0 0.5	Good	2	Product was slimy, sticky due to locust bean gum.
8	Modified Starch Wheat Gluten	2.0 0.025	Very Good	1-2	Slight cracking during compression
9	Modified Starch Egg Albumin Wheat Gluten	1.0 1.0 0.025	Fair	3	Product tasted and felt dry in the mouth.
10	Modified Starch Soy Protein Wheat Gluten	1.0 1.0 0.025	Fair	3	Some areas felt slightly dry.
11	Modified Starch Gelatin Wheat Gluten	1.0 1.0 0.025	Fair	4	Product did not regain its original shape and size. Also, product looked dry.
12	Modified Starch Gel. Durum Flour	1.0 0.28	Fair	4	Product did not regain the original shape. Also, product tended to imbibe extra water and became soggy.

TABLE 8 (Cont'd)

Formula No.	Binder	% of Raw Meat	Rehydration	Overall Qualifications[1]	Comments
13	Modified Starch	1.0			
	Durum Flour (ungel.)	0.29			
14	Modified Starch	1.0	Poor	4	Product looks soggy and crumbly outside. Inside has a few dry spots. Product does not regain original shape and size.
	Gel. Durum Flour	1.0			
15	Modified Starch	2.0	Fair	4	Product looks soggy and crumbly outside. Inside has a few dry spots. Product does not regain shape and size.
	Wheat Gluten (meat treated with papain)	0.025			

The above screening tests led to a formulation of beef meatballs made with 2.5% modified cross-linked high-amylose (National No. 10) and 0.1% wheat gluten (Paniplus) which produced an exceptionally good product. This product did not fragment on compression. Rehydration (of the product containing $\simeq$ 10% moisture content initially) and the texture quality were also very good (see B&D in Table 6). The following effect of binder combination on overall panel rating was evaluated and the results are shown in Table 9.

TABLE 9

Effect of Binder Combination on Overall Panel Rating.

Product	Binders	Overall Panel Score (1)
I. Meatballs, Deep-Fat Fried but Undehydrated		
A	Gelatinized Corn Meal 2.5%	5.6
B	Modified Starch (National No. 10) 2.5%	7.6; 6.5
C	Modified Starch (National No. 10) 2.25% Pregelatinized Starch (National No. 711) 0.2% Gluten 0.1%	7.6
II. Meatballs, Fried, Freeze Dried, Moistened, Compressed (2)		
D	Same as in B	7.2
E	Starch (American Maize Amylomaize VII) 2.5% Gluten 0.1%	5.6
F	Starch (Stein Hall Supergel 40) 2.5% Gluten 0.5%	5.6
G	Starch (National No. 10) 2.5% Pregelatinized Starch (National No. 711) 0.25% Gluten 0.1%	5.3
H	Starch (National No. 10) 2.5% Pregelatinized Starch (National No. 711) 0.2% Gluten 0.1% (quite similar to C).	6.2
I	Starch (National No. 10) 2.5% Pregelatinized Starch (National No. 711) 0.2% Gluten 0.125%	5.9
J	Starch (National No. 10) 2.5% Pregelatinized Starch (National No. 711) 0.2% Gluten 0.150%	5.6

(1) Overall panel score is based on hedonic scale from 1 to 9. Scores of 6.0 or above indicate the acceptable product.

(2) All the compressed products were compressed with 10-12% moisture and panel tested in 24 to 48 hrs.

The results of overall panel score further strengthen the conclusion that meatballs made with modified cross-linked starch (National Starch Co.) 2.5% and wheat gluten (Paniplus) 0.1% were the best products. Before dehydration, B & C were essentially equal in panel tests. After dehydration, the simple formulation, with only one kind of modified starch, was preferred. The second pregelatinized amylose (National 711) was not needed for "fat pocket control" as with sausage meat.

3. Rehumidification and Compression

It was previously mentioned that following freeze drying the product needed to be remoistened before compression. Behavior upon compressing after using different remoistening agents is shown in Table 10. It was found that the propylene glycol by itself in the range of 5-15% by weight resulted in excessive fragmentation. Also, rehydration of the product was poor. In combination with water, it shows no additional advantages since the final drying step was still necessary.

When using glycerine by itself for remoistening of the products, it was found that the product fragmented when compressed. At higher concentration of glycerine, the surfaces of the product became soft, yet the interior of the product still remained brittle. When used in combination with water, the product fragmented upon rehydration in an excess of water.

Steam rehydration of the product tended to cook the product besides rehydrating it. Also, the compression of the products following steam rehydration resulted in more fat than usual being squeezed out. A typical moisture uptake curve during steam remoistening is shown in Fig. 6.

Pure distilled water was used as a remoistening agent with great success. It was easy to handle, and easy to sterilize if necessary. After spraying of water, equilibration which was carried out in a desiccator under vacuum was attained more slowly but more uniformly.

Moisture levels of 10 to 12 percent were found to be suitable for compression of the product without fragmentation.

TABLE 10

Rehumidification and Compression

Humidification Agent(s)	Observations	Rehydration[1] Ratio
I. Propylene Glycol (P.G.)		
8% water + 2% P.G.	Cohesion of bar good	----
	Rehydration fair	----
10% water + 2% P.G.	Cohesion of bar poor	----
	Rehydration good	
12% water + 2% P.G.	Poor cohesiveness	----
5% P.G.	Rehydration good for meatballs	
14% P.G. equilibrated at room temperature	V. good cohesive properties	----
	Product crushed, disintegrated during compression and rehydration	----
14% P.G. equilibrated at 50°C	V. good cohesive properties - Poor rehydration	----
12% P. G.	Good rehydration but excessive fragmentation	
17% P. G.	Cohesiveness of bar good but rehydration poor.	
II. Glycerine (G)		
6% water + 5% G.	Excessive fragmentation	2.31
7% water + 5% G.	Considerable fragmentation	2.33
8% water + 5% G.	Considerable cracking	2.3
9% water + 5% G.	Slight cracking	2.4
10% water + 5% G.	No cracking, Rehydration good	2.32
11% water + 5% G.	No cracking, Rehydration good	2.3
12% water + 5% G.	Product slightly relaxed	2.32

TABLE 10 (cont'd)

Humidification Agent(s)	Observations	Rehydration[1] Ratio
III. Water		
5%	Excessive fragmentation occurred.	----
6%	"	----
7%	"	----
8% water	Considerable cracking of the product occurred.	
9% water	Slight cracking, rehydration good.	
10% water	No cracking, rehydration complete and uniform.	
11% water	Very good rehydration. No breakage.	2.13
12% water	Very good product, slight relaxation after removal of pressure.	2.13
17% water	Product relaxation after removal of pressure is excessive.	2.1
21% water	Product relaxation after removal of pressure is excessive.	2.2

1. A hypothetical "standard" rehydration ratio is estimated (for both meatballs and sausages) to be 2.5 to 2.7 based on the moisture condition of the products following deep-fat frying. Such frying serves to cause some moisture evaporation.

After remoistening, products were compressed to reduce their volume. The pressure that was used for compression was, therefore, a very important factor which would ultimately affect the rehydration properties of the compressed products. Table 11 indicates the effect of compression pressure on the product at 10% moisture level.

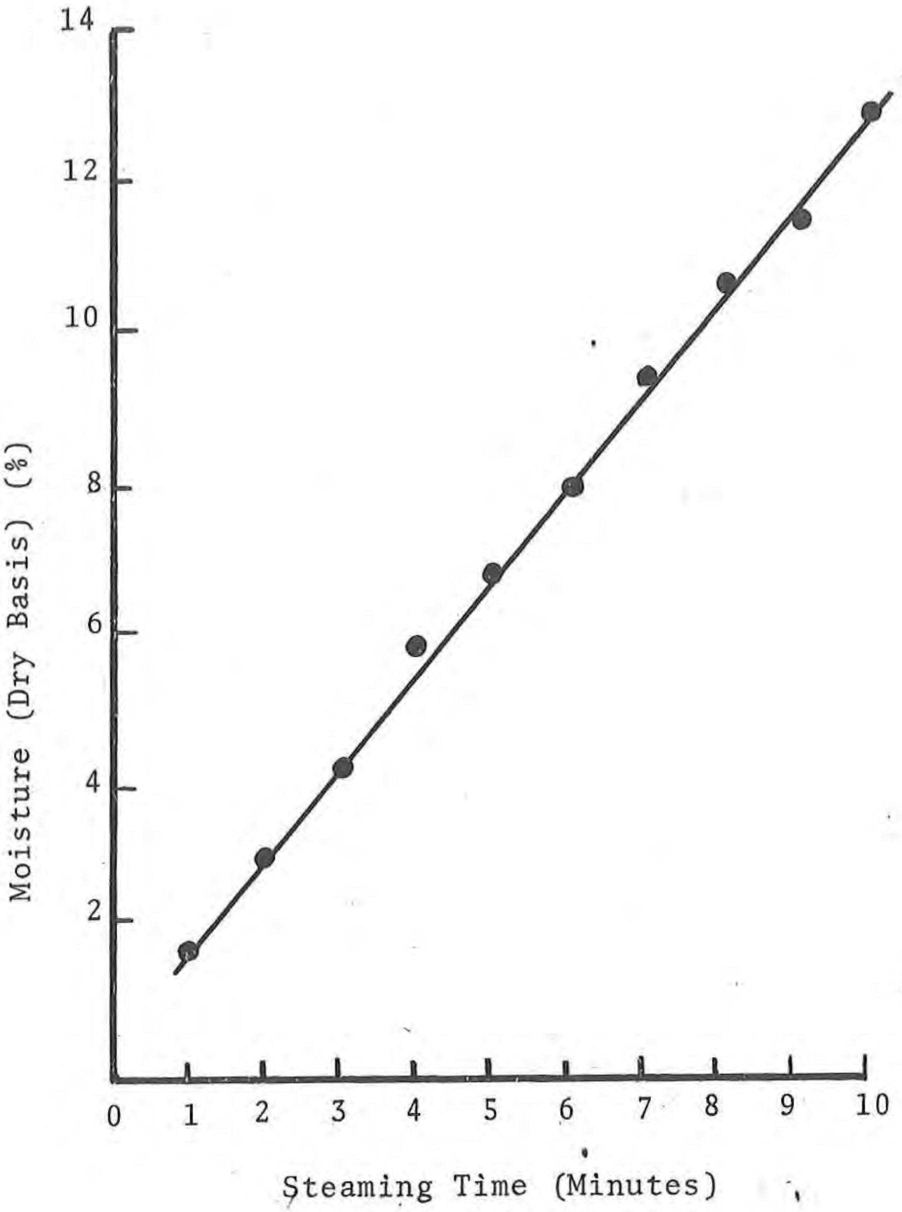


Fig. 6. Moisture uptake by freeze-dried meatballs during steaming

TABLE 11

Effect of Compression Pressure on Meatballs

Total Compression Pressure, lbs.	Observation	R.R.[1]
1000	No cohesiveness among internal meat pieces. Rehydration good, no breakage.	2.33
2000	No cohesiveness among internal pieces. Rehydration good, no breakage.	2.3
4000	No cohesiveness among internal pieces. Rehydration good, no breakage.	2.6
6000	Cohesiveness slightly better. Product cracked and fragmented.	2.6

[1] See footnotes on Table 10.

Results showed that increasing the compression pressure from 1000 to 4000 lbs. had little or no effect on increasing the rehydration ratio. When compression was carried out at 6,000 lb. cracking fragmentation of the product occurred. Using these results, a compression pressure between 1,500 - 2,000 lbs. was decided upon under the following conditions: 2 rows of meatballs, 3 high, 6 total meatballs in one die.

4. Redrying.

The effect of redrying on rehydration properties of compressed products is shown in Table 12.

TABLE 12

The Effect of Redrying on Rehydration Properties of Compressed Products

Product	Redried To	Observation	Rehydration Ratio[1]
Sausage (10% moisture)	10% Moisture (no redrying)	Complete rehydration.	2.22
	5% Moisture	Complete rehydration. No dry spots; good flavor & texture.	2.07
	4%	Incomplete rehydration. Dry spots visible.	1.75
	3%	Incomplete rehydration. Dry spots visible.	1.61
Meatballs (10% moisture)	10% Moisture (no redrying)	Complete rehydration.	2.69
	4.5%	Complete rehydration. No dry spots.	2.43
	2.0%	Complete rehydration. Dry spots visible.	2.39
12% M + 2% Propylene Glycol	3% (Freeze dried)	Cohesiveness good. But incomplete rehydration.	-
9.7% M + 5% Glycol	2.5% M.	Incomplete rehydration. Product did not regain original shape.	-
8% M + 2% Propylene Glycol	2% M.	Rehydration completely inhibited. Product like rocks.	-

[1]See footnotes on Table 10.

These results indicate that redrying compressed products to below 10% would decrease the rehydration ratios. In other words, when redried to lower moisture levels, the products usually did not rehydrate as well as they did at the 10% level. Upon rehydration, dry spots were sometimes found in those products which had been dried to lower levels of moisture content following compression. Table 9 data further strengthen the view that the product with a 10 to 12% moisture level was the best, and that redrying is an undesirable step from the rehydratability standpoint. Incomplete rehydration at the center of meatballs or sausages redried to 2% or 4.5% moisture content was experienced, however, only when the cooking cycle was shortened or at lower cook-water temperature. When the specified rehydration conditions (i.e., 75-85°C for 10 minutes) was observed faithfully, all the products of the final recommended formulations, even at lowered initial moistures, rehydrated satisfactorily at the very centers. A mean cooking temperature of 80°C for 10 minutes was found to give good rehydration results.

The redrying process was also carried out by air drying in our pilot plant using an electrically heated Blue-M Air Dryer. After remoistening and compression, the products were redried in perforated-bottom trays to 4.5% and 2% moisture content, respectively. Drying time with cross-circulating air at 54°C was approximately $3\frac{1}{2}$ and $5\frac{1}{2}$ hours, respectively.

Table 13 compares the results of air drying with vacuum oven drying. In general, vacuum oven dried products give a better (higher) rehydration ratio and smaller peroxide value, but a little higher browning rate was found in beef meatballs. But because of the insignificances of differences obtained, it appears that either of the two methods (air or vacuum) can be appropriately used for drying purposes.

TABLE 13

Comparison of Vacuum-oven Dried and Air-dried Meat Products

Drying Methods:	Air Dried (130°F)				Vacuum Oven Dried (122°F, 29 in. Hg)			
Product:	Pork Sausages		Beef Meatballs		Pork Sausages		Beef Meatballs	
Moisture Level %	2.0	4.5	2.0	4.5	2.0	4.5	2.0	4.5
Rehydration Ratio	2.10	2.23	2.17	2.26	2.27	2.30	2.29	2.33
Peroxide Value	3.10	2.30	3.20	2.60	2.70	2.30	2.50	2.40
Browning, A375	0.195	0.165	0.185	0.165	0.190	0.170	0.215	0.193

5. Stacking

Various methods were employed to get units of the compressed products to stick together. One method which was used unsuccessfully was to sprinkle dry gelatin between the products before they were then compressed. The dry gelatin particles remained visible and the sausages immediately separated. Using a few drops of 10% to 25% (w.b.) gelatin solution before compression, the sausage became "glued" together and remained in this state until rehydration. Table 14 gives the results of using 10% gelatin solution on stacking the products together.

TABLE 14

Water Gain and Rehydration Ratio of Freeze Dried Compressed Meat Product Stacked with 10% of Gelatin Solution

Amount of 10% Gelatin Solution (Drops)	Weight of Sausage Before Rehydration (g)	Weight of Sausage After Rehydration (g)	Rehydration Ratio	Amount of Water, Gain (g)	% of Water Gain
1	11.0[1]	23.7	2.15	12.7	115.5
3	21.0[2]	41.7	1.98	20.7	98.6

[1] Weight of two sausages.

[2] Weight of four sausages.

It was indicated that 1 drop of 10% gelatin solution gave the best results on stacking compressed meat products. The gelatin dissolved in hot water during the sausage reconstitution and did not seem to impair rehydration or flavor.

6. Moisture

Moisture contents in raw and storage product were determined by either oven-dry or GLC methods. It was found that in raw pork and beef the moisture level was about 66%. After freeze drying, the moisture levels dropped to 2.5-3%.

By using G L C for determining the moisture levels, a standard curve was prepared as indicated in Section III-2. Using this curve, the amounts of water in the product could be calculated from its peak heights. The results from GLC determination correlated to those found in oven drying. For comparison of these two methods, remoistened samples were selected at random, and results obtained from oven drying method and GLC method are compared in Table 15.

TABLE 15

Moisture Determination: Vacuum Dry vs. GLC Methods for Meatballs and Sausages

Products	% of Moisture	
	Vacuum Dry	GLC Method
Meatball #1	6.90	7.00
#2	7.15	7.50
Sausage #1	9.05	9.25
#2	9.75	9.90

This table (Table 15) indicates that moistures determined by GLC were higher than by vacuum drying, but the difference in the results between these two methods could be ignored within the practices of the processing involved in this development work. Hence, either one of these two methods may be adopted for moisture determination.

Comparable to the Karl Fischer method which also uses methanol as solvent for water, higher results are to be expected by the GLC method. More bound, relatively non-volatile water is extracted by methanol.

7. Fat Content

By Soxhlet extraction method, it was found that the trimmed raw pork used contained about 18% fat and raw beef contained about 17% fat. It was also found that the finished products had a higher fat content than either of the raw products. This was believed to be the result of deep frying during which fat was absorbed into the products as well as the loss of some moisture which naturally raised the solids and fat content. There was almost no change found in fat content in products found in a twelve weeks storage study (as would be expected).

8. Peroxide Value

Peroxide value was used to determine the degree of rancidity in the stored products. A summary of data for peroxide values for freeze dried compressed meat products (sausage and meatballs) is given in Table 16.

TABLE 16

Peroxide Values for Freeze Dried Compressed Meat Products During Storage

Storage Time (wks.)	Storage Temp. °C	PRODUCTS					
		Pork Sausage			Beef Meatballs		
		Moisture Level %					
		2	4.5	10	2	4.5	10
		Peroxide Value (Meq O_2/Kg fat)					
0	5	3.2	2.6	2.09	2.50	2.40	1.0
	22	3.2	2.6	2.09	2.50	2.40	1.0
	38	3.2	2.6	2.09	2.50	2.40	1.0
4	5	4.1	2.7	2.16	2.10	2.0	1.97
	22	5.2	4.4	3.04	2.10	1.9	2.48
	38	9.3	7.9	5.55	2.00	2.20	2.97
8	5	2.0	2.1	2.20	2.10	2.2	2.40
	22	2.8	2.5	2.30	2.50	2.0	3.20
	38	3.2	2.2	2.30	2.03	2.1	3.80
12	5	2.2	2.50	2.80	2.50	2.0	1.85
	22	3.3	2.60	2.70	4.60	3.0	2.25
	38	3.4	3.10	2.60	3.70	2.7	2.20

9. Browning

Quantitative estimation of the browning reaction was carried out using hot water (85-90^{o}C) extraction method (Pearson, et al., 1962) or enzyme (trypsin) extraction method (Labuza, 1973). The effect of enzyme concentration upon the amount of browning pigment released from the meat products is shown in Fig. 7, which illustrates that for trypsin concentration below 0.25%, the pigment released increased almost linearly with the amount of enzyme and thereafter exhibited an asymptotic behavior. Therefore, 0.25% of trypsin was considered to be a suitable and economic concentration for extraction.

The results comparing the hot water and enzymatic extraction methods are presented in Fig. 8, which illustrates that 0.125% and 0.25% of trypsin (in warm water @ 40^{o}C) give less effective extraction of brown pigment than hot water without proteolytic enzyme. This comparison confirms the feasibility of using simple hot water extraction without costly enzyme.

Browning reaction was affected by the moisture content in the meat products, The results are also shown in Fig. 8, which indicates paradoxically that with increased moisture level in the products, the browning reaction was less advanced. Actually, the anomaly demonstrates that secondary drying initiate temporarily a greater extent of browning. The results of browning reaction of pork sausages during 12 weeks storage at three stored temperatures (5^{o}, 20^{o} and 38^{o}C) are shown in Fig. 9 which indicates that slight difference was found between 5^{o}C and 20^{o}C, but significant increase in browning reaction apparently occurs in products stored at higher temperature (38^{o}C). The temperature effect on browning reaction, therefore, can be expressed as follows:

$$38^{o}C >> 22^{o}C > 5^{o}C.$$

As can be seen from Fig. 9 for pork sausage, the elevated storage temperature showed a highly significant effect on the browning reactions. A rapid browning occurred during the first four weeks of storage at all temperatures, but thereafter, the change was slower, being quite significant at 38^{o}C and practically negligible at 5^{o}C. An almost similar behavior was exhibited by the meatballs. This is seen in Fig. 10.

For some reason that we could not understand, non-reproducible results were often obtained when hot water extract was measured at 420 nm; but at 375 nm the data were more consistent in measuring the browning pigment. Therefore, all hot water extracts were measured at 375 nm. However, 420 nm was used for comparison of enzymatic and non-enzymatic browning pigment extraction procedures, since 420 nm happens to be conventional for enzyme-treated extracts.

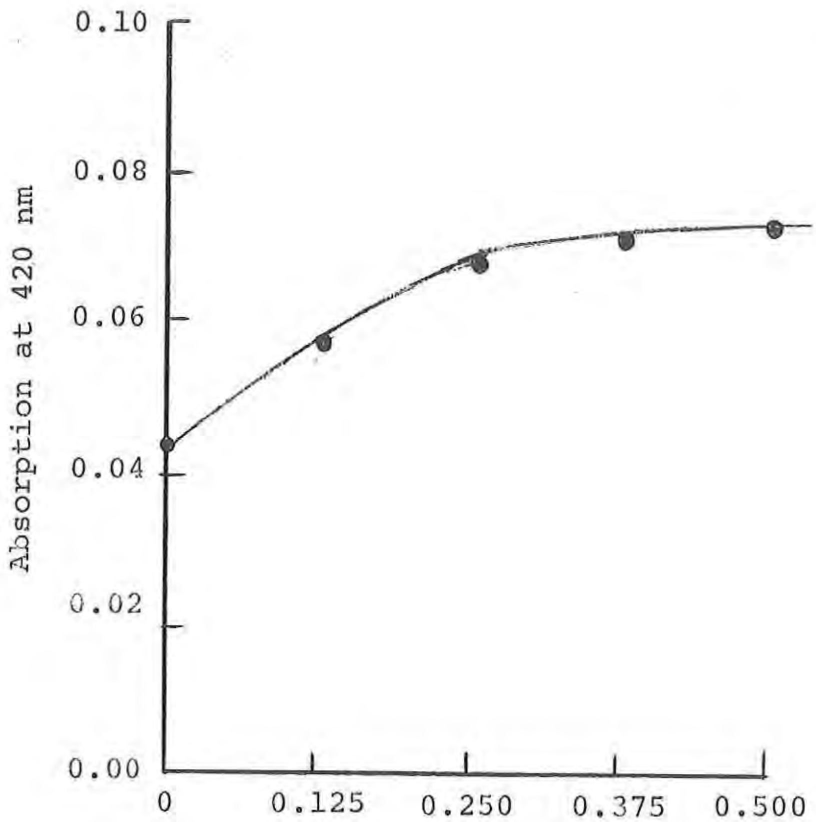


Fig. 7. Effect of the concentration of trypsin in releasing of browning pigment from freeze-dried compressed meat products ($40^{o}C$).

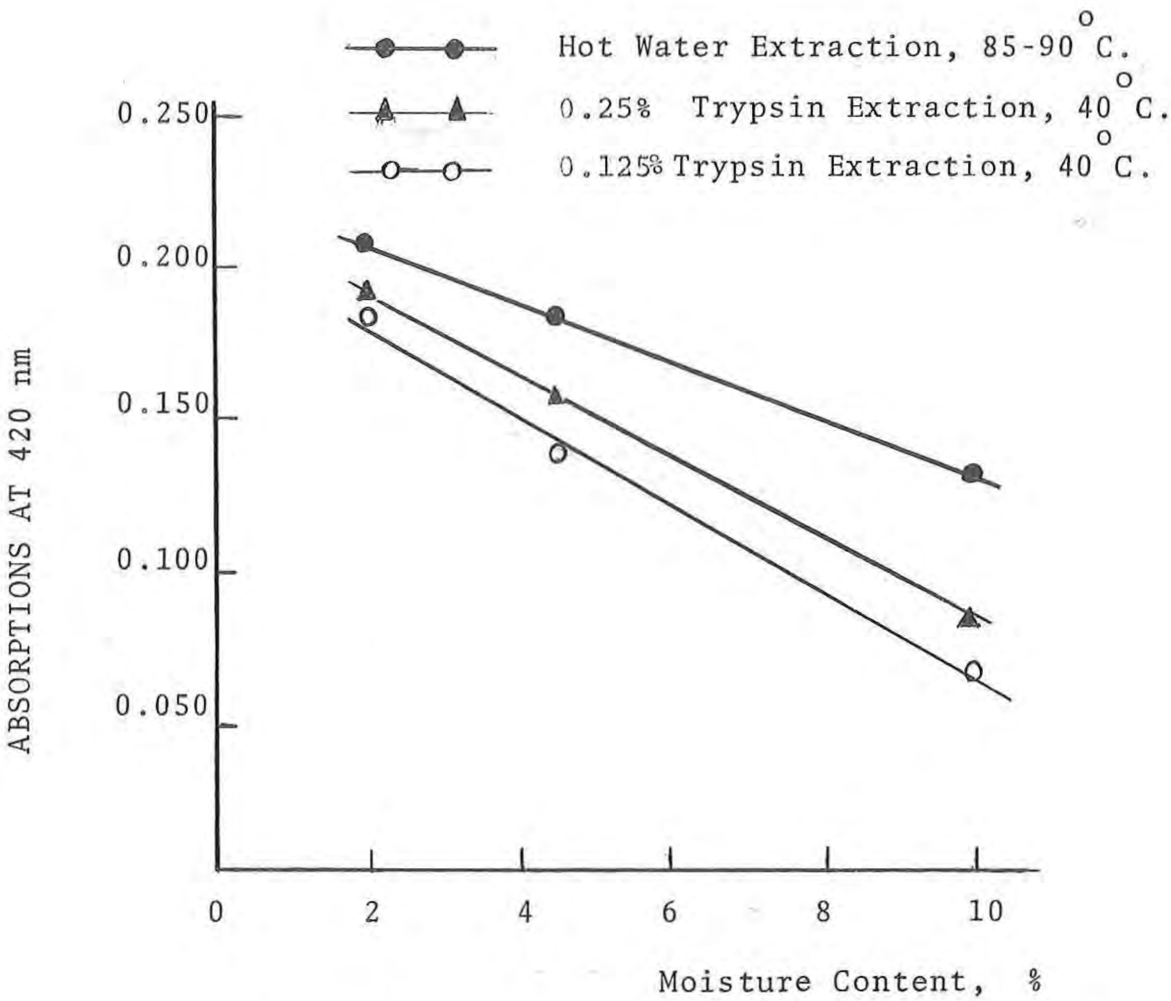


Fig. 8. Comparison of extraction methods used for browning determination of freeze dried compressed meat balls with different moisture levels

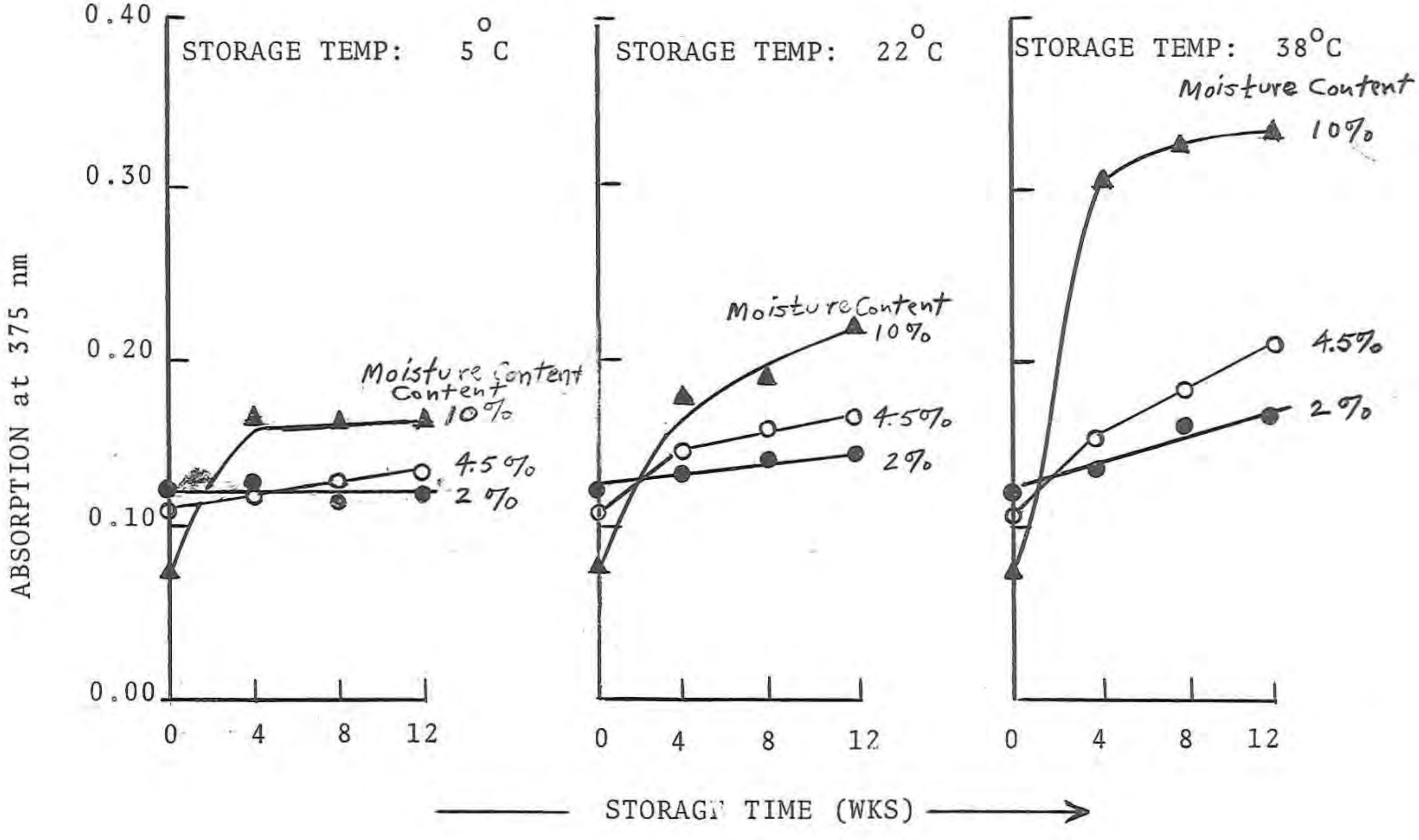


Fig. 9. Effect of moisture content and storage temperature on browning reaction of freeze dried and compressed pork sausages (Hot Water Extraction Method).

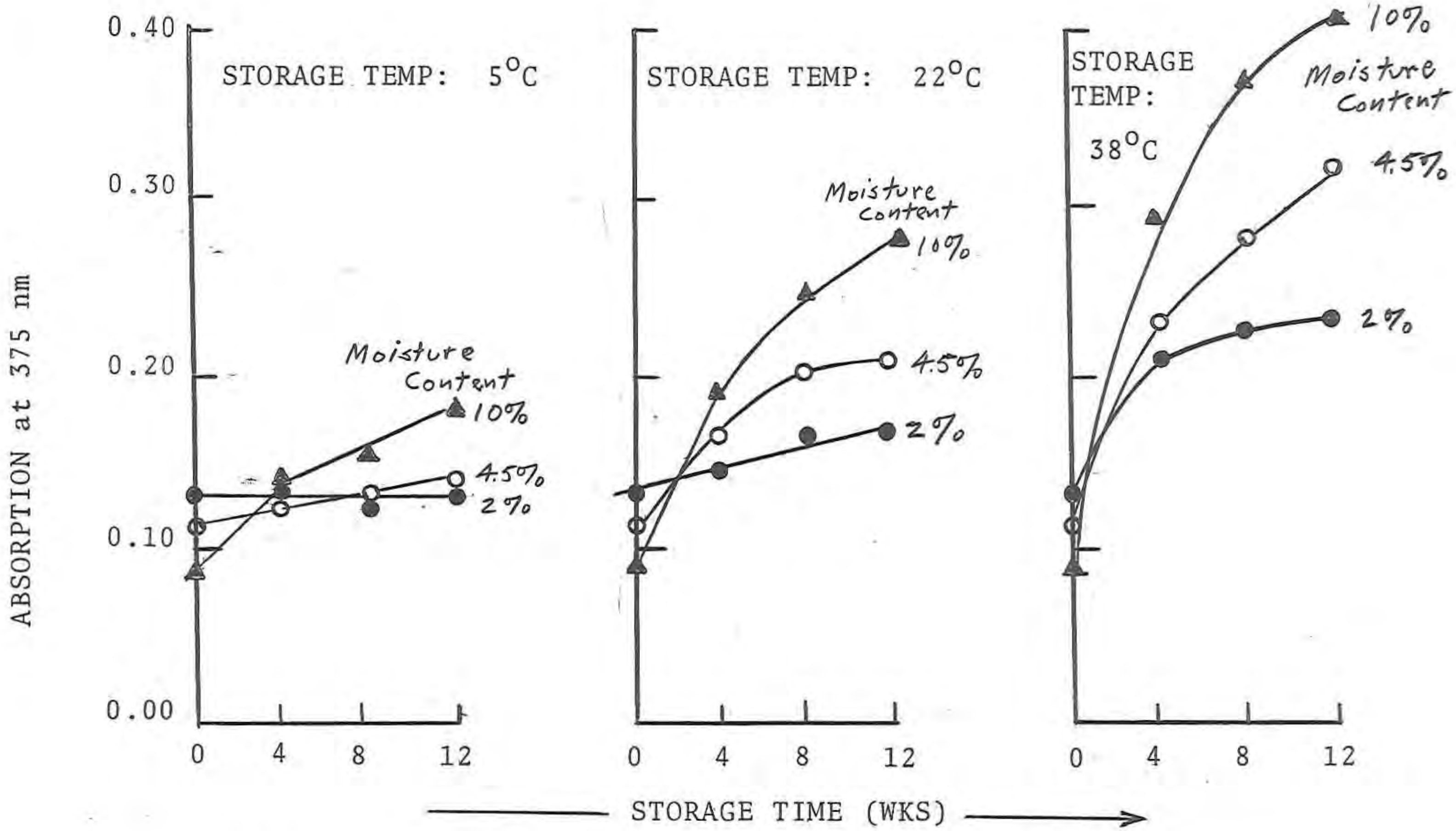


Fig. **10.** Effect of moisture level and storage temperature on browning reaction of freeze dried and compressed beef meat balls (Hot Water Extraction Method).

10. Oxygen Determination:

Freeze dried compressed meat products, pork sausages and beef meatballs were packed in 16 oz Mason jars and stored under nitrogen. Oxygen in headspace was determined as described in Sec. II-1B-1. Results are shown in Table 17.

TABLE 17

Change of Oxygen Content in Jar Headspace During Storage at Three Different Temperatures

Storage Time (wks)	Moisture Level %	Beef Meatballs			Pork Sausages		
		Storage Temperature°C					
		5	22	38	5	22	38
		% Oxygen					
0	2.0	2.06	2.06	2.06	2.06	2.06	2.06
	4.5	2.06	2.06	2.06	2.06	2.06	2.06
	10.0	1.74	1.74	1.74	1.74	1.74	1.74
4	2.0	1.01	1.30	0.00	1.36	1.53	0.11
	4.5	1.26	1.19	0.00	1.34	1.24	0.23
	10.0	0.82	0.00	0.00	1.45	0.52	0.72
8	2.0	0.98	1.01	0.00	1.28	1.08	0.00
	4.5	0.75	0.52	0.00	1.30	1.09	0.00
	10.0	0.85	0.00	0.06	1.36	1.34	0.07
12	2.0	0.98	0.60	0.00	1.09	0.94	0.00
	4.5	0.79	0.22	0.00	1.10	0.65	0.00
	10.0	0.91	0.04	0.03	1.30	0.79	0.00

These results illustrate that O_2 uptake by the product is lower at 5°C than that of 38°C. It generally indicates that headspace O_2 was transferred to product during the first period of storage (4 weeks). Thereafter there was no significant change of O_2 content in headspace.

11. Rehydration

Stored meat products' rehydration performances were examined in an excess of hot water (75-85°C). The criteria for examination were amount of water absorbed and return to original size and shape. Results are shown in Table 18.

TABLE 18

Effect of Storage Time and Temperature on Rehydration Ratio of Meat Products at Different Moisture Levels

Storage Time (wks)	Moisture Level %	Products					
		Beef Meatballs			Pork Sausage		
		Storage Temperature °C					
		5	22	38	5	22	38
		Rehydration Ratio					
0	2.0	1.97	1.97	1.97	1.95	1.95	1.95
	4.5	2.22	2.22	2.22	2.19	2.19	2.19
	10.0	2.35	2.35	2.35	2.33	2.33	2.33
4	2.0	1.98	1.97	2.02	2.07	2.01	2.15
	4.5	2.04	2.15	2.18	2.07	2.01	2.15
	10.0	2.28	2.20	2.24	2.23	2.08	2.28
8	2.0	2.02	1.96	1.98	1.90	1.96	2.24
	4.5	2.12	2.05	2.10	2.00	2.19	2.31
	10.0	2.30	2.28	2.18	2.05	2.15	2.23
12	2.0	1.97	1.90	2.02	2.00	1.99	2.22
	4.5	2.12	2.12	2.15	2.03	2.05	2.15
	10.0	2.55	2.29	2.05	2.04	2.08	2.08

The data in the above table indicate that samples stored at 5°C do not give a significant change in rehydration properties, but a slight decrease in the rehydration ratio is found with the products stored at 22°C. A larger decrease in rehydration ratio with increase of storage time was observed in products with 10% moisture and stored at 38°C.

12. Density:

Density of meat products, before and after compression, was determined. Results are shown in Table 19.

TABLE 19

Comparison of Density Change of Products, Before and After Compression

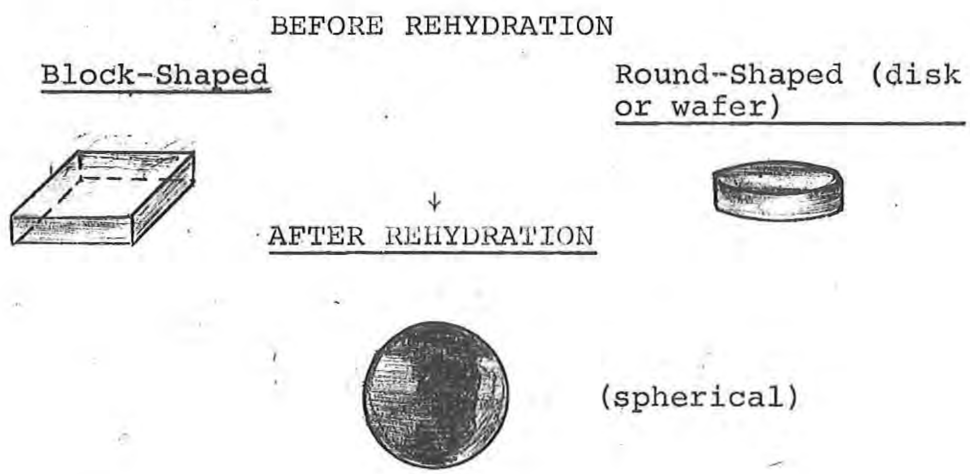
DENSITIES (g/cm^3)

Sausage		Meatballs			
		Block Shaped		Round Shaped	
Before Comp.	After Comp.	Before Comp.	After Comp.	Before Comp.	After Comp.
0.6640	0.7810	0.6913	0.8650	0.6267	0.9571
VOLUME (cm^3)					
12.15	8.12	8.18	6.25	8.58	5.10

Significant increases in product density and reductions in volume are seen from the above table.

The rehydration performance of block and round shaped meatballs is shown in Fig. 11.

Fig. 11. The rehydration performance of block and round shaped meatballs.



It was indicated that meatballs were able to rehydrate into their original spherical form from either block or round shaped forms. The rehydration ratio were 2.20 and 2.37 for block and round shaped meatballs, respectively.

It was found that either round (cylindrical) or block shaped units rehydrated equally well as regards wholeness or lack of cracking.

13. Adsorption and Desorption Isotherms of Freeze Dried Meatballs and Sausage:

The adsorption and desorption, at 20 and 30°C, of freeze dried meat products are shown in Figs. 12 and 13 for pork sausages and Figs. 14 and 15 for beef meatballs. The relationships between moisture content in products and its water activity can be seen in these figures. A comparison of these relationships on our meat products is listed in Table 20.

TABLE 20

Water Activities of Freeze Dried Meat Products Related to its Moisture Level

Moisture Level (%)	Pork Sausage		Beef Meatballs	
	Temperature °C			
	20	30	20	30
	a_w			
2	0.080	0.098	0.045	0.140
4.5	0.225	0.262	0.125	0.285
10.0	0.560	0.595	0.515	0.585

When comparing these results to Fig. 1, the low magnitudes of a_w indicate products with 2, 4.5 and 10% of moisture content will not support the growth of mold, yeast and bacteria. Therefore, from viewpoint of microbial growth, products with a moisture level about 10% will be considered as stable and safe against microbiological deterioration.

Throughout this treatise there is admitted bias to leaving the moistened products (following the compression) at the 10 to 12% moisture level rather than redrying to 2% or 4.5%. There is a recognized cost in more extensive browning encountered but there are several compensating values (e.g., reduced processing steps).

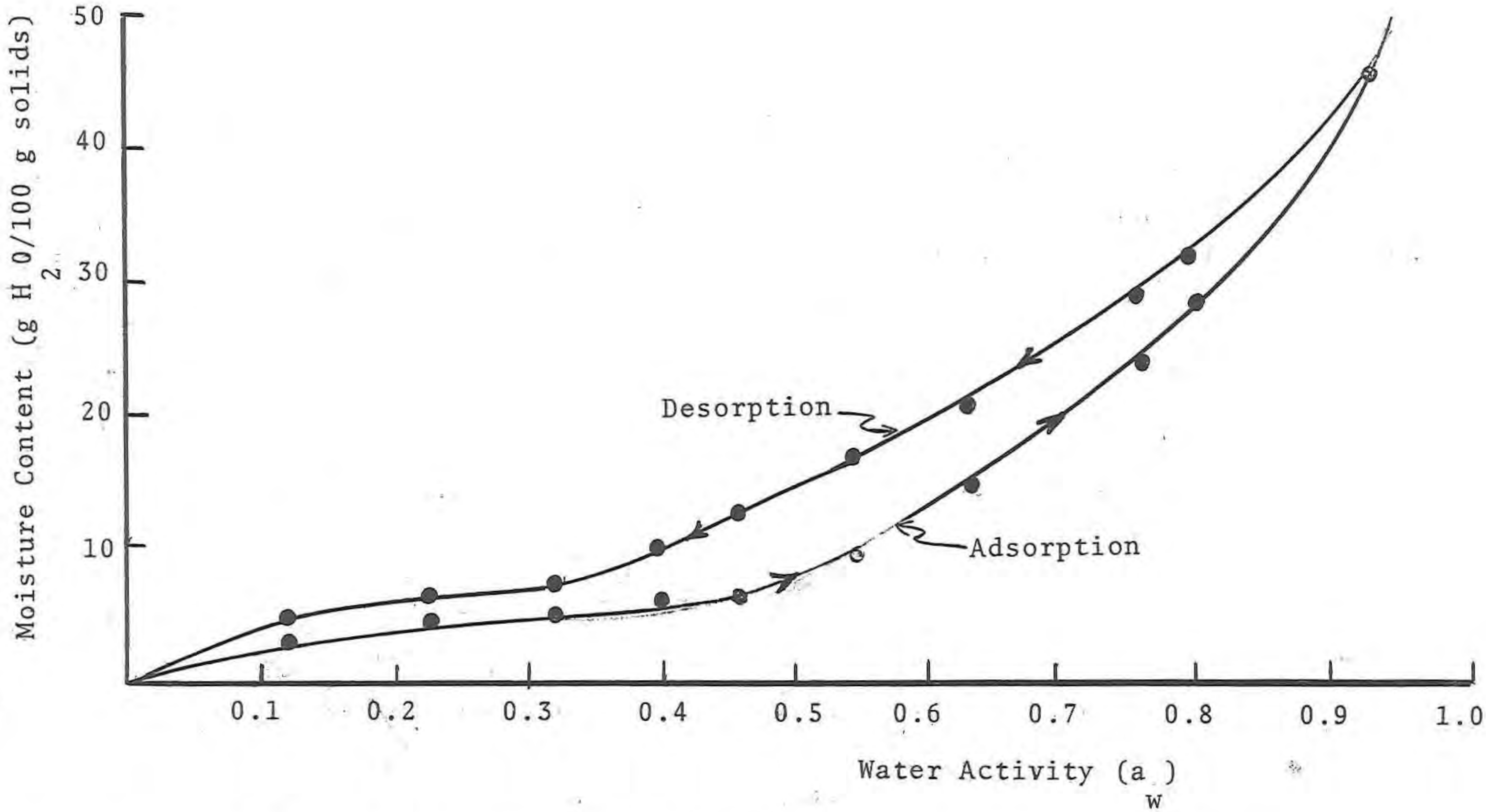


Fig. 12. Adsorption and desorption isotherm for freeze dried pork sausages at 20°C.

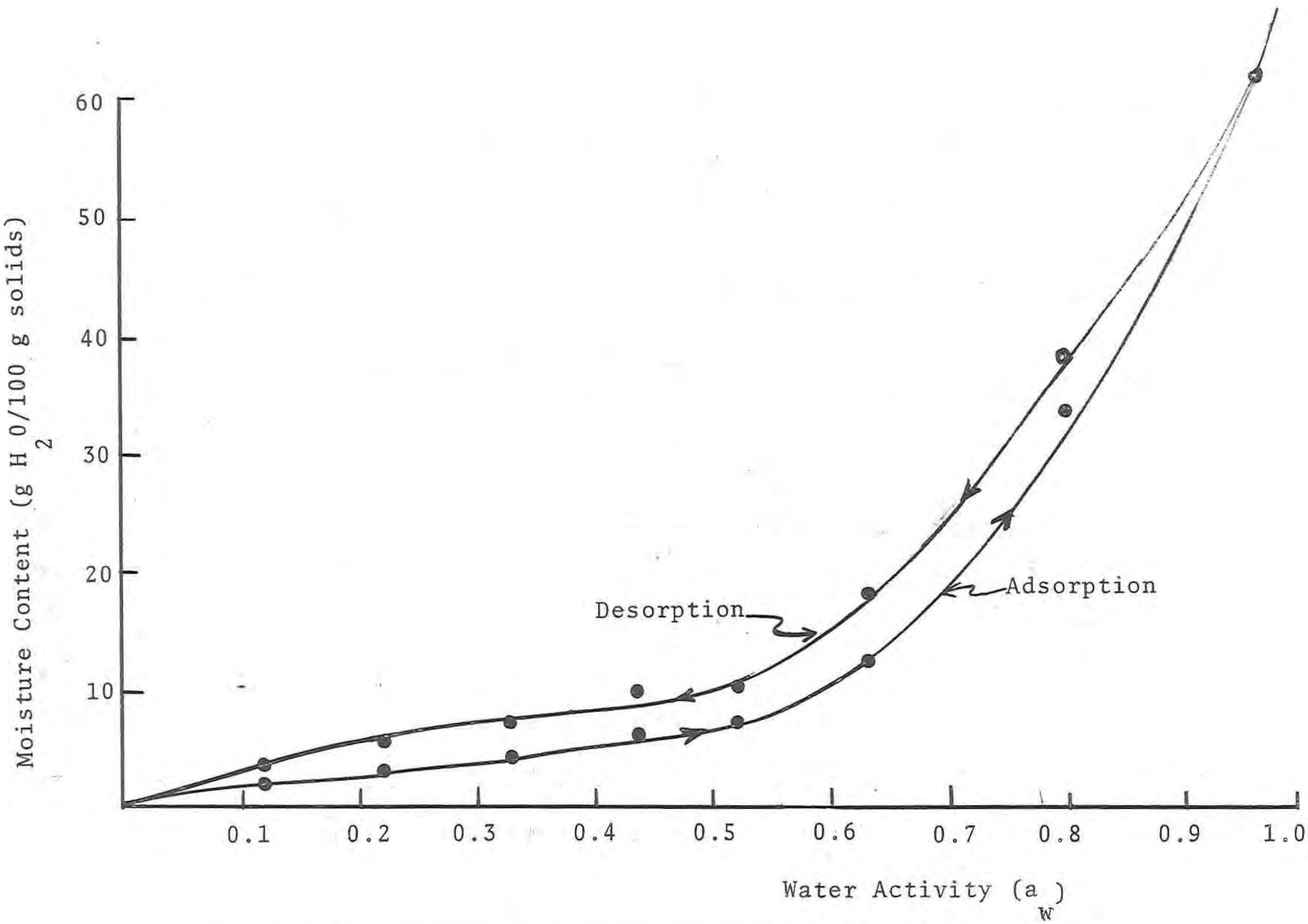


Fig. 13. Adsorption and desorption isotherm for freeze dried pork sausage at 30°C.

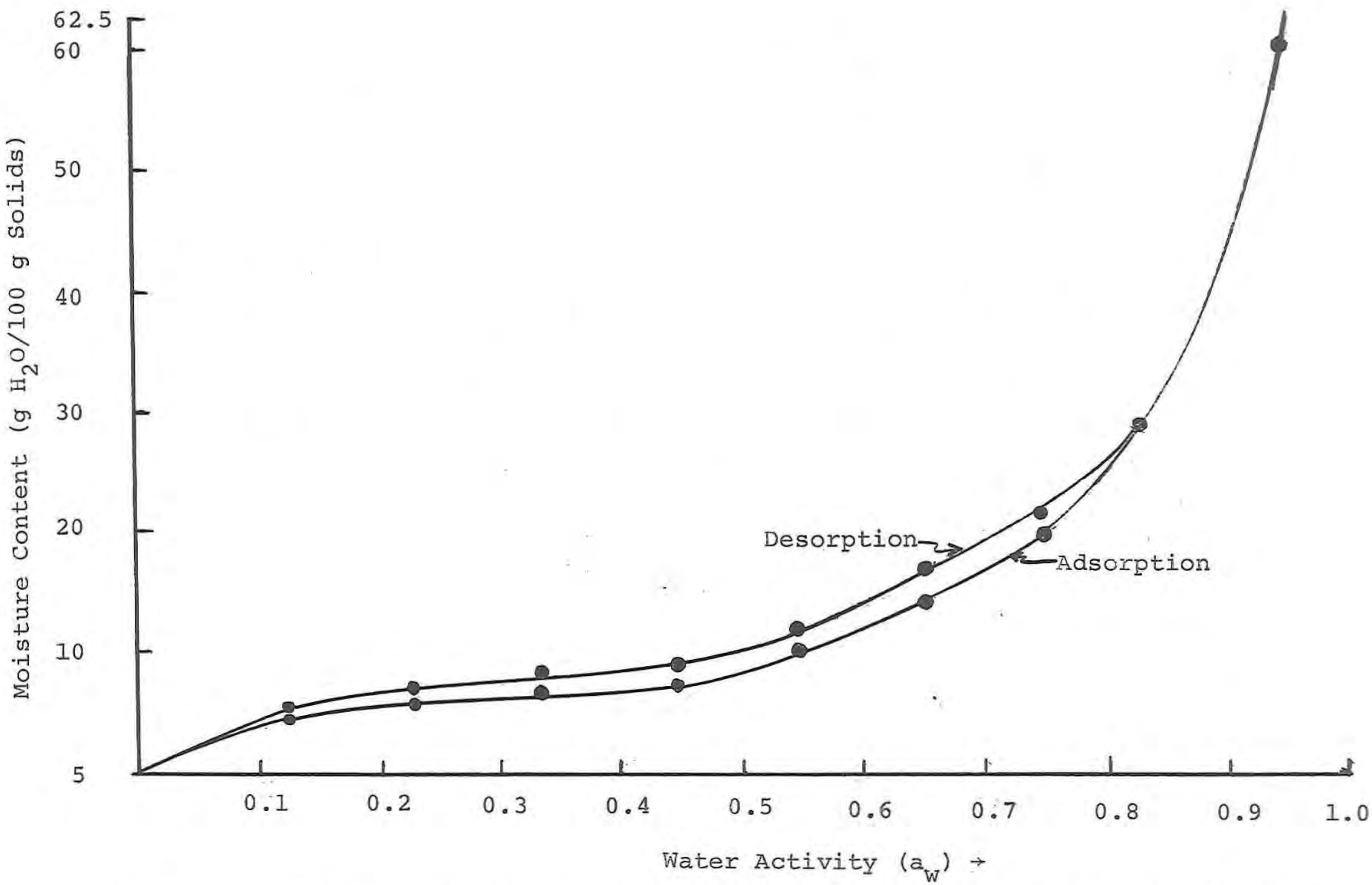


Fig. 14. Adsorption and desorption isotherm for freeze-dried beef meetballs 2t 20°C.

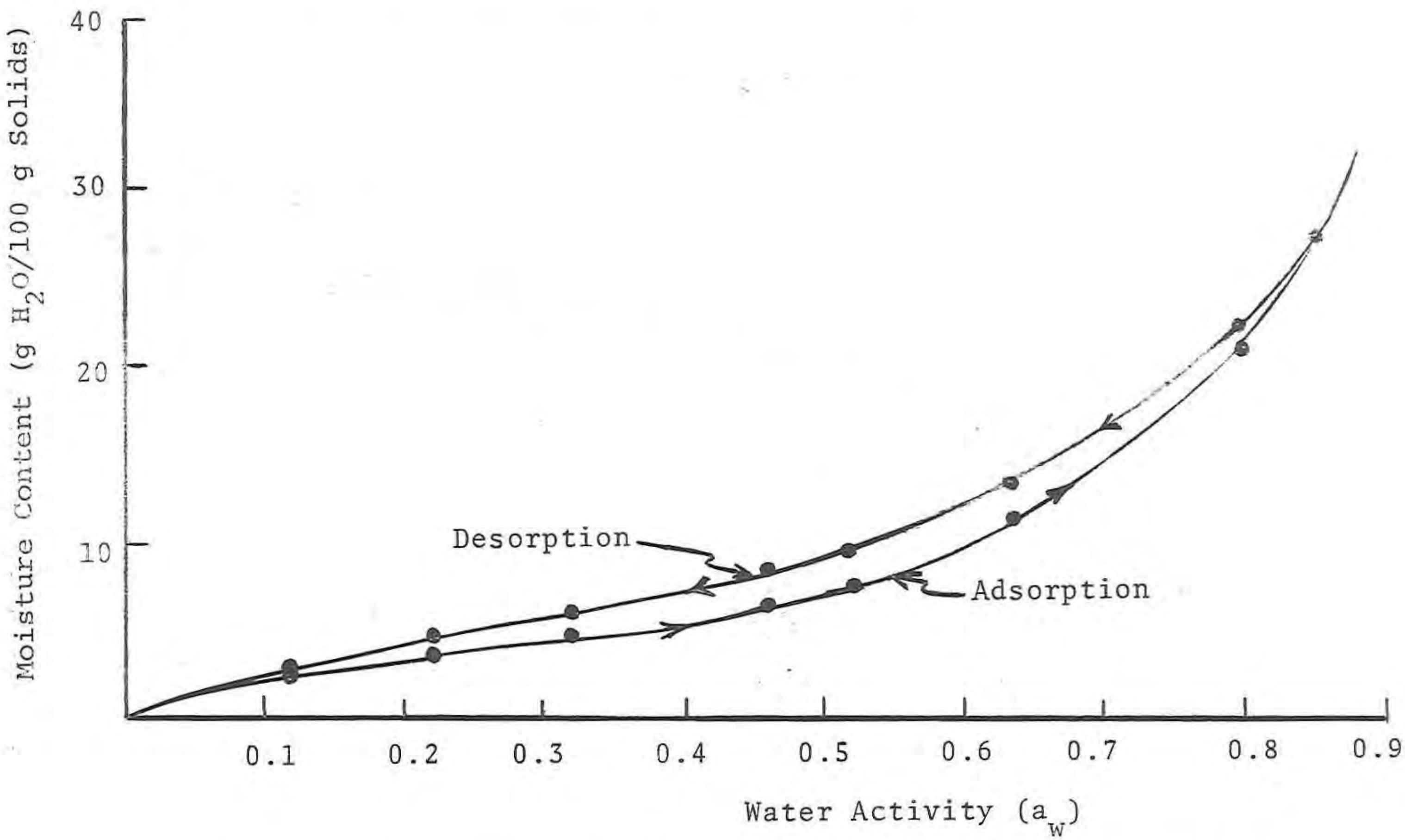


Fig. 15. Adsorption and desorption isotherm for freeze dried beef meat balls at 30°C.

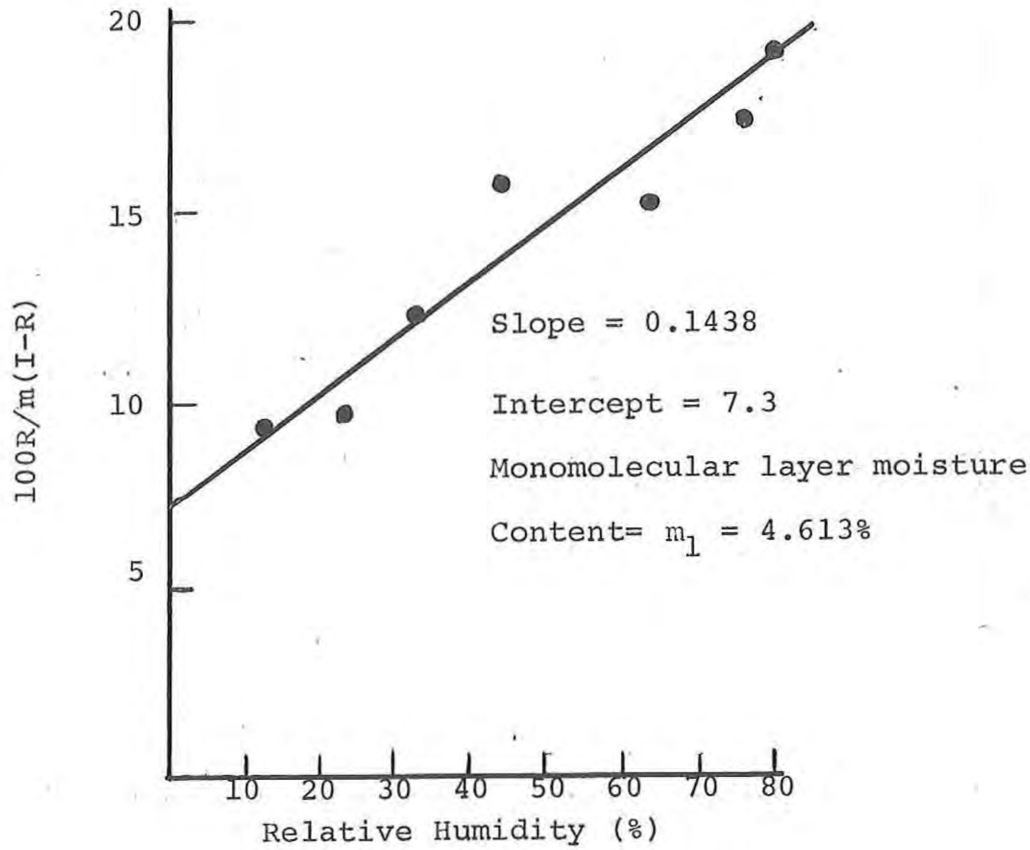


Fig. 16. BET monolayer plot for freeze dried beef meatballs.

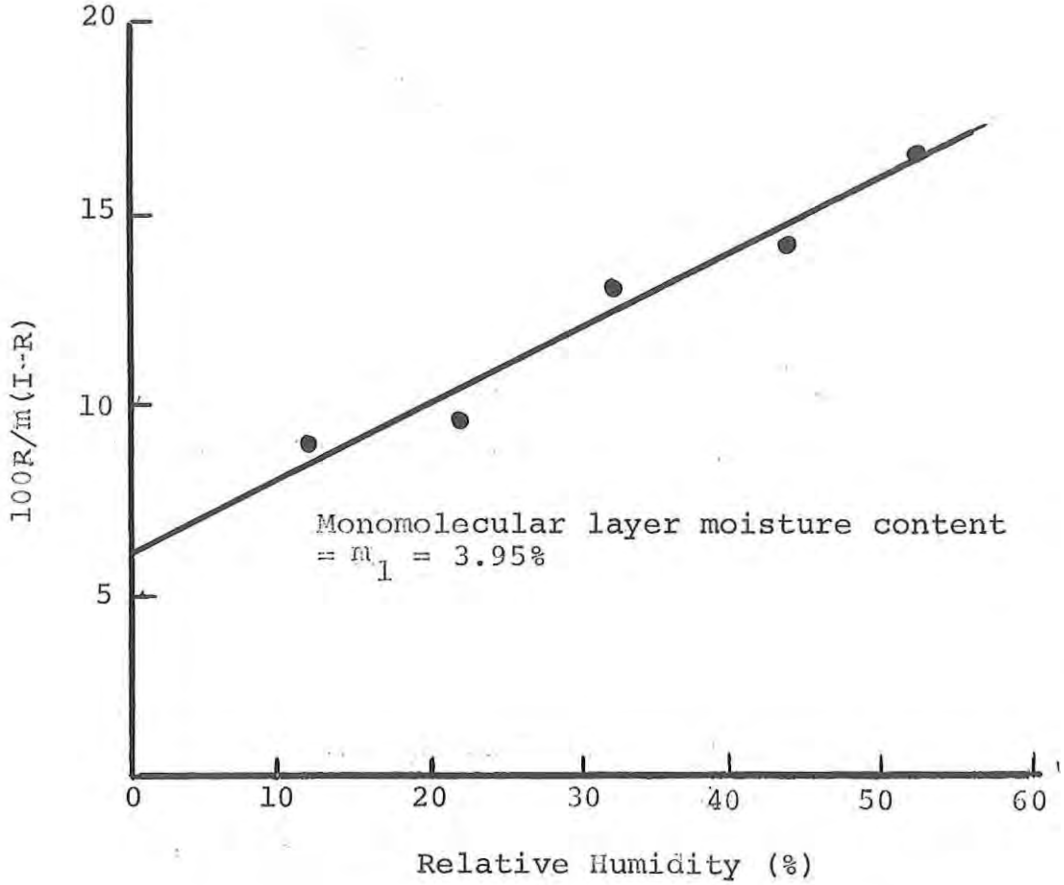


Fig. 17: BET monolayer plot for freeze dried pork sausages

For monomolecular layer moisture contents of freeze dried beef meatballs and pork sausage, the BET isotherms are shown in Fig. 16 and 17, respectively. Based upon these data, an average value of 4.5% moisture was adopted for the redrying of many test products for comparison with the specified 2% moisture levels.

14. Microbiology:

Owing to some persuasion on the part of these researchers to justify a 10-12% (unredried) moisture level, microbiological activity in the processed meat products was studied throughout the project in order to ascertain safety at the higher as well as the lower moisture levels. Total bacterial counts were made using total plate counts. Yeasts and molds count were determined using Potato Dextrose Agar, Lauryl tryptose broth was used to test for the presence of coliforms. The methods used for these determinations are described in Section II-C. Results of these investigations are shown in Table 21 and 22.

TABLE 21

Amount of Microorganisms Present in Fresh Pork and Beef

Products	Microorganism		
	Standard Plate Count Per Gram of Product	E. coli Per Gram of Product	Mold and Yeasts Per Gram of Product
Beef	1.7×10^5	25-45	30-40
Pork	9.6×10^4	25-45	30-40
Specification	2.0×10^5	40	not defined

TABLE 22

Effect of Storage Time and Storage Temperature on the Amount of Microorganisms Present in Freeze Dried and Compressed Meat Products at Three Different Moisture Levels

Storage Time (wks)	Storage Temp. °C	Moisture Level (%)	Standard Plate Count Per Gram of Product at 22°C, x 10^4		E. coli Per Gram of Product		Mold and Yeast Per Gram of Product, X 10^2	
			(M)[1]	(S)[2]	(M)[1]	(S)[2]	(M)[1]	(S)[2]
0	-	2.0	1.8	5.2	0	0	3	6
	-	4.5	2.5	7.4	0	0	6	3
	-	10.0	2.5	9.4	0	0	8	2
12	5	10.0	0.4	2.4	0	0	0.3	2.4
	22	10.0	1.6	0.5	0	0	4	1.9
	38	10.0	3.5	1.2	0	0	1	1.1

(1) Meatballs

(2) Sausage

Despite the fact that the production of the meatballs and sausages was a hand operation, the number of organisms was not above the critical 2 x 10^5 gram level (per specification). Yeast, but not mold, was found to be present but also at low levels. (No defined standard is given by Natick Lab.) No coliforms were found in any samples. Of the three tests, the results of the Lauryl tryptose broth tubes were the most significant. In some cases gas was found in the Lauryl tryptose Broth gas tubes, but upon running further tests with the positive samples in Brilliant Green Bile Broth, the tell-tale gas indicating coliform presence did not form. (Standard of E. coli is 40/gram.) In fact, there is a decrease in bacterial population in the 10% moisture samples stored at any of the temperature conditions tested.

Storing samples at higher temperatures had little effect on the number of organisms. This favorable effect is undoubtedly due to the low water activity, even at the highest moisture level, 10-12%.

15. Texture Study:

Texture evaluation - with compression plates of the Instron machine (Model No. T.M., Instron Corp., Canton, Mass.), single plate (1/8" wide) through cell, and expressed as peak deformation force (lbs.)—was investigated for rehydrated freeze-dried and compressed meat products at three different temperatures and three different moisture contents. Table 23 shows the results, and typical curves are given in Fig. 18 and 19.

TABLE 23

Texture Change of Freeze-Dried and Compressed Meat Products (following rehydration)

Storage Time (wks)	Storage Temp. (^{o}C)	Moisture Level (%)	Peak Deformation Force (lbs.) on Rehydrated Products	
			Beef Meatballs	Pork Sausage
0		2.0	3.44	2.59
		4.5	3.38	2.52
		10.0	3.32	2.38
12	5^{o}	2.0	3.41	2.56
12		4.5	3.14	2.43
12		10.0	2.97	2.32
12	22^{o}	2.0	3.34	2.48
12		4.5	2.86	2.46
12		10.0	1.95	2.16
12	38^{o}	2.0	3.25	2.56
12		4.5	2.64	2.40
12		10.0	1.20	2.00

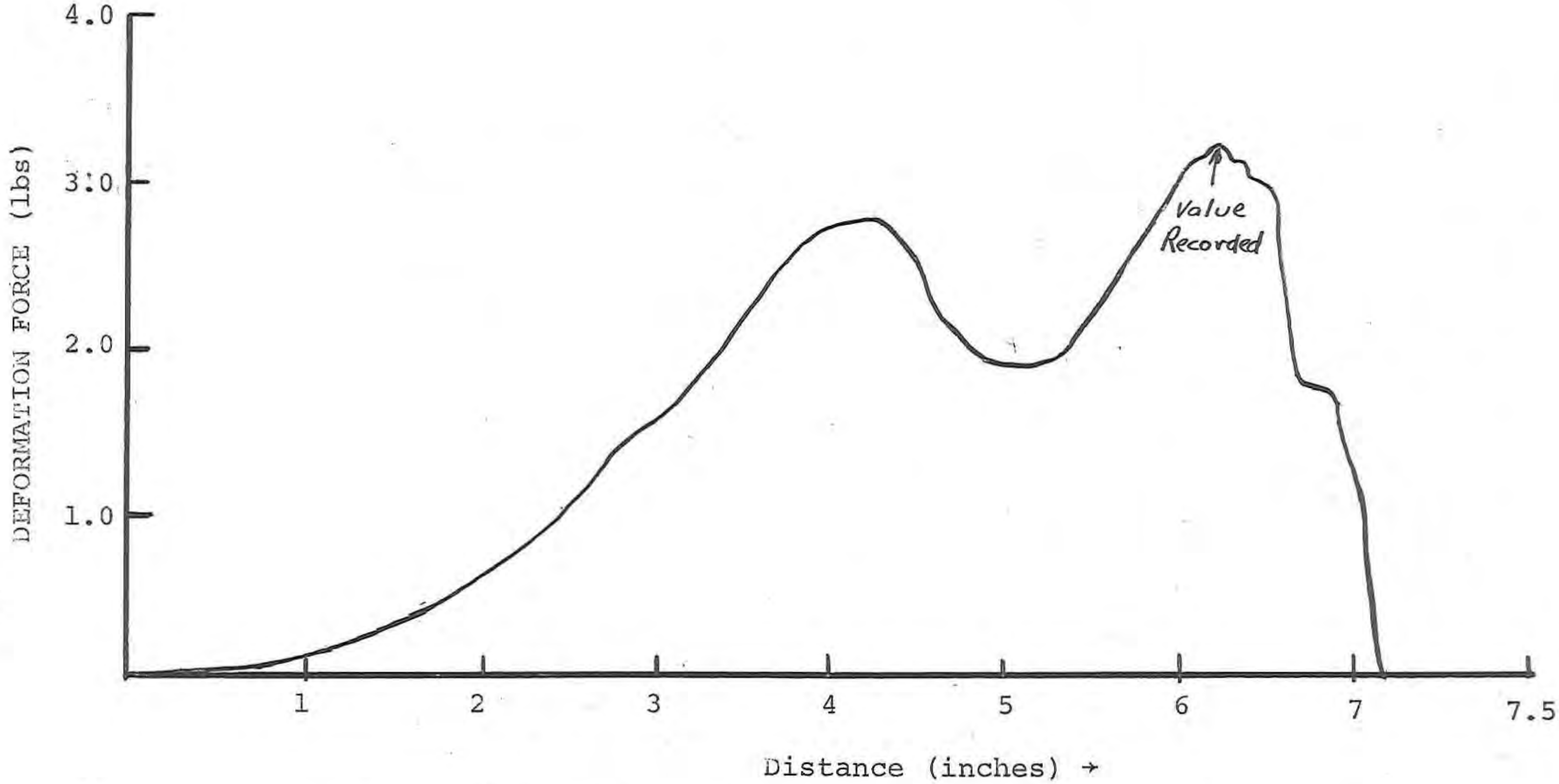


Fig. 18. A typical deformation curve for freeze-dried and compressed pork sausage after rehydration (typical double peak; higher peak value accepted)

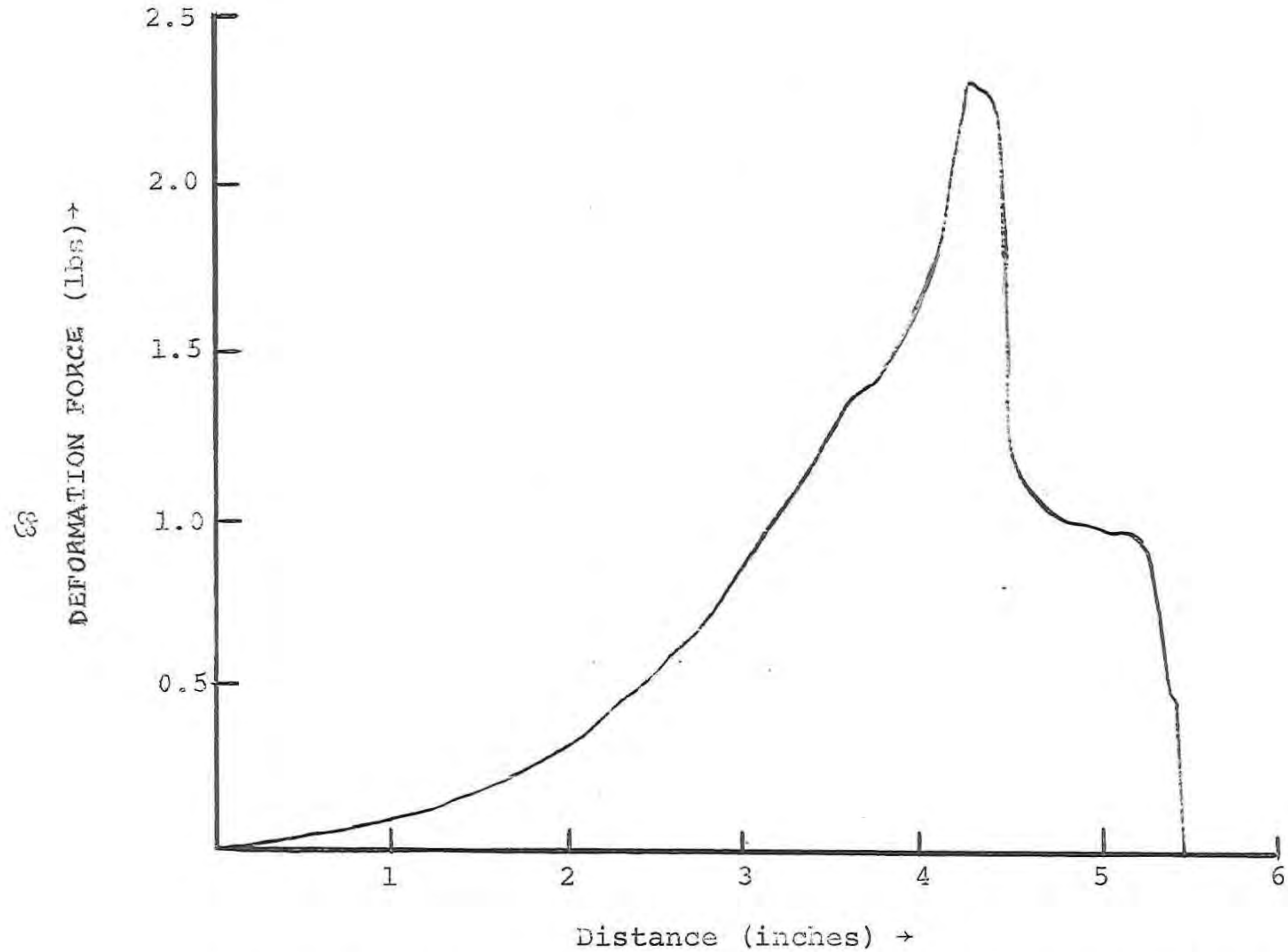


Fig. 19. A typical deformation curve for freeze-dried and compressed beef meatballs after rehydration (single peak).

As it can be seen, the originally higher moisture levels of the products correspond to a decrease in deformation force (decrease ∿ increased tenderness). In other words, products stored with 10% moisture indicate a more tender texture after rehydration than products with 4.5 and 2% moisture. These latter moisture contents showed less significant change in their peak deformation force at the three different temperatures (after 12 weeks storage). On the other hand, the storage temperature does affect the texture of the product with higher moisture level; a significant decrease in the peak deformation force is shown in both meatballs or sausages stored for 12 weeks at 10% moisture level. However, the change is more dramatic with the meatballs.

16. Sensory Evaluation

The final formulations used to make pork sausage and beef meatballs were based on the results of the sensory panel acceptance as well as the pre-screening by the developmental scientists. (Overall panel scores of the various binder combinations used for product formulation are given in Table 7 for pork sausage and Table 9 for beef meatballs). Pork sausage made with the defined binders resulted in the highest panel score, 7.6 on a nine point scale; beef meatballs with the defined binders also had a score of 7.6. Such scores correspond to good acceptability.

The concentration of gluten was one of the major factors influencing the rehydration performance of the freeze dried compressed meat products. The gluten provided a valuable texture property by virtue probably of forming a very thin three-dimensional web like an overextended chewing gum (bubble gum). Table 24 shows that a conspicuous increase of gluten in the meatballs significantly reduced the panel score. Therefore, a level of 0.1% gluten was used in the final formulation for beef meatballs (0.15% gluten was used in pork sausage). The higher level of gluten in sausage was necessitated by the higher fat content.

TABLE 24

Effect of Gluten Concentration on Panel Acceptance

Product(1)	Amount of Gluten(2)	Overall Panel Rating
Meatballs I	0.1%	6.2
Meatballs II	0.125%	5.9
Meatballs III	0.150%	5.6

(1) These products are freeze dried and then compressed with 10-12% moisture content.

(2) Other binders used at the time of this test were Starch (National No. 10) 2.5% and pregelatinized Starch (National No. 711) 0.2%.

Sensory panel studies on the effect of moisture level at the time of compression indicate (Table 25) that products containing 10-12% moisture gave the best compressed product. Products with moisture levels below 8% usually disintegrated during compression. All panel tests were on rehydrated products (cooked 10 min. at 80°C).

TABLE 25

Effect of Moisture Content at the Time of Compression on Panel Acceptance

Product	% Moisture	Panel Rating
Meatballs I	12	7.2
	8	5.0
Meatballs II	11.5	6.2
	8.5	5.6
Meatballs III	11	5.6
	8	4.8
Meatballs IV	7	Product disintegrated on compression.
	6	Product disintegrated on compression.
	4	Product disintegrated on compression.
Sausage I	$\simeq$12	6.2, 6.5
	8	5.1
Sausage II	$\simeq$12	6.5, 6.3, 7.5
	$\simeq$ 8	5.9

Panel tests also illustrated that redrying the products following compression decreased acceptability. This is shown in Table 26.

TABLE 26

Effect of Redrying of Compressed Products on Panel Acceptance

Product	% Moisture	Panel Rating
Meatballs I	12	7.2
	4.5	6.9
	2.0	6.3
Meatballs II	8.5	5.6
	4.5	5.7
	2.0	5.5
Sausages I	12	7.5
	4.5	6.1
	2.0	5.8

A series of preliminary screening studies was carried out on beef meatballs and pork sausage in order to ascertain the most acceptable formulation for these products. The panel usually comprised of 18 or more judges, was experienced in sensory testing. The formulations selected were used in subsequent storage tests of freeze dried and compressed products.

Previous experience on using the testing procedures in which appearance, flavor, texture and an overall rating were evaluated on a nine-point scale indicated that a panel score of 6.0 was acceptable. Initial scores on sausages were within the acceptable range although flavor on the 4.5 percent moisture sample was slightly less than 6.0 (Table 27). Flavor and overall rating scores are nearly identical in most cases as can be noted in the data on the sausage. In 2% moisture-content samples stored at 5°C essentially no change occurred over 12 weeks. At 22°C, there was a slight drop as was true at 40°C*. In the 4.5% moisture-content samples, the initial evaluation was slightly low and there was a minor trend upward over the 12 weeks storage period. The 10% moisture samples stayed constant for 12 weeks at 5°C and dropped slightly after 12 weeks when stored at 22°C or 40°C (Table 27).

For some reason, the pattern on the meatballs varied somewhat. Initial evaluations on both the 2% moisture-content and 4.5% moisture-content samples were considerably lower than anticipated. Although there was some variability at the sample times, these samples remained essentially the same over an 12 week storage period. Only the 10% moisture samples exhibited any really dramatic changes. At 5°, there was a one point drop in flavor acceptability, at 22° about a one and a half point drop, and close to two points at 40°. Beef is normally considered more stable than pork in so far as flavor is concerned. However, the additional spices and fats could be creating interactions not usually apparent in beef.

---

*Storage temperature was changed from 40° to 38° after 8 weeks storage. Whereas 38°C storage was specified in the contract, it was elected to use a room already set at 40°C for another project. This election was approved by Natick's representative as acceptable with the understanding that this contractor was willing to bear the risk of the additional 2°C (3.6°F). As of October 3, 1973, the research that relied on 40°C was concluded, and the storage temperature was then reduced to 38°C for the remainder of the storage time.

Although acceptance levels were sometimes lower than hoped for, it should be remembered that testing procedures were quite rigorous. One does not normally consume a plain sausage or meatball; they are usually served in a sauce of some type. It is suggested that properly sauced, following rehydration, an acceptable product would result even after prolonged storage at high temperatures.*

One kilogram quantities of freeze dried and compressed meatballs and sausage products, contract samples, were submitted by E. Huang and E. Seltzer to Natick Laboratories on October 15, 1973 for Natick panels test, and results phoned by Dr. M. Brockmann indicated that the submitted samples have been approved by the Natick panelists. These samples were first demonstrated for rehydratability, texture, appearance, etc., on October 16th to Messrs. Tuomy, Brockmann and Helmer in Natick.

---

*This rationalization, as well as the preceding two paragraphs, was contributed by Dr. Elizabeth Stier under whose supervision the taste tests were carried out.

TABLE 27

Sensory Evaluation of Freeze Dried and Compressed Pork Sausage and Beef Meatballs for 12 Weeks Storage

The fresh meatballs have the following panel scores: Appearance: 6.9, Flavor: 7.5, Texture: 7.1, and Overall 7.1.

The fresh pork sausages have the following panel score: Appearance: 7.0, Flavor: 7.5, Texture: 7.1, and Overall: 7.2.

Product	Pork Sausage											
Moisture Level (%)	2											
Storage Temp. (°C)	5				22				40[1]			
Storage Time (wks.) / Items	App.[2]	Flavor	Texture	Overall	App.[2]	Flavor	Texture	Overall	App.[2]	Flavor	Texture	Overall
0	6.2	6.3	6.2	6.3	6.2	6.3	6.2	6.3	6.2	6.3	6.2	6.3
4	6.2	6.3	6.5	6.4	6.1	5.7	6.0	5.8	5.8	6.1	5.8	5.8
8	6.2	6.6	6.3	6.5	5.9	5.5	5.3	5.5	6.5	5.5	5.8	5.7
12	6.1	6.5	6.0	6.0	6.4	6.1	6.1	6.2	5.8	5.6	5.8	5.9

[1] Storage temperature was changed from 40°C to 38°C after 8 weeks storage.

[2] App. - Appearance

TABLE 27 (cont'd)

Product	Pork Sausage											
Moisture Level (%)	4.5											
Storage Temp. (°C)	5				22				40[1]			
Storage Time (wks.) \ Items	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all
0	6.2	5.8	6.0	5.8	6.2	5.8	6.0	5.8	6.2	5.8	6.0	5.8
4	5.4	5.5	6.3	5.8	6.4	5.8	6.3	6.3	5.8	5.6	6.7	5.8
8	6.4	6.5	6.5	6.4	5.8	6.5	6.8	6.6	6.4	6.0	6.4	6.4
12	5.1	5.5	6.3	5.5	5.5	5.5	5.6	5.3	5.4	5.4	5.1	5.9

[1]Storage temperature was changed from 40°C to 38°C after 8 weeks storage.

[2]App. = Appearance

TABLE 27 (cont'd)

Product	Pork Sausage											
Moisture Level (%)	10											
Storage Temp. (°C)	5				22				40[1]			
Storage Time (wks.) \ Items	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all
0	6.6	7.2	6.8	6.9	6.6	7.2	6.8	6.9	6.6	7.2	6.8	6.9
4	5.9	6.9	6.3	6.7	5.9	5.6	6.1	6.0	6.9	4.7	5.7	5.0
8	5.0	5.9	5.8	5.9	5.4	5.6	5.0	5.3	5.2	4.8	4.9	5.1
12	6.9	6.5	6.3	6.8	6.3	6.1	6.3	6.2	6.3	6.1	6.3	6.2

[1]Storage temperature was changed from 40°C to 38°C after 8 weeks storage.

[2]App. = Appearance

TABLE 27 (cont'd)

Product	Beef Meatballs											
Moisture Level (%)	2											
Storage Temp. (^{o}C)	5				22				40[1]			
Storage Time (wks.) \ Items	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all
0	5.8	5.6	5.1	5.5	5.8	5.6	5.1	5.5	5.8	5.6	5.1	5.5
4	6.7	6.2	5.6	5.9	6.5	5.3	4.6	5.0	6.2	6.1	5.4	5.8
8	6.5	6.4	5.8	6.2	5.9	5.1	5.6	5.5	5.9	4.6	5.6	5.0
12	6.4	6.0	5.4	5.5	6.1	5.1	5.8	5.3	5.8	5.4	5.4	5.3

[1]Storage temperature was changed from 40^{o}C to 38^{o}C after 8 weeks storage.

[2]App. = Appearance

TABLE 27 (cont'd)

Product	Beef Meatballs											
Moisture Level (%)	4.5											
Storage Temp. (^{o}C)	5				22				40[1]			
Storage Time (wks.) \ Items	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all
0	6.2	5.8	5.7	5.8	6.2	5.8	5.7	5.8	6.2	5.8	5.7	5.8
4	7.1	6.1	5.9	6.2	6.9	5.4	5.7	5.8	6.7	5.2	5.8	5.3
8	6.1	5.3	6.1	5.6	6.1	5.8	5.4	5.9	6.2	5.9	5.5	5.8
12	6.2	5.6	5.7	5.3	5.8	5.6	5.0	5.4	5.5	4.8	5.1	4.7

[1]Storage temperature was changed from 40^{o}C to 38^{o}C after 8 weeks storage.

[2]App. = Appearance

TABLE 27 (cont'd)

Product	Beef Meatballs											
Moisture Level (%)	10											
Storage Temp. (°C)	5				22				40[1]			
Storage Time (wks.) \ Items	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all	App.[2]	Fla-vor	Tex-ture	Over-all
0	6.7	6.5	5.2	6.3	6.7	6.5	5.2	6.3	6.7	6.5	5.2	6.3
4	6.6	6.6	5.7	6.5	6.3	5.7	5.4	5.7	6.4	4.5	4.7	5.1
8	6.8	6.7	6.3	6.7	6.6	6.1	6.1	6.1	6.0	5.0	5.3	5.1
12	6.3	5.6	4.8	5.3	5.7	5.1	4.7	4.8	5.9	3.9	4.8	4.6

[1]Storage temperature was changed from 40°C to 38°C after 8 weeks storage.

[2]App. = Appearance

Discussion

Dehydrated meats and meat products are especially suitable as military rations owing to their light weight and excellent keeping qualities (in the absence of moisture). If the product is precooked, it can be prepared for consumption in a minimum amount of time and with little effort. With stability and convenience features such as these types of products demonstrate, they have the potential of being a boon to the civilian population.

Conventional freeze-drying, in which the product remains frozen throughout the drying cycle, dries the product to moisture levels of 2% or less with no appreciable change in the original size and shape. A compression step though can only be carried out if the freeze-dehydrated product has been rehydrated to a slightly higher level of moisture and allowed to equilibrate to uniform moisture throughout. If the dry product is compressed without such remoistening, it will be crushed to powder. The level of moisture content to which these products need to be rehydrated before compression was established as being at 10-12%. At this level of moisture the products could be compressed without fragmenting yet maintained the ability to return to their original shape when completely rehydrated at the time of consumption.

The product quality (which includes rehydration properties, flavor, and texture) depended mainly on the type or types of binders used. Various binders and combinations of binders were tried until a combination was discovered which gave good flavor and texture and rehydrated well. The final binder combination used in pork sausage consisted of protein-reactive modified starch (National 10), pregelatinized modified starch (National 711), and wheat gluten. For meatballs, the final binder combination consisted of wheat gluten and protein-reactive modified starch (National 10).*

Both modified starches were supplied by the National Starch and Chemical Corporation of Plainfield, New Jersey. The National 10 product is described as a "Food-Starch-Modified", which is refined from regular corn, and prepared in

---

* Patent applied for by the National Starch & Chem. Corp. to cover its application specifically as binder for comminuted meats because of its unique reactivity with meat protein. The combination of this starch with wheat gluten is a Rutgers development and is not expected to be part of National Starch Company's claim of invention.

accordance with the F.D.A. Food Additives Regulation 121.1031. It is labelled "Food-Starch-Modified" as required by said regulation. It is understood that this modified starch is a mildly inhibited cross-linked starch which is prepared by treating the starch with a cross-linking agent. These cross-linking agents have at least two functional groups each. National 10* binds excellently to the water and proteins of the beef and pork when it is used at levels of 2-4%. The final product exhibits a reduced tendency to break apart (even with rough handling) and has an improved bite.

Pregelatinized modified starch (National Starch 711) is an easily dispersed "Food-Starch-Modified" that has been refined from waxy corn (almost 100% amylopectin). These two starches associate by means of secondary forces such as hydrogen bonds and/or van der Waal's forces, to form a continuous three-dimensional network to reinforce the meat products. When the products are rehydrated, the starch granules swell, thereby entrapping water within the product. The cross-linked structure of the National Starch 10 allows good rehydration by resisting overabsorption of water. It is also believed that National Starch 10 tends to cross-bind with the meat particles to form a more continuous network. This characteristic imparts the compressed meat with a "memory", enabling it to return to its original shape upon rehydration. Alternative starches to the National starches have been obtained from Stein-Hall Co., and American Maize Co. Some of these have in common a high amylopectin content and a pregelatinization. Cross-linked starches are also available from these sources.**

It was observed that deep fat fried meatballs and sausages offer resistance to freeze-drying owing to a surface film which develops during the frying. The exact nature of the surface film is unknown, but it is believe to be the result of an interaction between the meat proteins and the binder systems brought about by the high frying temperatures.

After freeze-drying, the products require remoistening before compression. If the products are compressed immediately following the drying step (moisture 2-3%), they will be crushed to powder. A possible explanation of this phenomenon may be that during the drying cycle the starch returns to its original "powdered state". This tends to weaken the strong interlinked system, allowing the product to be crushed. When

---

*Patents assigned to National Starch that relate to comparable modified starch are: U.S. Patent 3,052,545, Sept. 4, 1962. J.J. Ducharme and H.S. Black, Jr., "Deep-Fried Food Batter Mix". U.S. Patent 3,208,851, Sept. 28, 1965, J.A. Antonori and M.W. Rutenberg, "Process for Preparing a Breaded Deep-Fried Food".

**For example, Stein Hall Co.has tapioca starch (high content of amylopectin) modified by cross-linkage or by hydroxy-propylation.

the product is remoistened to a level of between 8-10%, the three-dimensional starch system is reactivated and the starch-protein skin is strengthened, thereby imparting the meat product with a resistance to compression. A pressure of 1500-2000 lbs. in a hydraulic press was found to be the ideal pressure for compressing the 10% moisture products without causing them to break up. Propylene glycol and glycerine were experimented with as remoistening agents, but they were not as effective as simple distilled water. Propylene glycol has a strong affinity for water, and it is this characteristic which made it a poor remoistening agent. There was a competition for the water between the meat and starch and the propylene glycol. This competition prevented complete adsorption of water into the product and created fragmentation upon compression.

Following remoistening of the freeze dried products, they were placed under vacuum to equilibrate, usually overnight. This vacuum equilibration process is faster than one carried out at atmospheric pressure, but the resulting product is one of uniform moisture throughout which can permit compressing without breaking up. This equilibration occurs by diffusion of the water molecules from the outside of the product to the interior (movement from a region of greater moisture concentration to that of a lesser concentration). If an incompletely rehydrated product is compressed, it will be crushed.

Having solved the problems of formulation, rehydration, compression, and equilibration, it became necessary to study the problem of storage. Some of the compressed meat products (moisture levels being 10-12%) were dried in a vacuum oven to lower moisture levels, 4.5% and 2% being the chosen targets. The purpose of this step was to determine the optimum moisture level consistent with ease of processing, good storage stability, good rehydratability and taste panel acceptability. Storage studies were conducted by placing 30 meatballs or sausages in 16 oz. Mason jars. These jars were evacuated and flooded with nitrogen. A successful evacuation operation reduced the oxygen in the headspace to a level of 2% or less in earlier work. The oxygen content in the headspace was determined using the gas chromatograph. Levels of 0.1% oxygen could be reached in later work using the cabinet of the freeze-dryer as a buffer between the vacuum pump and the vacuum source orifice to a desiccator containing one or more Mason jars. The latter jars had perforated caps which were sealed with silicone cement after three cyclic vacuum and nitrogen exposures. A typical graph and the results of this operation are shown in Table 28.

The presence of oxygen in the headspace was thought to be a factor contributing to the deterioration (browning and lipid oxidation) of the stored product. The oil used for deep fat frying was a relatively unsaturated vegetable oil (Wesson). Deep fat frying in this kind of oil makes the product susceptible to rancidity if there is much oxygen left in the jar. Choice of frying fats and shortening was made for Wesson oil after a seemingly intelligent and diligent effort to find fats that would qualify more precisely under MIL-P-43383 A(3.2.3). Such hydrogenated fat or oil is difficult (if not impossible) to procure at retail, and an inquiry was made unsuccessfully via Prof. Stephen S. Chang's industry relations. It was understood after discussion with Natick personnel at an early stage of this project that some freedom of choice was permissible since modern oil manufacture now skillfully utilizes powerful trace antioxidants and sequestrants such that required AOM stability and other characteristics are usually available in retail oils. Wesson oil which is labelled as "soybean-cottonseed oil" is believed to be partially hydrogenated. It was chosen because of ease of local procurement with the precaution that its use per batch would be for only five consecutive frying cycles, 150 seconds per frying cycle, within not over two hours of elapsed time; after which the oil was discarded. This use of Wesson oil constitutes a freedom of procedure assumed by the researchers here with some risks of stability during storage.

The jars were then stored at three different temperatures for twelve weeks. The three storage temperatures were 5°, 20°, and 40°C. Within the twelve weeks period, it was found that the oxygen utilization and, therefore, the development of rancidity was accelerated at 40°C. The samples stored at 5° and 20°C each contained a small quantity of oxygen and had not deteriorated to the extent of the 40°C sample.

TABLE 28

Percent of O_2 in Headspace of Mason Storage Jar After Evacuation and N_2 Gassing.

Run No.	% of Oxygen in Headspace of Mason Jar (by GC)
1	0.098
2	0.096
3	0.101
4	0.092
Average	0.097

The peroxidation of an unsaturated fatty acid is one of the major problems. It is a free radical reaction, and leads to the formation of hydroperoxides. As the oxidation progresses, the hydroperoxides break down and products of their breakdown begin to accumulate. These reactions are sensitive to temperature, electromagnetic radiation (light and heat) and the dispersion of reaction end products, as well as to the presence of catalysts and inhibitors. This sequence of reactions explains why the peroxide values are higher for samples which have been in storage for 8 weeks than they are for samples stored for 12 weeks. As oxidation progresses, the formation of the non-radical products will reduce the amount of peroxide titratable in peroxide determination analyses.

One of the more distinctive qualities of a freeze-dried product is its ability to rehydrate to its original size and weight. The property of a material to both freeze-dry and rehydrate upon the addition of water depends on said material's ability to form an open porous structure which contains no barriers that may be impermeable to water. This kind of structure is one which would be formed during the freeze-drying step.

It seems that the ability of freeze-dried compressed products to return to their original size and shape upon rehydration in an excess of water depends upon the penetration of water due to capillary action. This penetration, in the freeze-dried compressed products, is aided by the meat proteins which become moistened and the starch granules which begin to swell and entrap water in their three-dimensional network. It was discovered that as the moisture levels of the compressed products were increased the rehydration ratios rose also. All the products (i.e., those at 2, 4.5, and 10-12% moisture) were rehydrated under the same conditions to obtain these results. The conditions for rehydrating these products were as follows: The products were placed in an excess of water, which was held at temperatures of between 75-85°C, usually 80°C. They were removed after ten minutes, held on filter paper for approximately 15 seconds, and weighed to determine the rehydaration ratio.

An explanation for these differing rehydration ratios may be traced to the starch binders. In the products which were rehydrated to the 10-12% levels, the amount of water added may have served to cause swelling of the starch granules and wheat gluten thereby reactivating their three-dimensional network. This network as previously mentioned has a "memory" and will entrap water molecules, allowing the product to return to its original shape. The redried products (2% and 4.5% moisture) have so little moisture that they are at or below the monomolecular water level area. At such low moisture levels, the starch and wheat gluten might have a tendency to form a coating around the meat particles. A meat particle with such a "skin" would have to undergo a two-step rehydration. The first step would entail absorption of water to remoisten both the starch and wheat gluten coating and the meat particle. The second would involve further absorption of water to facilitate the swelling of the product. It is also believed that at lower moisture levels the meat proteins become denatured, and this combined with the migration of soluble solids or fats, tends to make the product less hydrophylic, thereby slowing the rate of water penetration into the product.

Changes in the meat proteins during extreme drying can bring about physical changes in the product which can adversely affect both the functional properties and those which make the product palatable. Publications of Karel indicate that the lipid-protein complexes present in meat products are involved in bringing about these changes. He showed that in foods derived from muscle, which were stored in a frozen or a dried state, the products of peroxidation of the lipid constituents could interact with the protein constituents to bring about the aforementioned physical changes. Myosin is one protein which is particularly susceptible to these reactions. These peroxidation product-protein interactions can lead to the formation of colored, insoluble, or partially soluble complexes, all of which could be detrimental to the products' quality.

Rates of browning in freeze dried and compressed meat products were studied at three different temperatures and at three different moisture contents for each temperature. It is believed that there are three environmental factors affecting the stability of freeze-dried and compressed meat products, these being moisture, temperature, and reactants. When these products are stored at the aforementioned environmental conditions two types of deterioration may occur: (1) the development of a brown color and charred taste, and (2) the development of an off flavor. It is believed that both types of deterioration are accelerated with increased storage temperature, moisture and sugar content.

Rate of browning correlated with moisture content has been known to be one of the important factors in the storage stability in that the rate of deterioration is commonly increased with increasing moisture level. It is believed that at higher moisture contents carbonyl-amine browning occurs readily, this phenomenon having been experienced by most workers (Regier and Tappel 1956, Sharp 1957, and Seltzer, 1961). As mentioned before, the water content of dried meat has an important bearing on its behavior when compressed. If too dry, the dried meat products are brittle and the joined particles become broken down; while if the dried meat products are too moist, the fibres are so elastic that a considerable expansion takes place after the block has left the press and may culminate in the complete disruption of the block. Therefore, our freeze-dried products are remoistened to have moisture content about 10% and products later are redried to either a 4.5% or 2% of water level by mild vacuum oven drying. This redrying process was believed to add nevertheless a secondary "cooking" which will initiate an early start of a browning reaction. Hence our results do indicate that secondary drying gives the redried products a darker color than the higher moisture, compressed but unredried products (at 10-12% moisture). But it was agreed among most workers that during storage the products with higher moisture content eventually "catch up" and then begin to show more developed browning reaction compared to the lower moisture stored samples at any of three storage temperatures. This catch-up time is considerably accelerated by storage at elevated temperatures.

High storage temperature is very important in accelerating the formation of brown pigments. High temperature not only increases the rate of chemical reaction but also accelerates the generation of off-flavor, such as typical strong burnt flavors attributed to aqueous soluble substances of the meat. The insoluble protein residue which reacts with glucose to give a brown product is, however, relatively tasteless. At low moisture contents of 2% and 4.5%, the rate and degree of deterioration of freeze-dried and compressed meat products do not give as significant increases in formation of browning pigment at the three storage temperatures (compared to 10% moisture). This is believed to be due to the lack of water molecules which will act as an important medium for carbonyl-amine browning reactions. On the other hand, storage at 10% moisture content and 38°C could give an extensive browning reaction owing to the presence of sugar and starch in the system. When one increases the storage time at 10% moisture content and 38°C, starch sugar particles may possibly react with the amino groups of protein molecules according to the Maillard reaction. Thus, increase in storage life of freeze-dried and the compressed meat products can be obtained by using low reducing sugar contents, low moisture content, low storage temperature and packaging in an inert gas (i.e., absence of oxygen).

The sorption isotherm of a food material is usually presented as a plot of the amount of water adsorbed as a function of the relative humidity or water activity of the vapor space surrounding the material; meatballs and sausages are shown in Fig. 12, 13, 14, and 15. They indicate that the adsorption and desorption curves are rather close. This closeness might be due to the characteristics of a combination of ingredients rather than single components. On the same curve (Figs. 12 to 15), the effect due to hysteresis is also shown (adsorption vs. desorption experiment). This phenomenon may be a typical property of freeze dried and compressed meat product. It is known that the desorption hysteresis loop usually ends at or near the monolayer moisture content, but in our product it was found to go down to an activity of zero in most cases. Several theories have been proposed to explain hysteresis. The theories are usually based on the effect of water condensation in the capillaries.

Since our isotherms are not to be used in predicting the drying time of freeze dried meat product, therefore, it has no significant importance for our study. It was the basis, however, for assuming that redrying to 4.5% moisture content (an average approximation of the monomolecular moisture layer amount for these dehydrated meats) might be a more rational level for optimum final product moisture than the exaggerated lower level of 2% moisture.

Air-borne contamination of food products after processing and before packaging significantly reduces shelf life. In addition, the exposure of food products to air during or after any food processing operation, such as freeze-drying, introduces the chance of contamination by microorganisms which could be harmful to the consumer's health. Our studies on the microbial quality of freeze dried and compressed meat products at three moisture levels have shown low populations of bacteria, yeasts, and molds and no E. coli. These results were expected since the highest moisture content used is 10% which corresponds to a water activity of 0.58 to 0.63 in which range microbial growth should be practically completely retarded. Other reasons such as good working conditions, sanitary equipment, good handling of samples, and efficient sealing with nitrogen helped in eliminating all kinds of contamination.

It is again indicated that storage temperature and moisture content in the products are two important factors that affect storage stability. The functional properties of isolated dry wheat gluten in powder form dissipate unless it is stored under refrigeration (Wollermann, of Paniplus Co. 1973). Therefore, this isolated dry wheat gluten should be kept under refrigeration before use.

There is almost no change of deformation force in sausages but a significant change of deformation force was found in three temperature storaged meatballs. This is believed to be due to a different binder system. The pregelatinized starch was used in the sausage binder system, but not in meatballs. It is believed that certain kinds of interaction between gluten and starch molecules form a stronger network after the product is rehydrated. The lack of this pregelatinized starch in meatballs caused the texture of the product to be rather loose at 38°C. This loosened structure in meatballs is also believed to be one of the important factors in decreasing the panel score. The tasters seem to wish a more typically chewy texture, not a weak, soft texture. If further formula research is carried out, there may be justification (in the light of our complete experience) to add some National 711 to the meatball formula.

Appearance, color, texture and flavor were the primary important factors in the panel evaluation. An extensive evaluation was derived from a repeatedly-used panel of our graduate students in the Food Science Department. Panel score indicated the acceptance of the product. It was seen that our panelists constituted a uniform group and their organoleptic results did correlate with other physical or chemical aspects used also as criteria for storage stability studies.

Summary and Conclusions

An entirely new concept of sausage making has been derived. In this method, a new binder system was used instead of conventional sausage casings. A binder composed of 2.25% modified starch (National No. 10), 0.15% wheat gluten and 0.2% pregelatinized starch (National No. 711) was found most suitable for sausage making. A binder with 2.5% modified cross-linked starch (National No. 10) and 0.1% wheat gluten yielded an exceptionally good meatball product.

After freeze drying, both the sausage and the meatballs were partially and uniformly remoistened followed by compression. To achieve the best compression results, distilled water was used to increase the moisture content of the produts to 10% or slightly higher.

The rehydration ratio is a simple test for degree of reconstitution as well as for observing physical damage to a foodstuff during freeze-drying. The rehydration ratio increases with the moisture content left in the freeze-dried products as well as in the compressed meat products.

Peroxide values proved to be of little value in predicting the acceptability and rancidity of freeze-dried and compressed meat products. Therefore, lipid oxidation does not appear to be as important a deteriorative mechanism as color darkening. However, product stored at 5°C retained better flavor, texture and panel acceptability.

At the start of storage and for about four weeks of storage, the products redried to 2% or 4.5% moisture showed an elevated browning level. Thereafter the higher moisture products showed an extensive increase in non-enzymatic browning reaction (product containing 10% moisture). Likewise, with an increase of storage temperatures similar relative results were obtained. Products with lower moisture content did not give significant browning effects during the storage study.

No significant change in sensory evaluation score was encountered in products with 2 and 4.5% moisture content when stored below 22°C. Pork sausage was found to be completely accepted at all three levels of moisture content and three storage temperatures. Beef meatballs with 2% moisture content and at all three storage temperatures were found completely accepted by panelists after 12 weeks storage, whereas meatball products with 4.5% moisture content were also found to be accepted when stored below 22°C for 12 weeks, but were found unacceptable after 12 weeks at 40°C. Meatballs with 10% moisture were found to be rejected by tasters at any storage temperature for 12 weeks storage. There is a direct correlation among texture, temperature, and moisture content of a product during storage. A "loosened" texture of product (in meatballs) was found at 10% moisture and at 38°C storage temperature. Products with lower moisture content and stored at lower temperature did not exhibit a significant change in texture.

Generally speaking, reduction in weight and volume due to freeze drying and compression would facilitate and economize shipping. However, to obtain a shelf life of 12 weeks, the moisture of the product has to be kept below 4.5% or even lower to 2%, and the storage temperature has to be kept as close as possible to refrigeration temperature for best stability.

References

Brockmann, M. C. 1966 Storage Stability of Freeze-dried foods. ASHRAE J. Vol. 8(8), p. 54.

Buscemi, R. and J. M. Tuomy. 1964. Dehydrated fried meat cakes. U.S. Patent No. 3,150,985.

Choi, R. P., A.F. Koncus, C. M. O'Malley and B. W. Fairbanks. 1949. A proposed method for the determination of color of dry products. J. Dairy Sc. Vol. 32, p. 589.

Fitzmaurice, W. J., R. L. Helmer, and J. M. Tuomy. 1969. Compressed freeze-dried meatballs and pork sausage links. Technical Report 70-27 VI. Project reference No. 1J6-62708-D553, U.S. Army Natick Labs., Natick, Mass.

Hamdy, M. M. 1960. Compression of dehydrated food. Review of literature. Contract No. DA 19-129-QM-1630. Quartermaster food and Container Institute for the Armed Forces, Chicago, Illinois.

Hamdy, M. M. 1962. Compression of dehydrated foods. Final Report. Contract No. DA 19-129-QM-1899. Quartermaster Food and Container Institute for the Armed Forces. Chicago, Illinois.

Heldman, D. R., F. W. Bakker-Arhema, P. O. Nzoddy, G. A. Reidy, M. P. Palnitkar, and D. R. Thomson. 1972. Investigation of the energetics of water binding in dehydrated foods at very low moisture levels in relation to quality parameters. Final Report. Contract No. DAAG17-67-C-0165.

Ishler, N. I. 1965. Methods for controlling fragmentation of dried foods during compression. Report No. 623712, Series: FD-13 Contract No. DA 19-129-AMCa (X), U. S. Army Natick Laboratories.

Ishler, H. and J. Knipper. 1968. Process for producing compressed, dehydrated cellular foods. U. S. Patent No. 3,385,715.

Karel, Marcus (1973) Recent research and development in the field of low-moisture and intermediate moisture foods. Critical Rev. Food Technol. 3, 329 - 373.

Labuza, T. P. 1968. Sorption phenomena in food. Food Technology, Vol. 22 (3). p. 15-17, 20, 22 and 24.

Labuza, T. P. 1971. Properties of water and the keeping quality of foods. Proc. of the 3rd Int'l Congr. of Food Sci. and Technol. SOS/70.

Labuza, T.P. 1973. Storage stability and improvement of intermediate moisture foods. Contract NAS9-12560 National Aeronautics and Space Administration, Houston, Texas.

Labuza, T.P., H. Tsyuki and M. Karel. 1969. Kinetics of oxidation of methyl linoleate J.A.O.C.S. Vol. 46. p. 409.

Military Specification. 1963. MIL-P-43383A. Pork sausage, dehydrated: Patties and links, cooked. U.S. Army Natick Laboratories, Natick, Mass.

Military Specification. 1967. MIL-M43506. Meatballs and meatball products, cooked, dehydrated. U.S. Army Natick Laboratories, Natick, Mass.

Mizrahi, S., T.P. Labuza, M. Karel. 1970. Feasibility of accelerated tests for browning in dehydrated cabbage. J. Food Sci. Vol. 35 p. 804.

Pearson, A.M., G. Harrington, R.C. West, and M.E. Spooner. 1962. The browning produced by heating fresh pork. The relation of browning intensity to chemical constituents and pH. J. of Food Sci. Vol. 27, p. 177-181.

Regier, L.W. and Tappel, A.L. 1956. Freeze-dried meat. IV. Factors affecting the rate of deterioration. Food Res., Vol. 21, pp. 640-649.

Seltzer, E. 1961. Importance of selection and processing method for successful freeze-drying of chicken. Food Technol. Vol. 15, p. 18-23.

Sharp, J.G. 1957. Deterioration by dehydrated meat during storage. I. Non-enzymatic deterioration in absense of oxygen at tropical temperatures. J. Sci. Food Agr. Vol. 8(1), p. 14-20.

Wollermann, L.A. 1973. Private communication. The Paniplus Co., Kansas City, Missouri 64127.

FOOD ENGINEERING LABORATORY DISTRIBUTION LIST

ANIMAL PRODUCTS

Copies

1 - Supply Management Policy
ATTN: OASD (I&L) SS
Pentagon, Rm 3B724
Washington, DC 20301

1 - Commanding Officer
Navy Food Service Systems Ofc
ATTN: Mrs. Majorie Kehoe
Bldg 166, Navy Yard
Washington, DC 20374

1 - Manager, Analytical & Tech Serv
RJR Foods, Inc.
Dept. of Food Science & Tech
P.O. Box 3037
Winston-Salem, NC 27102

1 - Hq 1st Corps Support Command
AC of S Services
ATTN: Food Advisor
Fort Bragg, NC 28307

1 - Dr. Jack E. Roberts
Mgr. Research & Development
Ore-Ida Foods, Inc.
Technical Center
P. O. Box 10
Ontario, OR

3 - Commander
US Army Foreign Sci & Tech Ctr
ATTN: AMXST-GE (Victoria Dibbern)
220 7th Street, N. E.
Charlottesville, VA 22901

1 - Dr. Helen McCammon
Office of R & D
Region I - Environmental Protection Agency
John F. Kennedy Bldg, Rm 2203
Boston, MA 02203

Copies

1 - American Can Company
American Lane
Greewich, CT 06830
ATTN: Armold A. Kopetz
Dir. Tech Serv - 3B1

1 - Dr. William H. Brown
Chairman, Committee on Radiation
Preservation of Food, NAS/NRC
P. O. Box 1557
Gainesville, FL 32601

1 - Stimson Library (Documents)
Academy of Health Sciences, US Army
Fort Sam Houston, TX 78234

1 - HQDA (DAL)-TST-S)
Washington, DC 20310

1 - Dr. I. J. Pflug
School of Public Health
543 Space Sci Ctr
University of Minnesota
Minneapolis, MN 55455

1 - Professor Walter M. Urbain
Dept. of Food Sci & Human Nutrition
Michigan State University
East Lansing, MI 48824

1 - Commander
US Army Materiel Command
Infantry R&D Liaison Ofc (AMX-LR)
Fort Benning, GA 31905

1 - HQDA (DASG-HEH-O)
Washington, DC 20314

2 - US Army Foreign Sci & Tech Ctr
200 7th Street N. E.
ATTN: AMXST-ISI
Charlottesville, VA 22901

Copies

5 - W. R. Grace & Co.
P. O. Box 464
ATTN Mr. A. T. Wilson
Duncan, SC 29334

1 - Commander
US Army Medical R & D Command
ATTN: SGRD-MDI-N
Washington, DC 20314

1 - COL R. T. Cutting
Health & Environmental Div
Office of The Surgeon General
Dept. of the Army
Washington, DC 20314

2 - COL P. L. Accountius, AMSC
Ch, Dietitian Sect., DASG-DBD
Rm 7G028, Forrestal Bldg
Washington, DC 20314

1 - CPT Ruth Tomsuden, SC USN
Commanding Officer
Navy Food Service Systems Ofc
Bldg 166, Washington Navy Yard
Washington, DC 20374

1 - Hq, Defense Supply Agency
ATTN: Mr. Jobe, DSAH-OP
Cameron Station
Alexandria, VA 22314

1 - Commander
US Army Training & Doctrine Com
ATTN: ATCD-S
Fort Monroe, VA 23651

1 - Mary Alice Moring
Asst. Head, Food Serv Sec
Facilities & Services Div I&L Dept.
Code LFS-4, Hq USMC
Washington, DC 20380

1 - Prof R. Burt Maxcy
Prof of Food Sci & Tech
University of Nebraska
Lincoln, Nebraska 68503

Copies

1 - Dr. K. C. Emerson
Deputy for Science & Tech
Ofc of Assist Secretary of Army R&D
Department of the Army
Washington, DC 20310

1 - COL Stanley C. White, USAF, MC
Military Assist for Med & Life Sciences
OAD/LS, The Pentagon, Rm 3B129
ODDRE, Washington, DC 20301

1 - Dr. Howard R. Roberts
Act. Dir., Bureau of Foods
Food & Drug Administration
200 C Street, S. W.
Washington, DC 20204

2 - Commander
US Army Troop Support Agency
ATTN: DALO-TAE
Fort Lee, VA 23801

3 - Commandant
US Army Quartermaster School
ATTN: ATSM-CTD-MS
Fort Lee, VA 23801

1 - Director
Defense Supply Agency
ATTN: DSAH-OWO(H. E. Brissey)
Cameron Station
Alexandria, VA 22314

1 - Dr. Emil M. Mrak
Chancellor Emeritus
University of California
Davis, CA 95616

1 - Medical Research Library
Letterman Army Institute of Research
Presidio of San Francisco, CA 94129

2 - Dr. G. E. Livingston
Food Science Associates
P. O. Box 265
Dobbs Ferry, NY 10522

Animal Products (Cont.)

Copies

1 - Hq, Dept of the Army
ATTN: DAMA-CSS-D
Washington, DC 20310

2 - Dr. I. A. Wolff, Director
Eastern Regional Research Center
Agricultural Research Service
US Dept of Agriculture
600 E. Mermaid Lane
Wyndmoor, PA 19118

1 - CDR Harold J. Janson, MSC, USN
Head, Food Service Branch
Bureau of Medicine & Surgery Navy Yard
Washington, DC 20390

1 - Commander
US Army Logistics Ctr
ATTN: ATCL-MS
Fort Lee, VA 23801

1 - Dr. Michael J. Pallansch
Acting Assistant Administrator
ARS - US Dept. of Agriculture
Washington, DC 20250

3 - Office of the Coordinator of Research
University of Rhode Island
Kingston, RI 02881

1 - Ch, Veterinary Activities
WRAMC
Washington, DC 20012

1 - Hq, USAF/SGV
Forrestal Bldg
Washington, DC 20314

1 - HQDA (DALO-TST-F)
Washington, DC 20310

1 - Associate Chief for Dietetics/ Nutr
Medical Food Serv Div
Malcolm Grow USAF Medical Ctr
Andrews AFB, Washington, DC

Copies

2 - Dr. Frank R. Fisher
Executive Director, ABMPS
National Academy of Sciences
2101 Constitution Avenue
Washington, DC 20418

2 - Air Force Services Office
DPKF
2800 South 20th Street
Philadelphia, PA 19101

1 - Commander
US Army Materiel Command
ATTN: AMCRD-TI
5001 Eisenhower Avenue
Alexandria, VA 22333

1 - Dr. Louis J. Ronsivalli
Fishery Products Tech Lab
US Dept of Commerce
Emerson Ave, Northern Region
Gloucester, MA 01930

1 - Ch, Food Service Division
Walter Rood General Hospital
Washington, DC 20012

1 - Director
Dept. of Nutrition & Food Sciences
Massachusetts Institute of Tech
ATTN: Dr. M. Karel
Cambridge, MA 02139

1 - Mr. Joseph V. Budelman
US Army Aviation Systems Command
ATTN: AMSAV-MK
P. O. Box 209, Main Office
St. Louis, MO 63166

2 - Commander
LAIR
PSF, CA 94129

1 - USDA, National Agri Library
Current Serial Record
Beltsville, MD 20705

Copies

1 – Government Documents Dept
University of California Library
Davis, CA 95616

1 – Logistics Library
Bunker Hall
Fort Lee, VA 23801

1 – COL Merton Singer, USA, (Ret)
Executive Secretary
Research & Dev Assoc for Military
Food & Packaging Systems, Inc.
Rm 1315, 90 Church Street
New York, NY 10007

1 – USAFSAM/VNEN
ATTN: Dr. Vanderveen
Brooks Air Force Base, TX 78235

1 – Mr. R. M. Frisosky
Sr. Lab Manager, Pet Foods
General Foods Corp
Tech Ctr, 250 North Street
White Plains, NY 10625

2 – NASA: Johnson Space Ctr
ATTN: DB-3 Dr. Malcolm C. Smith
Houston, TX 77058

2 – Commander
US Army Medical R&D Command
ATTN: SGRD-SSI
Washington, DC 20314

1 – Library
USDA, Southern Regional Research Ctr
P. O. Box 19687
New Orleans, LA 70179

1 – Commander
LAIR (ATTN: COL J.L. Fowler, VC)
PSF, CA 94129

2 – Exchange & Gift Division
Library of Congress
Washington, DC 20540

1 – Director, Dev Center
Marine Corps Dev & Ed Command
ATTN: Mobility & Logistics Div
Quantico, VA 22134

Copies

2 – Director
Development Center (ATTN: M&L Div)
Marine Corps Dev & Ed Command
Quantico, VA 22134

1 – Ch, Professional Policy & Doctrine Ofc
HQ, DA, OTSG, DASG-VCP
Forrestal Bldg, Rm 6B134

1 – Ch, Subsistence-Commissary Div
Subsistence & Food Service Dept.
US Army QM School
Fort Lee, VA 23801

1 – Technical Service Branch
Technical Operation Div-Directorate Sub
Defense Personnel Support Ctr
ATTN: Dir of Subsistence, DPSC-STS
2800 South 20th Street
Philadelphia, PA 19101

1 – Joseph F. Brugh, Dir
Naval Logistics Engineering Group
Cheatham Annex
Williamsburg, VA 23185

2 – US Dept of Agriculture
Animal & Plant Health Inspec Serv
(APHIS) ATTN: Ch, Product Standards Stf
Tech Services Staffs
Washington, DC 20250

2 – Dr. C. H. Harry Neufeld, Area Dir
Agricultural Research Service
US Dept of Agriculture
P. O. Box 5677
Athens, GA 30604

1 – Food Service School
Service Support
Marine Corps Base
Camp Lejeune, NC 28542

1 – Commandant of the Marine Corps
Code LFS-4, Hq US Marine Corps
Washington, DC 20380

1 – Commandant of the Marine Corps
Code RD, Hq US Marine Corps
Washington, DC 20380

Animal Products (Cont.)

Copies

1 - CINCSAC/LGSV
ATTN: CAPT Frank Dooley
Offut AFB, NE

1 - Hq ADC/LGSV
ATTN: CAPT Gary Metzinger
Ent AFB, CO 80912

1 - AF/RDPS
ATTN: LTC Domenic A. Maio
Pentagon
Washington, DC 20330

1 - AF/LGYUV
ATTN: LTC Fried
Pentagon
Washington, DC 20330

1 - AFSC/SG
ATTN COL McIver
Andrews AFB, MD 20331

1 - AF/SGP
ATTN: COL Carter
Forrestal Bldg
Washington, DC 20314

1 - AF/SGV
ATTN: COL Grau
James Forrestal Building
Washington, DC 20314

1 - Air Force Services Office
ATTN: Mr. Roger Merwin
2800 South20th Street
Philadelphia, PA 19101

1 - Air Force Services Office
ATTN: Mrs. Germaine Gotshall
2800 South 20th Street
Philadelphia, PA 19101

1 - DPSC/ST
2800 South 20th Street
Philadelphia, PA 19101

1 - USAFA/SGV
USAF Academy, CO 80840

Copies

1 - Hq TAC/LGSV
Langley AFB, VA 23665

1 - Hq MAC/LGSS
Scott AFB, IL 62225

1 - Hq ATC/LGSS
Randolph AFB, TX 28148

1 - Hq AMD/RDB
ATTM: MAJ David Beatty
Brooks AFB, TX 78235

1 - AFSC/SGB
ATTN: MAJ Thomas Kingery
Andrews AFB, MD 20331

1 - AFLC/SGV
ATTN COL Charles Fuller
Wright Patterson AFB, OH

1 - MAC/SGV
Scott AFB,IL 62225

1 - ATC/SGV
Randolph AFB, TX 78148

1 - SAC/SGV
Offutt AFB, NE 68113

1 - USAFE/SGV
APO NY NY 09012

1 - USAFSO/SGV
APO NY NY 09825

1 - AAC/SGV
APO Seattle WA 98742

1 - CINCPACAF/SGV
APO San Francisco CA 96553

1 - TAC/SGV
Langley AFB, VA 23665

1 - ADC/SGV
Ent AFB, Co 80912

1 - USAF School of Health Care Sci
MSSV
Sheppard AFB, TX 76311

FOOD ENGINEERING LABORATORY INTERNAL DISTRIBUTION LIST

ANIMAL PRODUCTS

Copies

12 - Defense Documentation Center

12 - Military Requirements & Development Programs Office

2 - Technical Library, NDC

20 - Division Branch Chiefs, Food Engineering Laboratory, NDC

2 - Marine Liaison Officer, NDC

3 - Air Force Liaison Officer, NDC

1 - Special Assistant for DOD Food Program, ATTN: Dr. E. E. Anderson, NDC

1 - US Army Representative for DOD Food Program, NDC

1 - US Air Force Representative for DOD Food Program, NDC

1 - Navy Representative for DOD Food Program, NDC

2 - Chief, Engineering Programs, Management Office, ATTN: Standardization Management Section

7 - Director, Food Sciences Laboratory, NDC

25 - Project Officer, Food Engineering Laboratory, NDC

10 - Alternate Project Officer, Food Enginnering Laboratory, NDC

NRC COMMITTEE MEMBERS

Animal Products

Copies

1 - Dr. Olaf E. Kolari
Head, Nutrition Section
Food Research Division
Armour Food Company
801 West 22nd Street
Oak Brook, IL 60521

1 - Dr. Harold E. Calbert
Professor and Chairman
Dept of Food Science
105 Babcock Hall
University of Wisconsin
Madison, WI 53706

1 - Dr. William W. Marion, Chairman
Dept of Animal Science
Poultry Section
Iowa State University
Ames, IA 50010

1 - Dr. William Milner Roberts
Professor and Head
Department of Food Science
P. O. Box 5992
North Carolina State University
Raleigh, NC 27607

1 - Dr. David Lee Crawford
Associate Professor
Dept of Food Science & Tech
Program Director
Seafoods Laboratory
250 - 36th Street
Astoria, OR 97103

1 - Dr. Pauline C. Paul
Director, School of Human Resources
and Family Life
260 Bevier Hall
University of Illinois
Urbana, IL 61801

Copies

1 - Dr. Nuri N. Mohsenin
Professor, Department of Agri Eng.
The Pennsylvania State Univ
University Park, PA 16802

1 - Dr. Orville S. Privett, Prof
The Hormel Institute
University of Minnesota
801 - 16th Avenue, N. E.
Austin, MN 55812

1 - Dr. Roy Teranishi
Head, Flavor Investigations
Western Research Laboratory
Agricultural Research Service
US Dept of Agriculture
800 Buchanan Street
Albany, CA

1 - Dr. Harold S. Olcott
Professor, Marine Food Science
Institute of Marine Resources
Dept of Food Science & Tech
University of California
Davis, CA 95616

1 - Dr. Darrel E. Goll
Professor of Animal Science,
Biochemistry & Food Science
Dept of Food Science
Iowa State University
Ames, IA 50010

1 - Dr. Karl F. Mattil, Director
Food Protein R & D Center
Faculty Mail Box 63
Texas A & M University
College Station, TX 77843