

# M- 1

## EXPERIENCE WITH FREEZE-DRYING OF MEAT AND MEAT PRODUCTS

by  
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The freeze-drying method of food preserving is an interesting procedure that has received considerable attention by the different food industries in recent years.

It is generally known that the process is particularly suitable for fruits, vegetables, shrimps and crustacea etc and that fairly good results have been obtained with poultry and some meat products.

For these reasons we found it important to carry out some investigations in order to consider what possibilities the freeze-drying procedure would offer our meat industry.

The experiments were carried out in cooperation with the Norwegian Research Board for Meat and Vegetable Preservation.

### Equipment.

From the firm Østlandske Lloyd A/S in Oslo representing the Vickers Armstrongs (Engineers) Limited we received a pilot plant freeze-drying unit for the experiments.

The drying capacity of the equipment was about 5 kg raw material a charge. The vacuum chamber had a volume of about 500 litres. In the upper part of the chamber the drying goods were placed on 2 net trays between electrically heated plates. The distance from the heat source to the surface of the material to be dried was about 15 millimeters. The heat transfer was brought about by radiation. In the lower part of the vacuum chamber were placed the refrigerated coils for condensing the evaporated water. These were cooled directly with Freon 22 from a 10 HP compressor. The vacuum

was established by a 2 HP Edwards vacuum pump. The temperatures of the heating plates and of the surface and interior parts of the products were registered by a continuous recorder. The principal parts of the equipment are illustrated in figure 1.

#### Vacuum and temperature.

Vacuum and temperatures were controlled by hand. The drying operations were carried out at pressures in the range from 0,01 - 1 mm Hg and <sup>the</sup> corresponding evaporating temperatures in the products were from  $\div 60 - \div 20^{\circ}\text{C}$ . The heating plates were brought up to surface temperatures ranging from  $60 - 150^{\circ}\text{C}$ . The higher temperatures were applied at the start of the process, and as the drying of the material proceeded, the temperatures were gradually lowered according to the temperature development on the surface, where it had not to exceed  $65^{\circ}\text{C}$ . A typical temperature diagram for 15 millimeter thick slices of raw strip loin is demonstrated in figure 2. The total drying time varied with the thickness of the meat slices, but it was generally found to be about one hour per millimeter thickness.

The internal temperatures of the products remained low until the last crystals of ice had sublimated. Then the temperature rose in the course of a couple of hours towards the surface temperature, and then the process had come to an end. Figures concerning processing technique, yield etc. are shown in table 1.

#### Experimental part.

The experiments comprise the following products.

##### Pure meat.

Raw, fresh strip loin  
 " tenderized strip loin  
 Cooked, " " "  
 Raw, fresh bottom round  
 " tenderized bottom round  
 Cooked, lean ham  
 " rein-deer hind leg  
 " " " tongues  
 " chicken meat  
 Minced beef :

##### Ready made dishes.

Emergency rations  
 Raw hamburgers  
 Fried "  
 Cooked Norwegian meat stew  
 " meat and bean stew  
 Beef goulash  
 Raw frankfurter forcemeat



### Preparation.

All visible fat was first trimmed off. The pure meat was then sliced and frozen overnight at  $\pm 25^{\circ}\text{C}$  before drying. In the experiments with precooked meat, the cooking was carried out before slicing in order to prevent loss of taste and flavour.

Ready made dishes were frozen in about 15 millimeter thick layers at  $\pm 25^{\circ}\text{C}$  overnight before the process.

Some runs were also performed without prefreezing of the material. In these cases the fresh foods were brought directly into the freeze-drying cabinet. Due to rapid evaporation of water from the product when vacuum was set on, the temperature fell within 10 minutes to about  $\pm 45^{\circ}\text{C}$  somewhat dependent upon the degree of vacuum applied.

### Packaging.

When the freeze-drying was completed, the vacuum was destroyed by filling the chamber with nitrogen. This was done in order to prevent oxygen from penetrating into the meat pores when it was removed from the vacuum chamber. Then the products were immediately vacuumpacked in aluminium - polyethylen bags. The size of the bags were 216x184 millimeter. Different types of films and foils were tried. It became apparent that the packaging material was most essential for the storage life of the products. Best results were obtained with the mentioned aluminium - polyethylen bags. If a leakage occurred in a package, the food was spoilt within a short time, mainly due to the fatbecoming rancid.

### Reconstitution.

In the directions for reconstitution of freeze-dried foods 10 - 15 minutes are generally recommended as adequate of rehydrating periods. In our experiments this was an insufficient length of time. In most cases the meat was rehydrated for about one hour. This was done in order to obtain the most favourable starting point for the consistency before the preparation and the following quality judgement

The water absorption was accelerated considerably by kneading the meat pieces by hand. By this treatment the gas enclosed in the meat pores was pressed out, and the water penetration facilitated. See figure 3.

Only a part of the water absorbed was naturally bound to the meat. The texture was after rehydration rather spongy, and much of the water could be squeezed out of the meat pieces by hand. This amount of loosely absorbed water seemed to be somewhat dependent upon the meat quality and the thickness of the slices. Cooked before drying, the meat apparently retained water a little better than meat dried in the raw state, when the calculation was based upon the water content of the cooked meat before freeze-drying. Calculated on the water content of the original raw meat, the water retention was much the same. See figure 4.

The percentage of water that could be squeezed out of different kinds of meat by hand is shown in table 2.

Table 2.

|                              | Thickness<br>mm | Water squeezed out<br>% |
|------------------------------|-----------------|-------------------------|
| Raw reconstituted strip loin | 15              | 11 - 13                 |
| " - " - " "                  | 10              | 22 - 24                 |
| Cooked " - " "               | 15              | 7 - 9                   |
| Raw " - bottom round         | 15              | 17 - 19                 |

The comparatively high figures for bottom round may be due to the fact that this meat had been stored for about 2 years at + 50°C, and thus lost some of its binding capacity.

Frying.

Usually the quality evaluation was carried out on samples fried for two minutes on each side, because freeze-dried meat lost much of its palatability by cooking.

During frying there was a more intensive water evaporation from the reconstituted samples in comparison with natural, fresh meat, even though a hot pan and the shortest possible frying times were applied. The water loss was about twice that of fresh meat fried in the same way. In fried, freeze-dried meat the water content was about 50 percent where as the corresponding figure for fried, fresh meat, was 70 percent. This refers in both cases to 15 millimeter thick slices. The varying water losses during the frying process are shown in table 3.

The high water losses could to a considerable extent be counteracted by dipping the meat pieces in an egg batter before frying.

Quality judgement.

The quality was judged by a taste panel consisting of 5 - 6 trained persons..The quality components were tasted for aroma/taste and consistency and in addition a score was given for general impression. Most samples to be tested were compared to a freeze-stored reference sample of the same meat.

The following scoring system was used:

- 10 Excellent
- 8 Very good
- 6 Good (normal)
- 4 Inferior
- 2 Bad

A survey of scores including all the runs produced can be viewed in table 4. The figures are average scores from the participating judges.



Discussion.

The freeze-drying equipment worked in a satisfactory manner. Vacuum and temperatures could be regulated as desired. A series of runs was processed by varying conditions with regard to temperature, vacuum etc. The results obtained substantiate in broad outline what had previously been found by other investigators.

It is very important for the results that there is a correctly balanced correlation between heat supply, vacuum and the condenser temperature. The temperature of the heating plates had to be kept at such a level that the temperature of the meat surface did not exceed 65°C in order to prevent denaturing of the meat. On the other hand it had to be kept high enough to supply the necessary heat for water evaporation within a reasonable length of time. How the heat supply should be regulated, was dependent upon the product in question, because some foods were more sensitive to heat than others.

Our experience is that pure meat is a very difficult product to freeze-dry, as considered from a quality point of view. Taste and flavour are fairly well retained, but the texture became dry and tough by the process. Some irreversible changes took place in the meat, so that it lost some of its natural properties and ability to retain water during preparation.

For minced meat and some mixed meat foods such as different kinds of stews, beef goulash etc. this quality defect was less predominant because that the meat texture is less important in these products.

The quality was a little better retained when the meat was cooked before freeze-drying.

Best results were obtained with cooked chicken meat, which after reconstitution had a far better quality than the other kinds of freeze-dried meat.

Lean meat was more fit for freeze-drying than fat pieces as the surface temperature during the process must be kept low in order to avoid melting of the fat. And in addition the difficulties in preventing fat meat from growing rancid during storage are considerable.

Systematical investigations concerning the storage life of the freeze-dried products were not undertaken, for the reason that with the qualities generally obtained this would be of only little interest. But it became evident, that the storage life was very dependent upon the packaging applied and on the packing technique.

Most of the products contained a certain amount of fat that had to be protected against oxygen and light in order to prevent it from growing rancid. Cans and glass jars were considered too heavy for freeze-dried foods. Best results were obtained with a polyethylene-laminated aluminium foil. Vacuum-packed bags of this material were low in weight and gave reasonably good protection against oxygen and light.

An important factor of freeze-drying is the production costs. The expensive machinery for the drying and packaging operations, requirement of high meat quality, and expensive packaging material in addition to the other production costs, result in a high retail price. So it is necessary for the products to have particular advantages that make them preferable to other meat foods in order to make them competitive.

In some cases a low weight or a long storage life without the necessity for refrigeration may be a decisive factor in the choice. Alternatively, it may be the quality or the convenience in usage which is considered important. At the present time we must take into account that the quantities of freeze-dried meat that can be marketed in our country are limited. For this reason it will be difficult to establish the specific production of freeze-dried foods. If, on the other hand, the whole scale of foods is included, the prospects for freeze-drying would appear somewhat more favourable.

#### Conclusion.

Our experience with freeze-drying of pure meat, is that these products to a considerable degree are reduced in quality during the process. Taste and flavour are retained quite well, but the texture is rendered tough and dry. Minced meat and some ready made dishes such as hamburgers and different meat stews appear to be more suitable for this process. Precooked chicken meat was particularly suited for freeze-drying.

According to our investigation the freeze-drying technique at the present stage appears to have only limited possibilities as far as pure meat is concerned.



S U M M A R Y .  
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Experiments with freeze-drying of meat and meat products have been carried out on a pilot plant scale. From a technical point of view the drying procedure worked satisfactorily. The results obtained, however, indicate that pure meat is not particularly suitable for freeze-drying. The quality of the products did not reach a level that would enable them to compete with similar types of preserved foods on the market as, for instance, frozen or canned meats. An exception was cooked freeze-dried chicken, which after reconstitution had a far better quality than the other types of freeze-dried meat.

It was first of all the texture of the rehydrated meat that was inferior. It became hard and tough during the process. Taste and flavour were retained fairly well. The quality was a little better when the meat was cooked before drying.

Minced meat and some ready made dishes such as fried hamburgers and different kinds of meat stews seemed to be more fit for freeze-drying than pure meat, because the texture of the meat is less important for the quality of these products.

The storage life of freeze-dried meat depends upon the packaging of the product. Most meat foods contain a certain amount of fat that has to be protected against oxygen and light in order to prevent it from getting rancid. This leads to comparatively high packaging costs, which in addition to the other production costs, make the finished freeze-dried products rather expensive.

Due to the high price and in many cases an unsatisfactory quality, it is unlikely that freeze-dried meat products will at present become a common household food in our country. For special purposes, where convenience in use, or nutritive value compared to weight are regarded as more important than palatability, freeze-dried meat products may meet a certain demand.

The conclusion drawn from our investigation is, that at its present stage of development this process of freeze-drying will be of only limited interest to the Norwegian meat industry.

  
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Z U S A M M E N F A S S U N G .

Versuche mit Gefriertrocknung von Fleisch und Fleischprodukten sind im Laboratorienmasstabe ausgeführt worden. Vom technischen Gesichtspunkt aus verliefen die Versuche zufriedenstellend. Die erreichten Resultate zeigten jedoch, dass reines Fleisch für Gefriertrocknung nicht besonders gut geeignet ist. Die getrockneten Produkte waren nicht von solch einer Qualität, dass sie mit anderen entsprechenden konservierten Nahrungsmitteln auf dem Markte konkurrenzfähig sein würden wie mit gefrorenem oder dosenkonserviertem Fleisch. Eine Ausnahme war gefriertrocknetes Kückenfleisch, bei dem das rehydrierte Produkt eine viel bessere Qualität hatte, als andere Sorten von gefriertrocknetem Fleisch.

Es war vor allem die Konsistenz der rehydrierten Produkte die zu tadeln war. Während der Gefriertrocknung wurde sie hart und zähe. Geschmack und Aroma wurden leidlich gut bewahrt. Die Qualität war etwas besser, wenn das Fleisch vor dem Trocknen gekocht wurde.

Hackfleisch und einige fertig zubereitete Gerichte wie gebratene Hamburger und verschiedene Sorten von Labskaus schienen für Gefriertrocknung besser geeignet als reines Fleisch, weil die Struktur des Fleisches für die Qualität dieser Produkte eine geringe Rolle spielt.

Die Haltbarkeit der gefriertrockneten Fleischprodukte ist von der Emballage abhängig. Die meisten Fleischwaren enthalten eine gewisse Menge Fett, das gegen Sauerstoff und Licht geschützt werden muss, um ein Ranzigwerden des Fettes zu verhindern. Das führt zu verhältnismässig hohen Emballagekosten, die zusammen mit den anderen Produktionskosten die fertigen Produkte ziemlich teuer machen.

Wegen höherer Preise und oft nicht ausreichender Qualität können gefriertrocknete Fleischwaren bei uns noch nicht gewöhnliche Wirtschaftswaren werden. Für spezielle Zwecke, wo Bequemlichkeit im Gebrauch oder der Nährwert im Verhältnis zum Gewicht wichtiger ist als Geschmack und Aroma, können gefriertrocknete Produkte einen gewissen Bedarf erfüllen.

Die Folgerung unserer Untersuchungen ist, dass der Gefriertrocknungsprozess im heutigen Entwicklungsstadium nur von beschränkter Bedeutung für die norwegische Fleischindustrie sein wird.



Опыт изсушивания мяса и мясных продуктов способом замораживания был проведён в лабораторном масштабе. С технической точки зрения процесс замораживания/изсушивания дал удовлетворительный результат. Достигнутые результаты показали однако, что мясо в чистом виде не особенно подходит для замораживания/изсушивания. Качество продуктов не достигло уровня, который бы сделал их достойными конкуренции со сходными видами консервированных продуктов потребления на рынке, как например мороженые или консервированные мясные продукты. Исключением было варёное, морожено-изсушенное мясо цыплят, где размоченный (reconstituted) продукт был значительно более лучшего качества, чем другие сорта морожено/изсушенного мяса.

Прежде всего состав размоченных продуктов остался твёрдым и упругим. Вкус и аромат сохранились довольно хорошо. Варёное мясо сохранило качество лучше чем сырое.

Молотое мясо из бифштекса и некоторые готовые продукты, как например жареные котлеты и разные блюда из мяса сваренного с овощами и с соусом, повидимому больше подходят для замораживания/изсушивания, чем чистое мясо, т. к. структура мяса играет менее важную роль для качества этих продуктов.

Очень важно для сохранения на складе морожено/изсушенного мяса целесообразная упаковка продукта. Большинство мясных продуктов содержит некоторое количество жира, который должен быть защищён от кислорода и света, чтобы предотвратить прогорклость. Это приводит к сравнительно высоким расходам на тару, что в добавление к другим расходам по продукции, значительно повышает цену на готовые товары.

Из-за высоких цен и во многих случаях недостаточно хорошего качества, замороженные/изсушенные мясные продукты не смогут в настоящее время являться обыкновенными хозяйственными продуктами. Но, если вопрос касается упрощения в потреблении, или там, где значение питательности важнее качества вкуса, то замороженные/изсушенные продукты могут покрыть потребность.

Результатом наших исследований является вывод, что в настоящей стадии развития процесс замораживания/изсушивания может лишь иметь ограниченное значение для мясного дела в нашей стране.



TABLE 1.

| Run n <sup>o</sup> . | Product          | State of material | Thickness<br>mm | Vacuum<br>mm HG | Processing time<br>hours | Yield dry material<br>% | Final water content<br>% | Reconstitution water uptake<br>% |
|----------------------|------------------|-------------------|-----------------|-----------------|--------------------------|-------------------------|--------------------------|----------------------------------|
| 1.                   | Rein-deer leg    | Raw               | 15              | 0,01-0,1        | 9½                       | 35,8                    |                          |                                  |
| 3.                   | - " -            | "                 | 19              | 0,01-0,1        | 10                       | 28,4                    |                          |                                  |
| 2.                   | - " #6ngues      | "                 | 18              | 0,01-0,1        | 10                       | 43,2                    |                          |                                  |
| 2.                   | - " "            | Cooked            | 18              | 0,01-0,1        | 4½                       | 47,5                    |                          |                                  |
| 6.                   | Lean pork meat   | Raw               | 16              | 0,01-0,1        | 20½                      | 27,2                    | 0,6                      | 94,6                             |
| 9.                   | Bottom round     | "                 | 30              | 0,01-0,1        | 48                       | 27,3                    | 0,9                      |                                  |
| 10.                  | - " -            | "                 | 30              | 0,05            | 35                       | 25,1                    |                          | 75,5                             |
| 5.                   | Strip loin       | "                 | 15              | 0,1 -0,2        | 12                       | 29,1                    |                          | 75,5                             |
| 7.                   | - " -            | "                 | 15              | 0,2             | 14½                      | 29,9                    |                          |                                  |
| 8.                   | - " -            | "                 | 15              | 0,01-0,05       | 15½                      | 29,9                    | 0,5                      |                                  |
| 11.                  | - " -            | "                 | 16              | 1,2 -1,4        | 12                       | 26,6                    |                          | 56,9                             |
| 12.                  | - " -            | "                 | 16              | 0,8             | 15                       | 27,2                    |                          |                                  |
| 13.                  | - " -            | "                 | 16              | 0,05-0,3        | 13                       | 27,6                    |                          | 80,6                             |
| 14.                  | - " - tenderized | "                 | 15              | 0,02-0,04       | 15½                      | 27,5                    |                          | 82,6                             |
| 15.                  | - " - "          | "                 | 15              | 0,01            | 12                       | 25,6                    |                          | 72,1                             |
| 17.                  | - " - "          | "                 | 15              | 0,02            | 14½                      | 26,4                    | 0,4                      | 81,9                             |
| 21.                  | - " - "          | "                 | 15              | 0,05            | 12                       | 24,7                    |                          | 79,0                             |
| 27.                  | - " - "          | "                 | 10              | 0,02            | 5                        | 24,8                    | 3,9                      | 84,9                             |

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TABLE 1 continued

| Run No. | Product                | State of material | Thickness<br>mm | Vacuum<br>mm Hg | Processing time<br>hours | Yield dry material<br>% | Final water content<br>% | Reconstitution water uptake<br>% |
|---------|------------------------|-------------------|-----------------|-----------------|--------------------------|-------------------------|--------------------------|----------------------------------|
| 27.     | Meat cubes             | Raw               | 17              | 0,02            | 7.1/4                    | 24,6                    | 1,3                      | 86                               |
| 20.     | Strip loin, tenderized | Cooked            | 10              | 0,5             | 3.                       | 37,8                    | 2,7                      | 93                               |
| 25.     | " " "                  | "                 | 16              | 0,01-0,05       | 8.1/2                    | 40,5                    |                          | 73                               |
| 4.      | Lean, minced meat      | Raw               | 18              | 0,03            | 9                        |                         |                          | 100                              |
| 31.     | " " "                  | "                 | 18              |                 | 9.                       | 27,8                    |                          | 100                              |
| 31.     | Minced meat            | "                 | 18              |                 | 9.5/4                    | 34,3                    |                          | 100                              |
| 22.     | Emergency ration       | Cooked            | 18              | 0,01            | 6.5/4                    | 46,3                    | 0,4                      | 100                              |
| 42.     | " " "                  | Raw               | 18              | 0,15            | 5                        | 46,5                    |                          | 100                              |
| 43      | " " "                  | "                 | 18              |                 |                          | 56,7                    |                          | 100                              |
| 26 a.   | Hamburgers             | Fried             | 15              | 0,05-0,1        | 15.1/4                   | 35,4                    |                          | 100                              |
| 26 b.   | " "                    | Raw               | 15              | 0,05-0,1        | 14                       | 24,8                    |                          | 81                               |
| 32.     | Norwegian meat stew    | Cooked            | 18              | 0,05-0,1        | 13.1/4                   | 18,8                    |                          | 100                              |
| 33.     | Meat and bean goulash  | "                 | 18              |                 | 8                        | 34,8                    | 1,3                      | 100                              |
| 34.     | Beef gulash            | "                 | 18              |                 | 5.                       | 32,7                    | 3,9                      | 100                              |
| 35.     | Frankfurter forcemeat  | Raw               | 18              | 0,14            | 6.1/4                    | 47,7                    | 0,0                      |                                  |
| 52.     | Bottom round           | "                 | 16              | 0,6-0,9         | 9                        | 27,9                    | 3,3                      |                                  |
| 53.     | " " tenderized         | "                 | 16              | 0,7-0,9         | 7.1/4                    | 28,4                    | 3,0                      | 77                               |



TABLE 3.

## COMPARATIVE FRYING EXPERIMENTS OF FRESH, FROZEN AND FREEZE-DRIED MEAT.

| Product                                    | Thickness<br>mm | Number of<br>parallels | Average<br>weight<br>g. | Water content:        |                      | Weight<br>loss<br>% | Weight loss<br>of original<br>or absorbed<br>water<br>% | Water content<br>before frying,<br>percentage of<br>original water | Original<br>water left<br>% |
|--------------------------------------------|-----------------|------------------------|-------------------------|-----------------------|----------------------|---------------------|---------------------------------------------------------|--------------------------------------------------------------------|-----------------------------|
|                                            |                 |                        |                         | Before<br>frying<br>% | After<br>frying<br>% |                     |                                                         |                                                                    |                             |
| Fresh<br>strip loin                        | 15              | 9                      | 105                     | 75                    | 70,8                 | 14,4                | 19,2                                                    | 100                                                                | 30,8                        |
| Freeze-stored,<br>tenderized<br>strip loin | 15              | 10                     | 129                     | 75                    | 69,0                 | 19,2                | 25,6                                                    | 100                                                                | 74,4                        |
| - " -                                      | 10              | 5                      | 86                      | 75                    | 63,4                 | 31,7                | 42,3                                                    | 100                                                                | 57,7                        |
| Freeze-dried<br>strip loin                 | 15              | 14                     | ( 100 )                 | 66,2                  | 51,5                 | 30,8                | 46,0                                                    | 65,4                                                               | 35,4                        |
| Freeze-dried<br>bottom round               | 15              | 5                      | ( 100 )                 | 66,3                  | 47,5                 | 37,5                | 55,4                                                    | 65,6                                                               | 30,2                        |

TABLE 4.  
QUALITY TESTING

| Sample no. | Product           | Freeze-dried | Aroma taste | Consistency | Overall impression | Overall impression of frozen ref. samples | Remarks:                                  |
|------------|-------------------|--------------|-------------|-------------|--------------------|-------------------------------------------|-------------------------------------------|
| 1.         | Rein-deer leg     | Raw          | 6,0         | 5,0         | 6,0                | ( 6,0 )                                   | Fairly good.                              |
| 3.         | " " "             | "            | 6,0         | 5,0         | 6,0                | ( 6,0 )                                   | " "                                       |
| 2.         | Rein-deer tongues | "            | 6,0         | 5,0         | 6,0                | ( 6,0 )                                   | " "                                       |
| 2.         | " " "             | Cooked       | 6,0         | 5,0         | 6,0                | ( 6,0 )                                   | " "                                       |
| 6.         | Lean pork meat    | Raw          | 5,5         | 5,0         | 5,8                | ( 6,0 )                                   | " "                                       |
| 9.         | Bottom round      | "            | 4,5         | 4,5         | 4,7                | ( 5,0 )                                   | Fairly good appearance.<br>Dry and tough. |
| 10.        | " " "             | "            | 3,8         | 3,2         | 3,3                | ( 5,0 )                                   | Failure. Burnt.                           |
| 5.         | Strip loin        | "            | 4,5         | 3,5         | 4,0                | ( 5,0 )                                   | Good colour. Dry and tough.               |
| 7.         | " " "             | "            | 5,2         | 6,0         | 4,8                | ( 6,0 )                                   | Failure.                                  |
| 8.         | " " "             | "            | 3,8         | 3,5         | 3,7                |                                           | Failure. Burnt.                           |
| 11.        | " " "             | "            | 4,6         | 4,8         | 4,6                |                                           | Fairly good appearance.<br>Dry and tough. |
| 13.        | " " "             | "            | 5,4         | 4,8         | 5,0                | ( 6,9 )                                   | Dry and tough.                            |
| 14.        | " " "             | "            | 4,2         | 5,0         | 4,4                | ( 5,8 )                                   | Dry and tough.                            |
| 15.        | " " "             | "            | 5,2         | 5,0         | 5,0                | ( 6,7 )                                   | Pale colour. Dry and tough.               |
| 17.        | " " "             | "            | 5,3         | 5,2         | 5,2                | ( 5,5 )                                   | Rather good colour.<br>Dry and tough.     |
| 21.        | " " "             | "            | 4,8         | 4,6         | 5,0                | ( 6,0 )                                   | Almost flavourless. Dry.                  |
| 27.        | " " "             | "            | 5,4         | 4,8         | 5,0                | ( 6,6 )                                   | Comparatively good. Dry.                  |
| 27.        | Meat cubes        | "            | 6,0         | 5,2         | 5,4                | ( 6,6 )                                   | - " - "                                   |
| 20.        | Strip loin        | Cooked       | 4,0         | 4,3         | 4,1                | ( 5,4 )                                   | Almost flavourless. Dry.                  |

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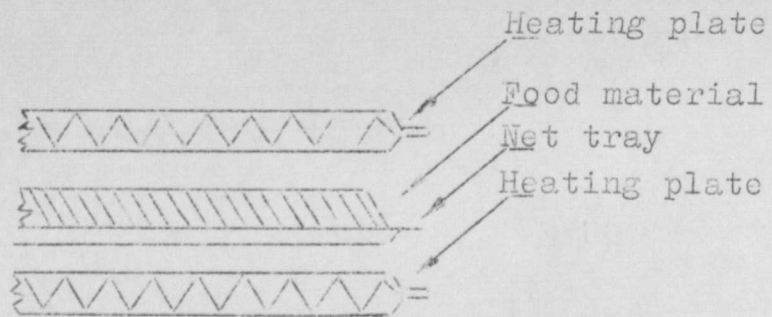


Table 4 continued

| Sample no. | Product                        | Freeze-dried | Aroma taste | Consistency | Overall impression | Overall impression of frozen ref. samples | Remarks:                                                 |
|------------|--------------------------------|--------------|-------------|-------------|--------------------|-------------------------------------------|----------------------------------------------------------|
| 25.        | Strip loin                     | Cooked       | 4,9         | 5,2         | 4,9                | ( 5,4 )                                   | Rather tender. Dry                                       |
| 4.         | Minced beef.                   | Raw          | 5,3         | 5,3         | 5,0                | ( 6,0 )                                   | Fried. Good taste. Dry                                   |
| 31.        | " "                            | "            | 4,8         | 5,2         | 5,0                | ( 6,0 )                                   | " " " "                                                  |
| 31         | " "                            | "            | 5,2         | 5,3         | 5,2                |                                           | " " " "                                                  |
| 31.        | Minced meat                    | "            | 4,7         | 4,5         | 4,5                | ( 6,0 )                                   | " " " "                                                  |
| 22.        | Emergency rations,             | Cooked       | 4,0         | 5,0         | 3,8                | ( 5,2 )                                   | Judged after 1½ week.<br>Rancid. Not good.               |
| 22.        | " "                            | "            | 2,3         | 4,2         | 2,5                |                                           | Judged after 6 weeks.<br>Strongly rancid.                |
| 42.        | " "                            | "            | 5,0         | 5,8         | 5,3                |                                           | Reasonably good product.                                 |
| 43.        | " "                            | "            | 2,5         | 4,5         | 3,0                |                                           | Very rancid. Leakage.                                    |
| 26 a.      | Hamburgers                     | Fried        | 6,2         | 5,6         | 5,6                | ( 5,6 )                                   | Good taste. Poor texture. Dry.                           |
| 26 b.      | " "                            | Raw          | 5,8         | 4,4         | 5,0                | ( 5,0 )                                   | Hard consistency. Dry.                                   |
| 32.        | Norwegian meat<br>stew, cooked |              | 6,3         | 6,7         | 6,5                | ( 6,5 )                                   | Quite good.                                              |
| 33.        | Meat and bean stew             | "            | 5,8         | 5,5         | 5,7                | ( 6,0 )                                   | Relatively good.                                         |
| 34.        | Beef goulash                   | "            | 5,8         | 5,7         | 5,8                | ( 6,0 )                                   | " "                                                      |
| 35.        | Frankfurter forcemeat          | raw          | 5,2         | 4,5         | 4,5                | ( 6,5 )                                   | Fried. Difficult to rehydrate.<br>Reasonably good taste. |
| 52.        | Bottom round.                  | Raw.         | 4,8         | 4,3         | 4,8                |                                           | Reasonably good, but dry and<br>tough.                   |
| 52.        | " "                            | "            | 5,5         | 4,8         | 5,0                |                                           | Dipped in egg batter before<br>frying.                   |
| 53.        | " "                            | "            | 4,0         | 3,3         | 3,8                | ( 5,8 )                                   | Somewhat burnt. Dry and tough.                           |
| 53.        | " "                            | "            | 5,5         | 4,8         | 5,3                |                                           | Dipped in egg batter before<br>frying. 524               |

FIGURE 1.

PRINCIPAL SKETCH OF THE FREEZE-DRYING EQUIPMENT



View of the drying section

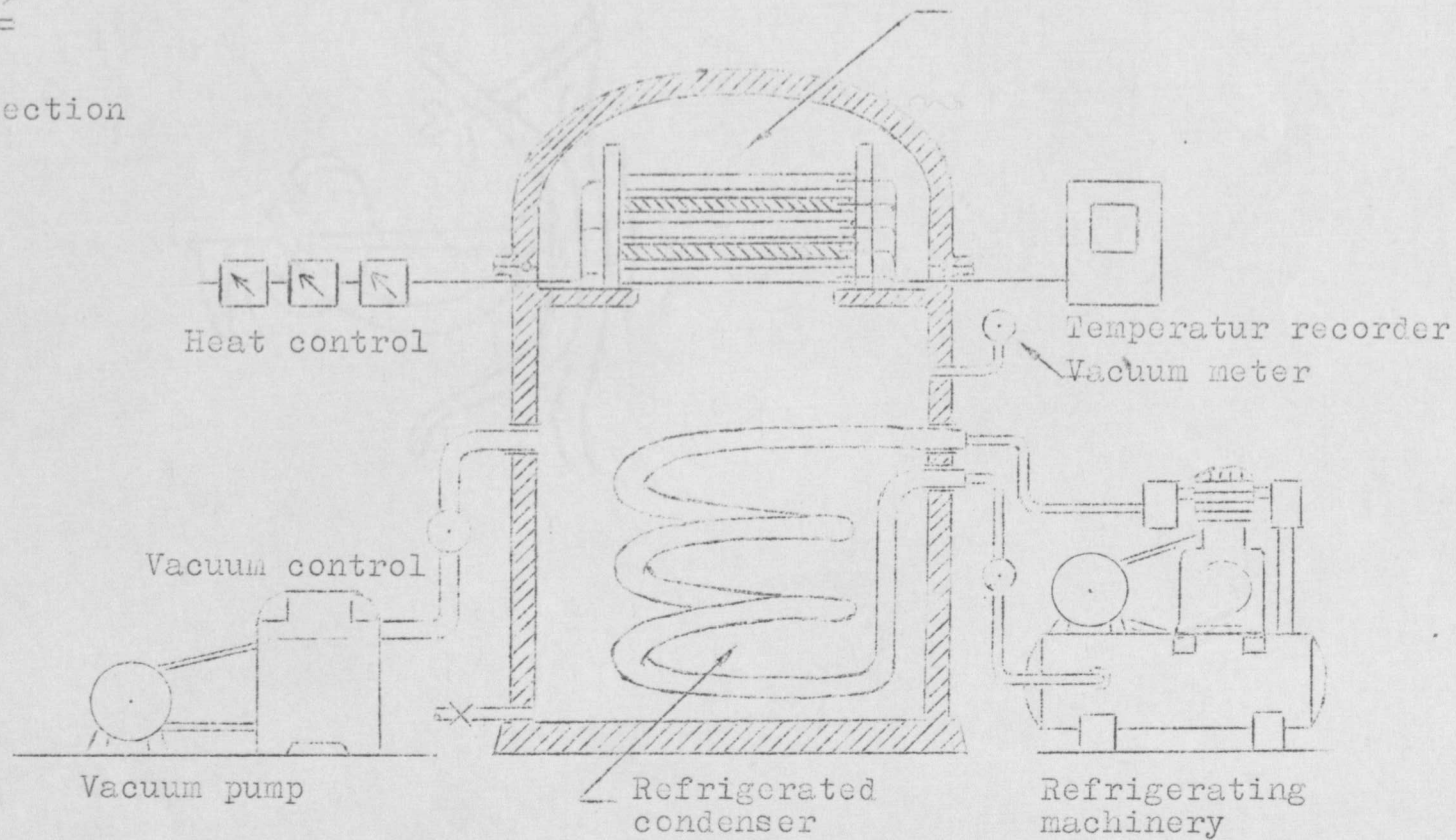




FIGURE 2.

TEMPERATURE CURVES DURING THE DRYING CYCLE

Product : Raw strip loin  
Thickness : 15 mm  
Vacuum : 0,01 - 0,04 mm Hg  
Condenser temperature:  $\pm 60^{\circ}\text{C}$ .

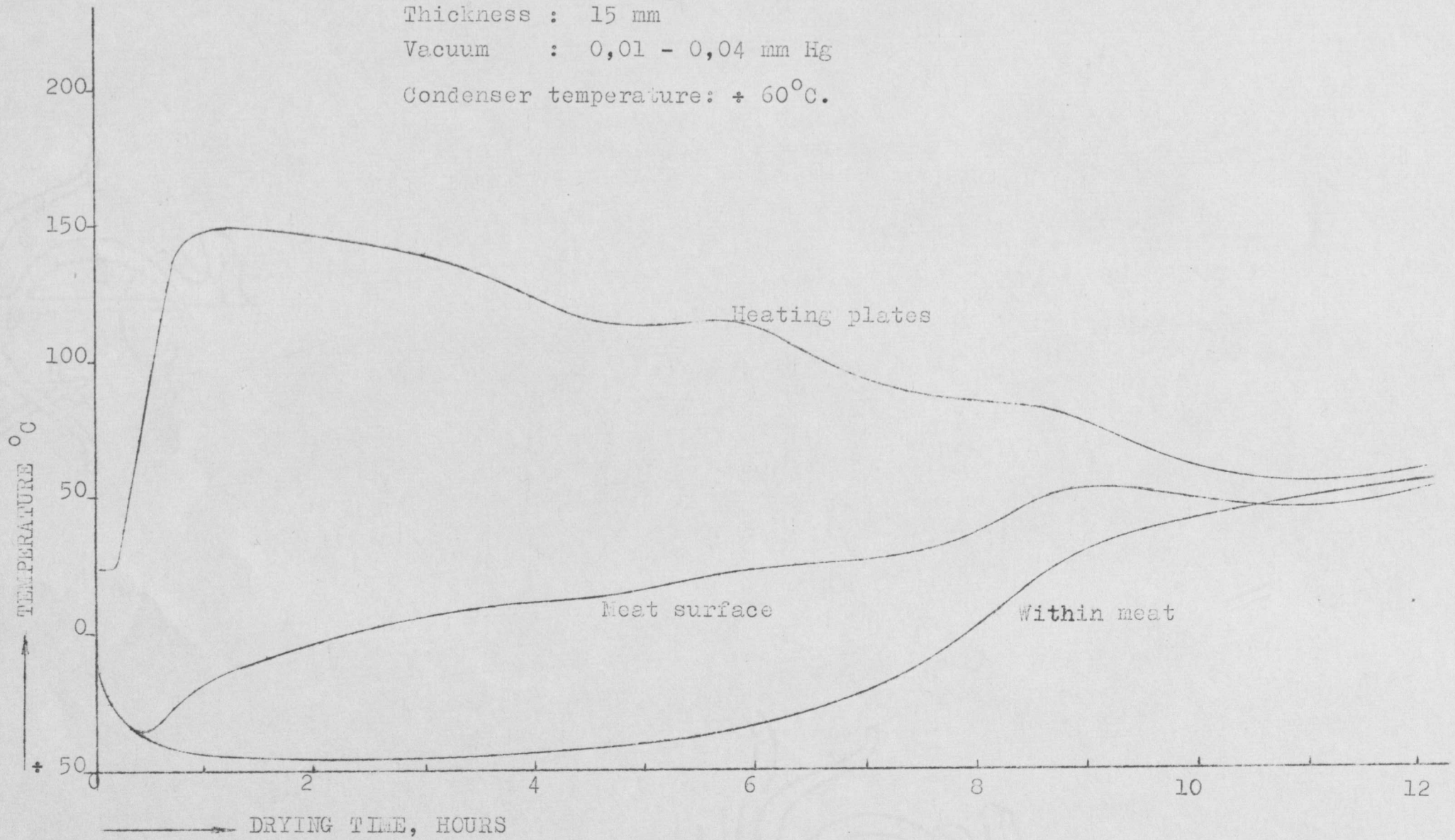


FIGURE 3

REHYDRATION OF RAW, FREEZE-DRIED MEAT  
AS RELATED TO REHYDRATION TIME.

The water absorption is calculated in  
relation to the original weight of meat.

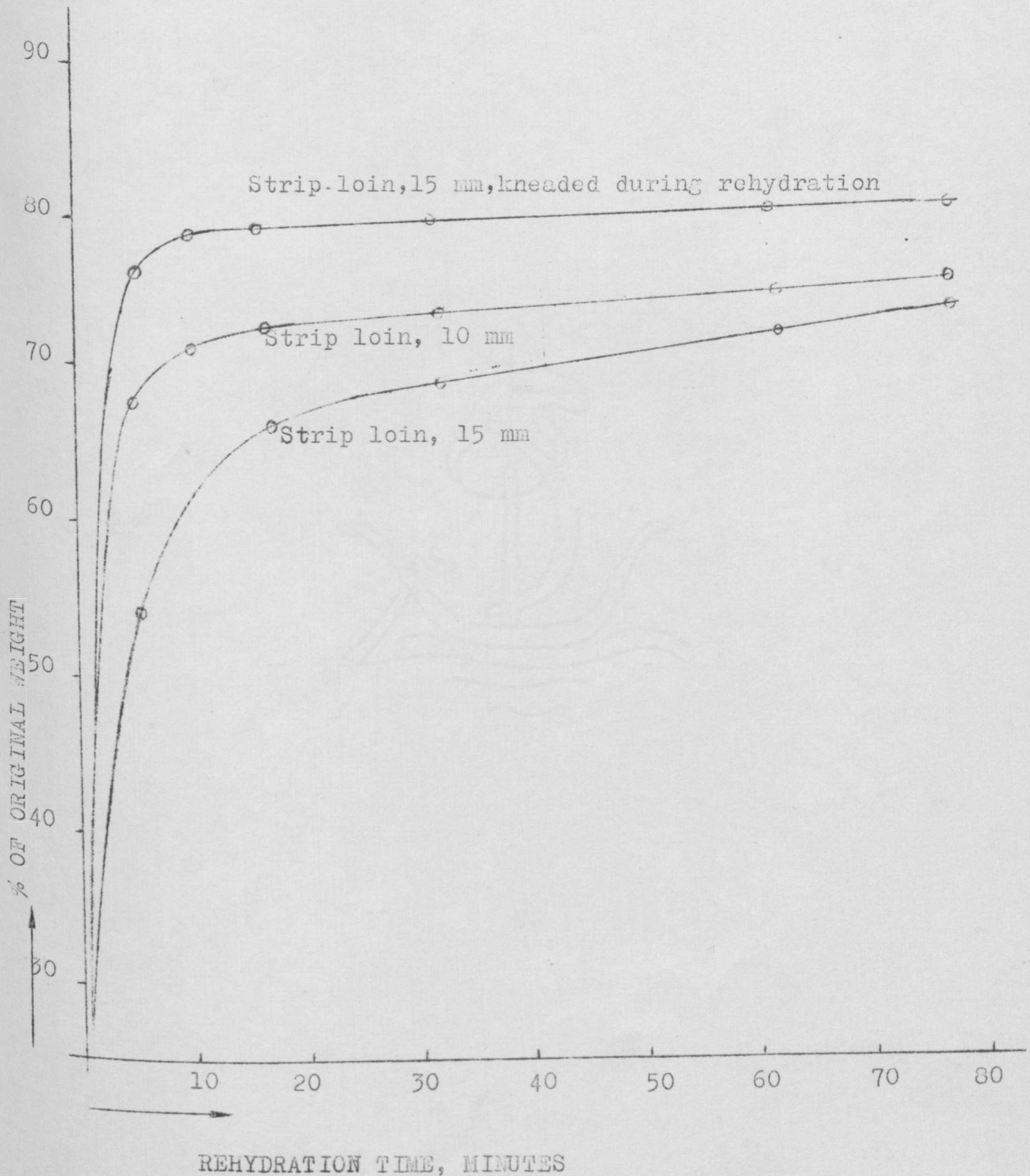




FIGURE 4.

REHYDRATION OF RAW AND COOKED FREEZE-DRYED  
MEAT AS RELATED TO REHYDRATION TIME.

