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The decomposition of starch in sausage products

In many countries the limitation of cheap additives to sausage products is subject to legislation. Some such ingredients, for instance rinds and potato flour, are necessary or at least desirable as binders in certain sausage products. From a technical point of view the addition of connective tissue (tendons), skim milk powder or soy meal seems questionable, unless there is an intention to bind excessive quantities of fat.

The prerequisites to a legislation should be reliable analytical methods and the possibility of controlling that the laws are obeyed.

In this paper the problem of analyzing the content of added products rich in starch, preferably potato flour, but also milling products of wheat, rye and barley, will be recorded.

Experimental

The content of starch was determined according to the well-known method of Grossfeld [1] (slightly modified). This method gives reproducible result if prolonged treatment with the alcoholic KOH is avoided - 45 min. by gentle boiling was applied - and the polarimeter-readings are made immediately or at least not more than 30 min. after dissolving the starch in HCl. The correctness of the method was ascertained by analyzing potato flours with known contents of starch, determined indirectly. Besides, the results of this method were compared with those obtained by gravimetric determination of the separated starch after due allowance for the water, ash, and protein content of the crude starch. This generally contained 10 % moisture, 25-50 % ash, ½-5 % protein. The results agreed very well, as is to be seen from Table 1.

Table 1

Comparison of polarimetric and gravimetric methods of analysis of starch content

Product examined	Content of starch, % according to	
	Polarimetric method	Gravimetric method
Beef	0.12	0.18
Veal, from newly born calves	0.6	0.6
Horse meat, frozen	0.6	0.7
" " , "	0.4	0.4
Bologna sausage (Falukorv)	2.6	2.5
" " (")	2.1	2.2
" " (")	0.6	0.7
" " , wide (Kokt Medwurst)	2.4	2.3
" " , 2nd quality (Bräckkorv)	3.3	3.1
Fresh " , finely chopped (Rå fläskkorv)	2.8	3.0
White pepper	56.5	56.4

From preliminary investigations it became evident, that the starch was decomposed in sausages, which had been pasteurized or otherwise treated by heat, so that the starch had been converted into a paste. Likewise the starch was decomposed in sausages containing starch products such as cooked potatoes and cooked pearl barley, in which the starch had turned gelatinous prior to the addition to the minced or chopped meat. On the other hand, native starch is not attacked. This was easily demonstrated in the case of starch in fresh sausage composed of finely chopped pork, veal, beef, and potato flour. Here the starch remained intact until the sausage became decayed.

How is the decomposition of the starch to be explained? When added to fresh meat in a cooked (gelatinous) state it is likely to be attacked by the α-amylase present in meat. The effect of the enzyme is accelerated by salt. In summer sausages acid hydrolysis and action of microorganisms must be regarded, too. When native starch is heated along with the meat ingredients in the sausage, however, gelatinization of the starch, inactivation of the meat enzymes, and the killing of vegetative bacteria will almost coincide. In consequence, it is to be expected, that rate of heating, width of the sausages, and final temperature attained will play a role for the decomposition of starch during and after processing. So samples were taken of various types of sausages on different stages of processing under practical conditions in a factory and during storing as well for analyzing the content of starch. For these experiments the homogenization was carefully accomplished and, besides, 5 samples were collected from each stage and mixed. The weight of potato flour etc., the weight of the whole lot of sausage, and the shrinkage at each stage was controlled to enable calculating the starch content on an equal basis. 38 lots were examined, the results of which are summarized in Table 2. In table 2 also the reduction power of extracts of the sausages was tentatively determined according to the method of Willstätter-Schudel, modified by Myrbäck [2].

Table 2

Changes of starch content during processing and storage of various kinds of sausage products. All data are calculated on a fresh (raw) weight basis. Temp. in core means temperature in core at the end of the smoking or cooking period. Finished means cooked, cooled in a shower-bath (except Nos. 31-32) and stored over night in the cooler.

Storage temperature was 6-10°C throughout, unless otherwise stated.

Remarks of processing:

The products Nos. 1-26 are emulsion sausages, to which 4-4½ % potato flour have been added (with the exception of No. 4), calculated on a fresh weight basis. According to a Swedish law 5 % potato flour is allowed in the finished product.

The products Nos. 1-4 are finely chopped fresh sausages as opposed to the English and American types of pork sausage, which are usually coarsely chopped. In the sausage No. 4 35 % cooked potatoes are added instead of potato flour. Meat ingredients: pork, veal and beef in Nos. 1-3, pork and beef in No. 4. Content of protein is about 8-10 %, fat 20-25 %, water 60-62 %.

Nos. 5-26 are finely chopped, smoked and cooked sausages containing pork, beef, and sometimes veal (as e.g. in Wieners). Bologna 2nd and 3rd quality and Luncheon Sausage 2nd quality also contained hearts. Unless otherwise stated, the smoking lasted between 1½ and 2 hrs; smoking temperature was 60-70°C. When smoking Wieners 80°C was applied at the end of the period. Cooking time varied between 10 min. (Wieners) and 1 hr (wide Bologna). Cooking temperature was kept between 75-80°C. Then the temperature in the core of the sausage had attained at least 70°C at the end of the cooking period. Content of protein in these sausages is about 10 %, fat 25 %, water 55-60 %.

Nos. 27-30 are smoked but not cooked, coarsely chopped sausages, containing beef and pork. Content of water about 50 %.

Nos. 31-33 are cooked but not smoked products constituting of a mixture of 2 parts cooked meats (beef, pork, hearts, lungs, kidneys) and 1 part cooked pearl barley, each kind separately cooked.

The Liver Pastes (Nos. 34-36) contained 40 % pig liver and 40 % pork. They were cooked for 2½ hrs at 85°C in moulds holding 2½ kg.

No. 37 and 38 contained 44 % pig blood, 10 % syrup, and 20 % rye flour. The sausage was cooked in horse casings (diam. 70 mm and wider) for 21/4 hrs at 80°C, the Black Pudding was cooked for 23/4 hrs at 100°C in cylindric moulds (diam. 125 mm) holding 3 kg.

The diameter of the sausages Nos. 5-9 was: 65 mm; Nos. 10-11 and 14-15: 52 mm; Nos. 12-13: 43-46 mm; Nos. 16-20: 32-35 mm; Nos. 21-22: 21-23 mm; Nos. 23-24: 20 mm; Nos. 25-26: 18-20 mm; Nos. 27-28: 65 and 50 mm; Nos. 29-30: 32-37 mm; Nos. 31-32: 38 mm and wider.

The length of the sausages Nos. 16-20 was: 15 cm; Nos. 21-22: 19 cm; Nos. 23-24: 15 cm; Nos. 25-26: 6 cm; Nos. 27-28: 40 and 60 cm; Nos. 29-32: 15 cm.

Lot No.	Product	Stage of processing	Starch content, %	Reduction power, calculated as % maltose
1	Fresh Sausage (Rå fläskkorv) pH of sausage: 5.8; 5.4; and 5.0 respectively	fresh stored 2 days in brine x) " 3 " " "	3.3 3.4 3.4	1.3 0.9 0.3
2	Fresh Sausage	fresh stored 1 day (dry) " 1 " in brine x)	3.4 3.3 3.3	1.4 1.4 0.8
3	Fresh Sausage	fresh stored 1 day (dry) " 1 " in brine xx)	3.2 3.1 3.1	1.2 1.2 0.8
4	Potato Sausage, fresh (Värmlandskorv) pH of sausage: 6.0; 6.0; and 5.9 respectively	fresh stored 1 day in brine x) " 2 days " "	4.9 2.7 2.8	2.3 2.4 2.1
5	Bologna, wide (Kokt medwurst)	fresh smoked finished stored 7 days	3.8 3.6 2.5 2.1	1.3 1.7 1.5 2.1
6	Bologna, wide Smoking { time: 125 min. temp. in core: 54°C	fresh smoked finished stored 7 days	3.0 3.0 0.5 0.3	1.8 1.6 3.4 3.2
7	Bologna, wide Smoking { time: 120 min. temp. in core: 52°C	fresh smoked finished stored 7 days	4.1 3.0 3.0 2.6	1.8 1.9 2.4 2.1
8	Bologna, wide Smoking { time: 120 min. temp. in core: 55°C Cooking { time: 50 min. temp. in core: 72°C	fresh smoked finished stored 7 days	3.8 3.3 2.7 2.0	1.3 1.2 1.8 2.2
9	Bologna, wide	fresh smoked finished stored 7 days	3.4 3.3 2.8 2.7	1.6 1.9 1.8 2.1

Lot No.	Product	Stage of processing	Starch content, %	Reduction power, calculated as % maltose
10	Bologna (rings) (Falukorv)	fresh smoked finished stored 7 days	3.9 3.7 3.7 3.4	1.3 1.3 1.4 1.5
11	Bologna (rings) Smoking { time: 150 min. temp. in core: 60°C	fresh smoked finished stored 7 days	3.6 3.3 3.4 3.1	1.8 1.6 1.5 1.8
12	Bologna (rings), 2nd quality (Bräckkorv)	fresh smoked finished stored 8 days	3.1 3.1 3.0 2.7	2.0 2.2 2.4 2.5
13	Bologna (rings), 2nd quality Smoking { time: 120 min. temp. in core: 59°C	fresh smoked finished stored 7 days	3.9 4.0 3.9 3.8	1.7 2.2 2.1 2.4
14	Bologna (rings), 3rd quality (Hackkorv)	fresh finished	3.5 0.3	– –
15	Bologna (rings), 3rd quality	fresh finished	3.3 0.1	1.6 4.5
16	Luncheon Sausage (Frukostkorv)	fresh smoked finished stored 7 days	3.4 2.7 2.7 2.4	1.2 1.4 1.4 1.5
17	Luncheon Sausage Smoking { time: 90 min. temp. in core: 60°C	fresh smoked finished stored 5 days	3.4 2.7 2.6 2.1	1.8 1.8 1.9 2.5
18	Luncheon Sausage, wide, 2nd quality (Knackwurst) Smoking { time: 120 min. temp. in core: 51°C	fresh smoked finished stored 7 days	3.3 2.9 1.1 0.8	1.3 2.0 3.1 3.6
19	Luncheon Sausage, wide, 2nd quality Smoking { time: 120 min. temp. in core: 52°C	fresh smoked finished stored 6 days	3.7 3.7 1.4 1.4	0.9 1.4 2.4 3.3
20	Luncheon Sausage, 2nd quality Smoking { time: 90 min. temp. in core: 60°C	fresh smoked finished stored 7 days	3.5 3.2 2.9 2.2	1.5 1.5 1.9 2.1
21	Frankfurters (Varmkorv)	fresh smoked finished stored 7 days	4.0 3.7 3.7 3.6	1.7 1.8 1.8 1.8
22	Frankfurters Smoking { time: 90 min. temp. in core: 62°C	fresh smoked finished stored 6 days	3.7 3.6 3.1 3.1	2.1 2.7 3.2 3.7

Lot No.	Product	Stage of processing	Starch content, %	Reduction power, calculated as % maltose
23	Wieners (Wienerkorv)	fresh smoked finished	3.5 2.9 2.9	1.8 2.2 1.9
24	Wieners Smoking {time: 90 min.; temp. in core: 72°C} Cooking {time: 10 min.; temp. in core: 75°C}	fresh smoked finished stored 7 days	3.7 2.4 2.5 2.4	0.9 1.6 1.5 1.5
25	Small Wieners (Prinskorv) Smoking {time: 90 min.; temp. in core: 63°C}	fresh smoked finished stored 7 days	2.9 1.5 1.6 1.4	1.0 1.7 1.6 2.2
26	Small Wieners Smoking {time: 90 min.; temp. in core: 64°C} Cooking {time: 10 min.; temp. in core: 75°C}	fresh smoked finished stored 8 days	3.0 1.9 2.0 1.8	1.5 2.2 2.0 2.2
27	Semidry Cervelat with cooked potatoes (Hushållsmedwurst) Drying and smoking {time: 4 days; temp.: 25-30°C} pH of sausage: 5.9; 5.9; 4.9; 4.6; and 4.8 respectively	fresh dried 15 hrs smoked stored 10 days " 15 "	2.4 0.8 0.7 0.6 0.7	2.9 3.3 4.8 4.6 4.8
28	Semidry Cervelat with cooked potatoes Drying and smoking {time: 4½ days; temp.: 23-25°C} pH of sausage: 5.8; 5.0; and 5.0 respectively	fresh smoked stored 14 days	2.4 1.6 1.5	2.9 3.3 3.8
29	Smoked fresh sausage with cooked potatoes and cooked pearl barley (Isterband) Drying and smoking {time: 30 hrs; temp.: 20-40°C} pH of sausage: 6.0; 5.8; 5.4; 5.1; and 4.5 respectively	fresh dried 14 hrs smoked stored 1 day " 8 days	6.7 6.3 6.3 6.1 5.4	1.6 2.3 2.3 2.4 2.8
30	Smoked fresh sausage with cooked potatoes and cooked pearl barley Drying and smoking {time: 30 hrs; temp. 20-40°C} pH of sausage: 5.9; 4.9; 4.5; 4.4; and 4.7 respectively	fresh smoked stored 2 days at 18°C stored 4 days at 18°C stored 7 days at 8°C	6.7 6.0 5.6 5.5 5.8	2.0 2.3 2.6 2.5 2.8
31	Cooked sausage with cooked pearl barley (Stångkorv) pH of sausage: 6.5; 6.3; and 5.9 respectively	finished stored 1 day at 8°C " 3 days at 8°C	7.3 6.8 6.7	1.7 1.7 2.3

Lot No.	Product	Stage of processing	Starch content, %	Reduction power, calculated as % maltose
32	Cooked sausage with cooked pearl barley pH of sausage: 6.1; 5.2; and 4.7 respectively	finished stored 2 days at 18°C " 4 " " "	7.5 6.7 6.6	2.2 2.6 2.6
33	Product composed similar to the preceeding item, not in casings but canned for 90 min. at 123°C in 1 kg cans (Pölsa)	mixed cooked ingredients canned	7.7 7.4	1.7 2.6
34	Liver Paste (Leverpastej) (meat ingredients chopped in a fresh state)	fresh cooked stored 6 days at 9°C	2.7 1.9 1.8	5.7 7.1 6.9
35	Liver Paste (meat ingredients chopped in a fresh state)	fresh cooked stored 7 days at 8°C	1.9 1.5 1.4	4.9 6.9 6.8
36	Liver Paste (meat ingredients precooked before being chopped)	fresh cooked	2.1 1.7	5.7 6.8
37	Black Sausage	fresh cooked	10.8 8.9	4.7 6.9
38	Black Pudding	fresh cooked	10.8 9.5	4.7 7.5

x) Concentration of brine: 4 %.
xx) " " " : 3 and 4 %. No different effect was observed in these brines.

Conclusions

As has already been mentioned the native starch in the fresh sausages Nos. 1-3 is not or practically not affected, not even after storage. Of course the reduction power will diminish when storing in brine, due to dialysis of reducing matters through the casing (hog casing).

In the fresh sausage No. 4, however, the starch of the cooked potatoes is decomposed to a marked degree, from 4.9 % to 2.7 %.

As to the Bologna sausages, Nos. 5-15, the decomposition of the starch has gone particularly far in the wide ones. An extreme break-down has occured in No. 6, less in Nos. 5, 7, and 8. As a rule, the starch is decomposed during cooking, although there are examples of a break-down during smoking, too (cf. No. 7). Evidently a disappearance of part of the starch occurs even during storage at relatively low temperatures (cf. Nos. 8, 5, and 7). In the more narrow types of Bologna, represented by Nos. 10-13, the decomposition of starch is insignificant. In the sausages Nos. 14 and 15, however, the break-down of the starch is extremely high, probably due to the enzymatic activity of the organs present in this type of sausage.

The still narrower smoked and cooked sausages, represented by Nos. 16-26, show a somewhat varying behaviour with regard to starch decomposition. Thus, in Nos. 16 and 17 a significant break-down of starch occurs during the smoking process, from 3.4 to 2.7 %, and, especially when considering No. 17, also during storage (from 2.6 to 2.1 % in 5 days). On the other hand, the starch in Nos. 18-20 is mainly decomposed during the cooking process, due to a relatively low smoking temperature. In Nos. 18 and 20 a significant "disappearance" of starch occurs during storage.

In Frankfurters and Wieners (Nos. 21-24) the starch passes the whole manufacturing process and the storage without being seriously attacked. Yet No. 24 makes an exception in so far, as a break-down of starch from 3.7 to 2.4 % occurred during smoking, no doubt on account of the high smoking temperature, which caused 72°C in the core at the end of the smoking period. In the sausages Nos. 25 and 26 the percentage of starch added was significantly lowered (1-1½ %) during smoking, probably of the same reason as in No. 24, but no marked change was observed during storage.

The reduction power of the sausages Nos. 4-26 is inversely proportional to the starch content. There are, however, exceptions. In these cases the reduction power calculated as maltose as a rule is a little lower than what is to be expected from the decomposition of the starch.

In the sausages Nos. 27 and 28 a strong break-down of the starch, deriving from cooked potatoes, has occured. Although of a different type than the sausage No. 4, the source of starch is the same. So the results are similar, too. The loss of starch is exactly covered by a corresponding increase of "maltose".

The sausages Nos. 29 and 30, containing cooked potatoes and cooked pearl barley, show a moderate decrease of starch during smoking. During the storage period, however, the decomposition of starch is stronger. There are three factors, which may contribute to an explanation as to these matters: 1) time is required to attack the cooked pearl barley; 2) pH is changed from about 6 to 4½; so hydrolysis must be considered; 3) growth of bacteria is favoured by time; so a break-down caused by bacteria may also occur.

In the sausages Nos. 31 and 32 a moderate lowering of the starch content, between ½ and 1 %, occurs during storage, probably of the same reasons (except the first one) as those mentioned in discussing the two preceeding products containing pearl barley. In the present type of sausage the ingredients have been cooked before mincing and mixing. So the development of bacteria is owing to infection during these processes and filling as well as to infection by the casings. During the canning process only a small change of the starch content is observable (cf. No. 33).

To the Liver Pastes, Nos. 34-36, 2 % wheat flour has been added. Besides, as a source of carbohydrate the presence of glycogen must be assumed, although most of it used to be broken down before processing. During cooking the starch content is lowered ½-1 %, whilst the reduction power, calculated as maltose, increases 1-2 %. Thus, other reducing substances than maltose are formed, too. The decomposition of starch was shown to go farther in the internal parts of the paste than in the outer ones, evidently due to a more rapid heat inactivation of the amylase in the latter parts. For instance, in the Liver Paste No. 34, an outer layer constituting 13.7 % of the total paste contained 2.53 % starch and an inner layer constituting 14.9 % had a starch content of 1.95 %, calculated on the same basis.

When comparing the Black Sausage and the Black Pudding Nos. 37 and 38, which have the same original composition, the break-down of starch is greater in the former than in the latter product. The reason for this is very likely the lower cooking temperature of the sausage (80°C), enabling the amylases in rye and blood to act during a relatively longer period until they become heat inactivated. On the other hand, part of the reducing substances (glucose, maltose etc.) are dialysed through the casings. No difference between horse casings and cellophane casings was observed in this respect. So the reduction power of the sausage, inspite of a more far-reaching decomposition of starch in the sausage than in the pudding, turned out to be less than in the Black Pudding, which was cooked at 100°C in closed moulds. – Here again, as was the case with Liver Paste, the starch was broken down to a higher extent in the centre parts of the Black Pudding than in its outer layers. Thus, 12.7 % starch was found in an outer layer constituting 5.5 % of the pudding as compared to 9.1 % starch in a core constituting 25 % of the total pudding. The reduction power, calculated as maltose, was 7.3 % and 9.1 % respectively. –

The content of "maltose" in the rye flour used was 4.1 % as compared to 4.7 % in the fresh Black Pudding.

From what has been discussed so far a common feature of the decomposition of starch in sausage products is the relation to heat treatment. It seems certain, that 1) gelatinization of the starch is a prerequisite for being acted upon, and 2) degradation by amylases are the most important factors involved in the break-down of the starch. Generally the processing time, during which the temperature is favourable for growth of bacteria, is very short. Besides, smoking will retard the development of microorganisms. So a degradation of starch by microorganisms may only be considered in some cases during processing (Nos. 27-30) and during storage (Nos. 29-32). In the products Nos. 27-32 the conditions for acid hydrolysis are present. On the other hand, the action of animal amylases is of minor importance at low pH. Wether bacterial action is of any importance by the decomposition of starch during storage of the cooked sausages Nos. 5-26 is uncertain, practically all vegetative microorganisms being killed during the cooking process. An approach to this matter was made by examining the number of microorganisms in the sausages after processing and at the end of the storage period. The number of microorganisms in the fresh sausages and in the various stages of processing was also determined but seems to be of no particular importance in this connection. The result was an almost invariable number of microorganisms growing on broth agar, the magnitude being 10^3 to 10^4 per gram (apart from No. 5, see below), both after cooking and at the end of the storage period (7 days). In some cases even a lesser number of microorganisms was observed after storing than after cooking. In particular, the number of microorganisms in the sausage No. 6 with highly decomposed starch was $2 \cdot 10^3$ per gram after cooking and $1 \cdot 10^3$ after storage for 7 days, as opposed to the sausage No. 5 with moderately decomposed starch, the corresponding figures being $1 \cdot 10^2$ and $2 \cdot 10^5$. – For comparison, the number of microorganisms in the sausages Nos. 27-28 and Nos. 29-30 growing on broth agar may be mentioned: in Nos. 27-28: $1.5 \cdot 10^7$ (fresh), $1 \cdot 10^7$ (smoked), and $7.5 \cdot 10^7$ (stored 14 days); in Nos. 29-30: $7 \cdot 10^5$ (fresh), $4 \cdot 10^8$ (smoked), and $3 \cdot 10^8$ (stored 7 days).

Thus, the bacterial activity is likely to be of no importance during low temperature storage of the smoked and cooked emulsion sausages Nos. 5-26. A fact, which has not been regarded in full is the variability of the quality of potato flour. Marked differences as to the viscosity of various lots of potato flour has been observed. With the exception of four of the sausage products investigated, one of which was No. 6, in which the starch was highly decomposed during processing, potato flour of practically the same viscosity was used in the manufacturing of the sausages in these experiments.

Alpers and Ziegenspeck [3] also investigated the degradation of starch in sausage products. They stressed the autolysis of starch pastes as an explanation of the disappearence of starch in sausages. Maybe autolysis is responsible for the break-down of starch under certain conditions and probably the quality of starch is of importance in this connection, but, when considering the very small changes of the starch content in the sausages Nos. 9-13, 16, 19, and 21-26 during storing, autolyses must have played a minor part in starch degradation. The said authors also made the conclusion, that the enzymatic decomposition of starch must be of great importance. On the other hand, the conclusions of these authors as to the break-down of starch by bacteria, are in accordance with the findings in some fresh sausages (Nos. 27-32) only, but are not in accordance with the findings in the smoked and cooked sausages Nos. 5-26.

Unfortunately the blank test of the reduction power, i.e. the value of reduction of the fresh sausages, cannot be considered as a constant, not even for the same type of sausage, as for example the Nos. 1-26 (except No. 4). Thus, the reduction power, calculated as maltose, fluctuates between 0.9 and 2.1 %. Yet, 1½ % seems to be a rather useful mean. About half of that was later obtained in a series of analyses of the reduction power by means of Fehling's solution, using phosphotungstic acid as the precipitant for protein. However, the same variations of the blank test as mentioned above were obtained. This was true both in fresh sausages and in beef, veal or pork alone. The determination of the reduction power of the carbohydrates is effected i.a. by the amino acids present in meat. A striking example of a high blank test is that of Liver Paste (Table 2), owing to an extensive glycogenolysis and proteinolysis in liver tissue. A recent investigation of the influence of amino acids on the determination of reducing carbohydrates according to various methods is made by Iwainsky [4].

Summary

38 various sausage products have been investigated with regard to the decomposition of starch during processing and storage. 4 fresh and 22 cooked and smoked products of the emulsion sausage type containing potato flour as an ingredient were examined. Furtheron, 4 smoked, semidry sausages (summer sausages) containing cooked potatoes and cooked pearl barley respectively, were investigated. Finally, 3 sausages consisting of meat and pearl barley, separately precooked before mixing, 3 Liver Pastes, 1 Black Sausage and 1 Black Pudding were also included in the experiments.

The results are summarized in Table 2. Generally a marked decrease of the starch content occurs during the cooking process due to gelatinization of the starch, thereby enabling the amylases to attack it. Not gelatinized starch remains unattacked. Decomposition of starch during storage is of importance primarily in summer sausages, to some extent also in wide Bologna. In the former products bacterial action and acid hydrolysis may play a role in the decomposition of starch.

The reduction power increased by decreasing content of starch.

References:

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Scans Centrallaboratorium, Malmö, August 7th, 1957

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