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INFLUENCE OF PASTEURIZATION PARAMETERS ON THE QUANTITY OF JELLY IN CANNED HAMS.

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The quantity of jelly i.e. that of the meat juice bound by addition of gellatine, expressed as a rule in net weight per cents of the can content is one of the basic criteria in estimating the commercial value of canned ham.

The meat exsudate is the outcome of denaturation of muscular proteins under theinfluence of thermal treatment/pasteurization/. The quantity of this juice briefly named jelly depends on numerous factors. The physico-chemical condition of the tissue proteins in raw ham, whose indices, among others, are pH and the water binding ability is also influenced to some extent by the technological process and determine the salt content after pickling and partly cause dehydration of the ham. Finally pasteurization parameters play an important role with regard to the range of applied temperatures and the duration of the process.

The present paper deals with the analysis of the relationship of these parameters and the quantity of jelly as well as with the organoleptical quality of canned ham based on a detailed characteristic of the development of temperatures in the canned bloc subjected to different methods of pasteurization.

Denaturation and Hydrolitic Changes Occuring in Proteins during the Pasteurization Process.

Pasteurization has to fulfill two principle tasks:

a/ - to modify the nature of proteins and to incite hydrolitic changes in a degree, which would make the product suitable for consumption and attain optimum quality such as bounding, succulence, tenderness, flavour and a possibly limited quantity of jelly

b/ - to assure a relatively long life to the product i.e. a durability, which-under definite storage conditions, determined for this kind of product-would be maintaned during the required period.

The pasteurization with regard to the quality of the product is mainly a matter of the degree of denaturation to which muscular proteins in ham are subjected during the process.

Denaturation is the most characteristic feature of proteins, which does not occur in other large molecules of a similar structure for example in polypeptides.

This modification of the protein structure has a more physical or intramolecular than chemical character causing changes in the specific spacious configuration of the protein particles /1/

This is a general definition put forward by Putman and determines the phenomenon of denaturation, which although known is extremely versatile and only partly explained.

Since denaturation is a intramolecular process it may be defined on the principle of changes of a physico-chemical or biological nature of the protein.

Among the most important denaturation changes occuring in protein are the following:

1. Reduced solubility
2. Loss of biological activity
3. Icrease of activity of some characteristic groups /radicals/ of the protein
4. Modifications in molecular configuration and size.

The most comprehensive symptom of denaturation is the reduction of its solubility.Irrereversible coagulation is its direct consequence.

The loss of biological activity of proteins is linked with the inactivation of the enzymatic system.

The increased activity of functional groups /radicals/ is bound with changes in configuration.This,as a rule,is estimated by measuring the number of SH groups this method being considered as the most convenient.

The configuration of denatured protein molecules is more complex,probably because of the presence of lateral polar chains impervious to ionization.Denatured protein molecules display moreover considerable contraction /decrease in volume/.

A closer investigation of the phenomenon of denaturation leads to the conclusion that it occurs in various degrees depending on the magnitude of changes changes which ensue in the proteins under the influence of diverse denaturing factors.The degree in which denaturation occurs in the structure and in the properties of proteins,depends on their kind as well as on the character,concentration and duration of this influence exercised by the denaturing agent.

All denaturing factors can be classed in three groups:

1. Physical
2. Chemical
3. Biological.

Heat is one of the denaturing factors,which has been investigated most comprehensively.It is actually heat,which is the denaturing factor while temperature is only a coefficient of the reaction rate.

The temperature coefficient is exceptionally large in the case of proteins and has led to the conception of coagulation temperature,otherwise the temperature which causes the inactivation of proteins.For example

when the rate of common,homogenous reactions in gases grows two or threefold with the rise of the temperature the rate at which denaturation takes place in proteins at the same pitch increased hundred or often as far as six hundred times.

At temperatures exceeding + 65° C the rate of denaturation is so high that practically it may be said to occur instantly.

Denaturation also depends on the concenrtration of H' or OH' ions,what in turn allows to presume that-among others-an acid-basic equilibrium is also involved in the process.

Steinhardt/4/ advanced a theory explaining the influence of pH on the rate of denaturation,as the effect of the ionization of certain groups.Protein becomes denatured all the easier the nearer its pH is to the isoelectric point.Proteins,where the pH is within the physiological range display the highest degree of resistance to denaturation.

Miosine and myogene fractions are those tissue proteins which are mainly exposed to denaturation.Without entering into details on the development of investigations carried out on these proteins only certain properties which interest us from the standpoint of the present paper will be considered.

Myosin is insoluble in water but dissolves in salt solutions.The pH of the isoelectric point equals 5.4 to 5.5 /5/ and the denaturation temperature varies between 45 to 50° C.

Myogene eqsily dissolves in water; the pH of the isoelectric point is 6.3 to 6.7.Denaturation temperature varies between 55-65° C.

In pasteurized ham the beginning of the denaturation of tissue proteins can be observed at temperatures averaging 40-50° C.The particular stages of denaturation

are linked with the efflux of meat juices released from the denatured tissue.It was found that meat juices drip in pickled pork starts at 53° C and reaches its maximum at 58° C.The meat then begins to contract/decrease in volume/ by about 10 per cent /6/.

The total quantity of exsudate from pasteurized meat is according to Tilgner and Osińska /6,7/ far higher under a rapidrise of temperature than under gradual warming up. It was also observed that a considerable portion of the juice was released when the meat reached the temperature of 65°C.

The decomposition of colagen in the sarcolemma and in the muscular fascia and the entire muscles /8/ takes place parallel with the denaturation changes of part of the proteins.

Beginning from 50° C colagen transforms into glutine, the process developing intensively above 60°C.Glutine forms colloidal aqueous solutions which cool into gel,capable of holding large quantities of water /8,9/.

The largest quantities of glutine are obtained from colagen by heating it gradually up to but not above 60-65°C.If the hydrolysis takes place suddenly and under higher temperatures,larger quantities of simpler substances such as gellatose are evolved.These substances are, as a rule,soluble in water,but lack the capacity of forming gels/8/.

According to observations carried out by Kurko /11/ and cited by Ziemba /10/ the resistance of colagen to decomposition varies,depending on the kind of the muscle, when the latter is heated in an undesintegrated state. Kurko established series of muscle resistance with regard to decomposition of colagen.For beef the consecutive resistivity increases as follows: lumbar muscle,long.dorsi muscle,semimembranaceus muscle,triceps femoris muscle, semitendineus muscle,deep thoracic muscle.

In the case of muscles containing small amounts of connective tissue for example in the case of the long.dorsi muscle,where decomsposition of colagen takes place at higher rates,the optimum consisctency of meat to be obtained mainly depends on the denaturation of muscular proteins.In muscles containing larger quantities of connective tissue and highly resistant colagen,the obtaining of optimum consistency is bound with the decomposition of colagen within the limits of 25 to 45 per cent.

These data indicate that a modification in pasteurization methods in view of applying lower maximum temperatures as well as gradual and slow heating are theoretically fully justified from the standpoint of the product quality.It is obvious that the technological process must be carried out carefully and with due observation of hygiene and the raw material suitably selected in order to produce an article of required durability.

The two tasks of pasteurization mentioned at the beginning of this paper are to a certain extent in mutual opposition because the highest quality, as a rule,obtained under a gradual process of pasteurization is liable to excite objections with regard to the durability of the product.Thus pasteurization in practice is a certain kind of compromise of the aforesaid conditions,where the higher the observed degree of processing-hygiene and grade of the raw material the more gradually can the pasteurization process be performed.

Continous endeavours can be observed with the aim to mitigate pasteurization conditions.USA regulations /for importers/,which require heating of the centre of ham bloc up to 72°C are obsolete.

Already in 1950 leading USA meat plants used such pasteurization conditions that the inner temperature of hams did not exceed 65.5°C.The maintenance of this temperature for approx.180 minutes satisfied all physico-chemical requirements.

The general tendency is to pasteurize gradually as far as it is possible,the aim being to release a product corresponding to a "cooked" degree featuring organoleptic qualities proper to the traditional pasteurized preserve.This is the reason why an analysis of the interdependency of pasteurization parameters and the quantity of jelly must be based on parallel investigations on the degree of denaturation /13/,"cooking",and the organoleptic analysis of the product.We shall not be satisfied with conditions of pasteurization providing a minimum quantity of efflux but at the same time contributing even in a small degree to the detriment of the organoleptic properties of the product.

P r o c e d u r e.

Six methods of pasteurization featuring different parameters /temperature and time/ taken from literature/14,15,16/ our own experience /17,18/ and current practice were investigated /19/.Table I shows pasteurizing temperatures and the duration of the process carried out under these methods on cans of uniform size. /Table I/.

Methods 5 and 6 were adopted as reference methods. The material consisted of pairs of hams from Class III carcasses with well developed muscles and of uniform weight.

The hams were taken from the slaughterhouse 24 hours after the animals were slaughtered/internal temperature 18-20° C/ and then chilled during 48 hours under constant conditions /Temp.4-6°C,relative humidity 90% /.

For the purpose of qualifying the raw material, pH and water-binding capacity were systematically measured in the hams at 24, 48 and 72 hours following slaughter.

The hams were then subjected to normal technological treatment /injections, pickling, dripping, smoking/ under uniform conditions in compliance with technological instructions /19/ in force.

After canning, from each pair of hams, one was pasteurized under the investigated method the other being pasteurized under one of the reference methods.

Each series of experiments included six pairs of hams and three or more repetitions were performed in order to estimate thoroughly the tested method.

The temperature of the centre of the can and in the outer layer was measured in serveral cans from each series. The cans were then opened after 48 hours and submitted to technological appraisal /per cent of jelly bonding etc./

The remaining cans were stored for about four weeks followed by technological appraisal and systematic organoleptic estimation in order to determine the influence of the particular method of pasteurization on the organoleptic properties of the product.

Temperature measurements were taken parallel at the Geometrical centre of the can and at a point located 2 cm below the surface of the product/appointed temperature of the superficial layers/by means of resistance and mercury thermometers.

The respective positions of the thermometers are shown on Fig. 1 and 2.

The distribution of temperatures inside the canned ham during pasteurization was found by additional measurements separately for each particular pasteurization method at four different points of the ham at the same time. The location of the thermometers in the latter case is shown on Fig. 3.

Measurements of the pH in the raw material were conducted by means of the "Radiometer 22" type pH-meter on the gluteus medius muscle, which-according to preliminary investigation- is best representing the pH in the whole ham.

Measurement of water-binding capacity: of hams used in the investigations were carried out by means of apparatusdeveloped by Błaszkiewicz and Bykowski /20/

Principles of measurement s: of water is released and absorbed by the filter papers under the influence of constant difference of pressures./0.4 atm/ on a determined surface/28.23 sq.cm/ in a definite period /40 seconds/.The result was expressed as the quantity weight of meat juice absorbed by the filter paper

types of used filter - VEB Nr.388

accuracy of measurement/weighing/ - 5 mg

The water-binding capacity was also measured on the gluteus medius muscle.

Determination of cooking degree was carried out according to the method suggested by Coretti/13/ allowing to determine whether the internal part of the ham, from which the sample is sliced for investigation was subject, during the stipulated time, to the action of temperature exceeding + 65°C.

The degree of turbidity of the aqueous solution of the meat sample sliced from the interior of a pasteurized ham heated to the appointed degree allowed, was expressed conventionally.

+++ - strong turbidity, coarse flocculent suspension

++ - mean turbidity, medium to coarse flocculent suspension

\+ - weak turbidity fine flocculent suspension, scarcely perceptible

\- lack of turbidity

Organoleptic quality appraisal of the pasteurized hams was performed in a special laboratory arranged for organoleptic investigations performed by persons answering requirements set up by modern organoleptic analytics.

Colour, bounding, flavour, succulence, tenderness, taste saltiness were determined in each pair of hams and the difference expressed by means of a five point scale. The scores are shown in Tabl. II.

Results and discussion.

Results of detailed temperature measurements in all six hams are shown in diagram 4-9. Two pairs of the most typical curves were selected for each method /with the exception of method 60/74/: the pair AA for the initial temperature averaging + 17°C and the curve BB' for the initial temperature of 10° C.

Curves A and B refer to temperatures in the centre of the ham, the curves A' and B' to the temperature in the superficial layers /measurements optionally 2 cm deep below the surface/.

Each pair of curves represents the mean value of at least three series of experiments and is to be noted here that the development of temperature for several repetitions of the same method of pasteurization were almost always similar and the maximum did not exceed 1.5-2°C.

Temperature development curves characteristic for pasteurization methods under investigation.

The analysis of the development curves plotted on the graphs indicated that each of them can be divided into three basic parts:

1. Temperature rise up to + 63°C- the rate at which the temperature rises during this period depends on the difference of the temperature of the heating medium /water in the pasteurizer/ and of the heated product.

For this reason the increase of the temperature is higher unser methods,which at the beginning of the pasteurization process apply more hot water/for example-method $100^{\circ}/80^{\circ}$- /

Since the difference between the temperature of the heating water and that of the heated ham diminishes with time,this phase may be divided into two stages:Stage I-representing intense temperature increase and Stage II-when the temperature rises slowly.These two stages are especially distinct,when pasteurization is carried out under methods,where at the beginning high and afterwards lower water-temperature are applied and are less disctinct by pasteurization where the temperatures are reversed.

2.Period when the centre of the ham is maintained under a temperature exceeding $63^{\circ}C$ This period is very important both because the ham attains the correct organoleptic properties and from the standpoint of the shelf-life of the product.This phase fits only partly into the time when the heating water reaches a suitably high temperature proper to the particular pasteurization method,partly overlaps the cooling period owing to the thermal inertia of the product.

3.Cooling period-when the internal temperature of the ham sinks below $63^{\circ}C$ and continues to do so.

Basing upon the aforesaid division a comparison of graphs 4-9 typical for the investigated pasteurization methods,proves that the particular methods differ in:

a/ the rate of temperature increase in the centre of the ham is $\frac{\Delta T}{t}$ This rate is the highest with methods 6 and 2 and the smallest with methods 1,3,4.

b/the period when the ham centre is exposed to a temperature exceeding 63°C.These periods differ according to the particular methods.The longest time under which the centre of the ham is exposed to a temperature exceeding 63°C occurs with methods 100°/80° and 100°/72° / average 130 minutes/,this period is somewaht shorter with methods 68°/74° and 60°/74° /average 105 and 95 minutes/.It is the shortest with methods 52°/74° and 50°/100°/80°/75° /75 minutes/. In all cases however it is longer than the time indicated by Coretti /13/.

The time during which the superficial layers of the ham remain under a temperature higher than 63°C is also a characteristic feature.

c/ <u>The maximum temperature reached by the ham centre.</u> /$T_{c\ max}$/. With the method 100°/80° this temperature amounts to 70-71°C ,with the method 100°/72° it is 67-68°C,with the method 68°/74° and 60°/74° it averages 67-68°C and is lowest with the methods 52°/74° when it equals to 65-65.5°C.

d/ <u>The maximum difference in temperatures obtained at the same time between the centre and the superficial layers</u> /$T_{ext.} - T_{c\ max}$/. awhich appears when the ham is heated /1-st stage of pasteurization/.

The above indicated properties,characteristic for the particular pasteurization methods are presented on Table III.

<u>Relationship between the characteristic properties of pasteurization methods and the quality of jelly.</u>

The comparison of properties of pasteurization methods presented on Table III and the respective quantity of the jelly seems to point to a mutual relationship between these values.For example there appears a dependency between the heating rate of the ham $\frac{\Delta T}{t}$

and the maximum temperature attained by the centre of the ham and the quantity of jelly as well as between the difference in temperatures between the superficial layers and the centre and the quantity of released jelly as well as between the difference of temperatures between the superficial layers and the quantity of jelly.

The relationship between the independent variables:

1. Temperature increase rate $p = \frac{^{o}C}{min}$ / X_1/
2. Time of exposure to temper.of 63°C t_r 63° /X_2/
3. Maximum temperature at centre of ham $T_{c\ max.}$ / X_3/
4. Maximum difference between temperature in centre of ham and in superficial layers /amplitude $T_{ext.}-T_{c\ max.}$/ /X_4 /

and the dependent variable-quantity of jelly /g/ expressed in per cents of net weight of the can was proved by computing the correlation coeefficients /22/

The results are shown in Table IV.

Since all the empirical values of the correlation coefficients "r" exceed the theoretical value /minimal/ one can assume that linear regression is proved.This indicates that the examined characteristic properties of pasteurization have a very decisive influence on the quantity of jelly in the product.

Regression coefficients have been calculated/a/ between x_1-x_4 and y /22/ in order to ascertain the degree at which the given variable influences the quantity of jelly,and which have the following values for the particular variables:

for x_1-a_1= 70% because p /temperature increase rate/ varies within hindredths of a p,we calculate the coeffiсient a´for 0.01 p´- amounting to 0.7%

for x_2-a_2 = 0.117% this means that the prolongation of the time of the exposure of the ham centre to a temperature exceeding + 63°C by one minute leads to an increase in the quantity of jelly by 0.117%

for x_3-a_3=0.94%, maximum temperature increase attained by the centre of the ham by 1°C leads to an increase of jelly quantity by 0.94%

for x_4-a_4=0.39% indicates that should the amplitude grow by 1°C the quantity of jelly will also increase by 0.39%

Contrary to the still existing assumption that a rapid temperature increase leads to an external coagulation of protein inhibiting exsudation from the interior layers, the obtained results seem to prove that the growing speed of the temperature rise causes an important increase in the quantity of jelly./regression coefficient a_1/.

The above confirms observations conducted by Tilgner and Osińska/6,7/. Analogous results have been obtained in the same way/regression coefficient a_1/ with regard to the range of temperature elevation influencing the quantity of efflux.

Interesting is also the dependence between the quantity of jelly and the difference in maximum temperatures between the ham centre and the superficial layers i.e. the degree of overheating of the superficial layers /regression coefficient a_4/.

Diagrams 10-13 represent the temperature of the ham centre for various pasteurization methods. The particular curves illustrate the temperature of the ham inner /at the same time/ as a function of the distance from the geometrical centre of the can. The curves have a parabolic shape.

The amplitude /maximum difference between temperatures in the centre of the ham and in its superficial layers/ depends on the temperature of the heating water/especially during the initial heating stage/ and is the more elevated the higher the temperature of the water during this period.

It appears thus that any elevation of this temperature by 1°C results in an increase of the jelly amount by about 0.4 per cent.The conclusion therefore is that even local temperature variations inside the pasteurizer may distinctly influence the quantity of jelly in canned hams.

In view of the data presented above it becomes obvious that conditions under which pasteurization is conducted have a decisive influence on the quantity of jelly.This is,apart from that of the quality of the raw material, one of the most important factors deciding the quality of pasteurized ham.

Comparison between the influence of the particular pasteurization methods on the jelly content in the product.

A precise statement on the effect which a given pasteurization method exercises in the jelly content is hindered by the varying quality of the raw material,which often is very considerable.This variability is determined by the physico-chemical state of the muscles at the time of processing,among which the most important is pH and the water-binding capacity.This causes differences in the jelly content as far as by 100 per cent or even more, with the same pasteurization method.It may therefore happen that when comparing the jelly content in hams pasteurized at differing parameters variations occuring within the group /of the same pasteurization method/ are larger than inter-group differences and in such a case the influence of the particular pasteurization method cannot be proved.

Investigations showed considerable variations of the

raw material both with regard to the pH and wateriness within wide limits.

In order to reduce partly x/ the influence of raw material variability investigations were performed on pairs of hams/from the same carcass/ one of which was pasteurized under the method subject to investigation the other under the reference method.

In order to prove the effectiveness of pasteurization under the method 6,method 5 /100°/80°/ was employed as reference,while method 6 /100°/72°/ was taken as reference method for the remaining ones.

The significance of the differences in jelly content evolved by different pasteurization methods was proved by means of the Student's criterium /23/.The are given in the Table V.

The above data indicate that method 5 significantly differs from method 6.The latter causes a distinctly lesser jelly content averaging 3.5 to 4.5 per cent, while from the standpoint of the period the interior of the ham is exposed to an elevated temperature -as important for bacteriological reasons-method 5 is only slightly better.

Lower quantities of jelly were obtained under method 1/average 5.4 per cent/and under method 4/average 6,34 per cent/ and method 3/avergage/6.5 per cent/.

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x/
It was found that in many cases even hams originating from the same carcass showed differences in pH and wateriness.

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Table V presents effects obtained under the investigated methods with regard to the quantity of jelly in comparison with the reference methods.To what degree do these methods differ among each other is also a point of interest.

The problem was solved by means of variance analysis /23/,the results being presented on Table VI.

It clearly appears here that depending on the particular pasteurization method,distinct differences occur in the jelly contents.To prove the magnitude of these differences confidence intervals were calculated for the jelly content for each comparable pair of methods and a two-dimensioned table was drawn up for the difference in the mean jelly content as per each particular method and its corresponding confidence interval /Table VII/.

When the difference exceeded the confidence intervalit was marked as important by the sign /+/,Unproved differences were marked by the sign /-/

Pairs of methods marked /+/ considerably differs among each other with regard to the quantity of jelly at the level of significance =0.95

Results assembled on Table VII indicate that all the investigated methods /with the exception of methods 3 and 4/ show large difference betweem one another with regard to the quantity of jelly.The consecutive order of the methods with regard to the above is:

-pasteurization under 100°/80° -mean jelly content 13.51%

- " " 100°/72°-mean jelly content 9.28%

- " " 68°/74°-mean jelly content 8.02%

- " " 50°/100°/80°/75°-mean jelly content 6.52%

-Pateurization under 50°/100°/80°/75°/
and 60°/74° -mean jelly content
6.43%

- " " 52°/74° -mean jelly content
5.41%

As especially large differences in the mean jelly content is observed between pasteurization carried out at 100°/80° and the remaining methods /4.23% and more/, the difference between the remaining methods 1-1.5%

The influence of the pasteurization method on the degree at which the ham is cooked.

Independently of the problem of the quantity of jelly pasteurization must necessarily cause a denaturation of the meat tissue to a degree which will provide an adequately cooked product, typical for a canned preserve.

It is assumed-as it has been mentioned in the first part of the present paper-that the ham is cooked to a sufficient degree if its interior is exposed for more than 30 minutes to a temperature exceeding 63°C.

The Coretti test was chosen for ascertaining the degree in which hams pasteurized under different methods are cooked. Two hams were submitted to the test from each repetition of the particular versions of the pasteurizing process. Results are presented on Table VIII.

The result /-/ indicates a complete lack of turbidity, what means that the sample remained for at least 30 minutes under a temperature of 63°C.

Results prove that all the pasteurization methods under investigatio correspond to the Coretti criterium in a positive manner i.e. that they indicate a degree of cooking, recognized as satisfactory by ham manufacturers from western countries. This is also confirmed by the development of the ham centre /diagrams 4-9/, where even under the most delicate pasteurization me-

thod the centre of the hams remained exposed for at least 65 minutes to a temperature exceeding 63°C.

Influence of pasteurization method upon the sensoric quality of the product.

A sensoric analysis of hams pasteurized under different methods was carried out for the purpose of estimating the influence of the particular method of the organoleptic properties of the product.The particular quality components were analysed such as colour,bounding succulence,tenderness,flavour and saltiness /by the score method mentioned before-see Table II/.

Three to four pairs of hams were analysed for each method.The quality of each ham was analysed twice by a group of five persons.

Results assembled on Table IX prove that no significant differences occur in the organoleptic quality of the hams,according to the applied pasteurization method,with the exception of differences appearing in their succulency and bounding,which are far better in hams pasteurized under slower methods than in hams subjected to pasteurization under method 100°/80°.

It must be noted here that considerable individual variations in the quality of the particular pairs of hams are due to that of the raw material.

The influence of these particular variations of quality is far larger than the influence of the particular pasteurization method; the quality of the pairs of hams,despite applying different pasteurization methods is very similar,whereas considerable differences are noted between the individual pairs.

Final remarks.

The analysis of pasteurization processes carried out under different systems of temperatures proves that

it is possible to express numerically and accurately the influence exercized by the particular components of the pasteurization process i.e. temperature increase rate, period during which the interior of the ham is exposed to a temperature exceeding 63°C, maximum temperature attained by central part of the ham and the maximum differences between the temperatures occuring in the ham centre and its superficial layers influencing the quantity of thermal efflux.

These magnitudes allow to characterize accurately the pasteurization methods and to explain the resulting differences in jelly content obtained under each of them and form a basis for employing such pasteurization conditions, which result in a stipulated quality of hams. similarly as it happens by chilling or deep-freezing of meat.

Computed coefficients of regression indicate taht the higher efficiency of method 100°/72° in relation to the method 100°/80° in view of jelly content reaches an average of 4 per cent of net weight of the can contents, what is more than 50 per cent in relation to the mean quantity of the contents under the 100°/80° methods and consists mainly on the lowering of the maximum temperature attained by the inside portion of the canned ham from 78° to 60° and also on diminishing the temperature increase rate from $\frac{0.234°C}{min.}$ to $\frac{0.190°C}{min.}$ and in diminishing the maximum difference between the temperatures of the superficial layers in relation to those of the internal portion of the canned ham from 32° to 20-22°C.

A comparison of the effectiveness of the particular pasteurization methods subject to investigation also proves that it is also possible to reduce thermal samage of muscular tissue proteins during pasteu-

rization and what follows to further limit the jelly contents, it still being possible to obtain an entirely satisfactory product with regard to the degree of cooking, bounding and other organoleptic properties.

Conclusions.

I. The following pasteurization parameters have a significant influence upon the jelly contents:

1. temperature increase rate during the initial heating period up to 63° C

$$\left(p \frac{^{\circ}C}{min.}\right)$$

2. time while the ham centre is exposed to a temperature exceeding 63° C

$$t_T > 63^{\circ} \quad min$$

3. maximum temperature attained by the ham centre

$$\left(T_c \text{ max.} \quad ^{\circ}C\right)$$

4. maximum difference between temperatures in the ham centre and the superficial layers

$$\left[\left(T_{ext.} - T_c\right) \text{ max.} \quad ^{\circ}C\right]$$

II. The magnitude of the influence of the consecutive parameters on the jelly content is determined by the following regression coefficients:

a/ regression coeff. a_1 /for 0.0 p/ = 0.7% of jelly
b/ " " a_2 /for $t_T > 63^{\circ}$/ = 0.11% "
c/ " " a_3 /for T_c max./ = 0.94% "
d/ " " a_4 /for $\left[\left(T_{ext.} - T_c\right) \text{max.}\right]$ = 0.39% "

III. The successiveness of the six pasteurization methods with regard to the mean content of the jelly is the following:

1. Method 100°/80° ..... 13.51 %
2. " 100°/72° ..... 9.28 %
3. " 68°/74° ..... 8.02 %

4. Method $80^{\circ}/100^{\circ}/80^{\circ}/75^{\circ}$ 6,52%
5. " $60^{\circ}/74^{\circ}$ 6,43%
6. " $52^{\circ}/74^{\circ}$ 5,41%

With the exception of method 4 and 5 all the other ones distinctly differ from each other by the quality of jelly at the significance of confidence =0.01

IV. All the investigated methods of pasteurization fulfill the Coretti criterion i.e. they cause a sufficient degree of denaturation, typical for a pasteurized canned ham.

V. The organoleptic quality of the hams pasteurized under the six investigated methods does not show any distinct differences with regard to the particular method, with the exception of succulency and bounding, which are better in hams pasteurized under slower methods.

VI. The determined dependencies between the pasteurization parametres and the quality of the issuing product, especially with regard to the quantity of the jelly permit to control the pasteurization process for the purpose of obtaining optimum results.

Table I.

Temperatures and duration of the investigated pasteurization cycles.

Ord. Nr.	Methods	Parametetres of pasteurization	
		I period	II period
1.	Investigated methods 52/74	Temperatures / °C/ Time /minutes/	
		52 / 210	74 / 180
2.	68/74	68 / 180	74 / 160
3.	50/100/80/75	50 + 100 / 210 + 10	80+75 / 90+80
4.	60/74	60 / 150	74 / 210
5.	Comparative methods 100/80	100 / 20	80 / 310
6.	100/72	100 / 20	72 / 310

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Table II. Five point scoring system of canned hams.

Quality factors:	Scale 5	4	3	2	1
1. Superficial fat a/uniformity	distinctly uniform	uniform	middle uniform	ununiform	extremely ununiform
b/texture	very firm	firm	softish	very soft	greasy
2. Colour: a/uniformity	dist. uniform	average uniform	enough uniform	ununiform	extremely ununiform
b/desirability	very desirable	desirable	neutral	lightly undesirable	very undesirable
3. Intermuscular fat	quite meagre	lightly streaky	tangible streaky	evidently streaky	distinctly streaky
4. Bounding	complete	almost without splits	traces of splits and holes	visible splits and h.	great splits and holes
5. Odour: a/intensity	very intense	intense	slightly intense	perceptible	unperceptible
b/desirability	" desirable	desirable	neutral	lightly undesirable	very undesir.
6. Succulence	succulent	lightly succ.	slightly succ. or a little watery	slightly dry or watery	distinc. dry or distinctly watery
7. Tenderness	very tender	tender	lightly tough	tough	very tough
8. Flavour: a/intensity	very intense	intense	slightly intense	perceptible	imperceptible
b/desirability	" desirable	desirable	neutral	lightly undesirable	very undesirable
9. Saltiness	very mild	mild	distinctly perseptible	too salty or too slowly salty	very salty or quite unsalted

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TABLE III. *Characteristic of the various pasteurization methods.*

Method	Initial temper. of hams /°C/	1st heating period Time /min/	1st heating period p-°C/min.	2nd heating period Time /min/	2nd heating period p-°C/min.	Heating period to 63°C Mean increase temp. °C	Heating period to 63°C Means p-°C/min.	Time of duration of ham centre in 63°C t 63°C	Maxim Temper. obtained in ham c. t max.	Difference between exter. temp. and that of cen. t ext. -t int.	Total time of pasteurization
100/80	10	110	0,254	100	0,250	53	0,252	115	70		
	17	140	0,257	65	0,223	46	0,224	140	70	32	265 min.
100/72	10	150	0,273	110	0,109	53	0,204	105	68		
	17	140	0,228	100	0,140	46	0,192	145	68,5	20-22	330
68/74	11	160	0,212	130	0,138	52	0,179	85	66,5		
	18	160	0,181	120	0,133	45	0,160	115	67	23	340
52/74	11	260	0,138	110	0,133	52	0,137	60	65,5		
	16	300	0,107	110	0,136	47	0,115	60	65	12	390
50/100/80/75	13	240	0,133	110	0,164	50	0,143	70	66		
	16	220	0,161	145	0,143	47	0,129	65	65	13	390
60/74	16	200	0,145	120	0,147	47	0,146	90	67		
	18	190	0,150	130	0,130	35	0,140	95	68	15	360 minutes

TABLE IV.

Correlation between independent variables x_1-x_4 and quantity of jelly in ham.

for	Degrees of freedom V=n-2	Theoretical coefficient of correlation "r" for 0,99 probability level	Empirical coefficient of correlation "r"
x_1	20	0,537	0,819
x_2	22	0,515	0,885
x_3	22	0,515	0,675
x_4	22	0,515	0,810

TABLE VI.

Analysis of variance.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F empiric.	F theore.	Significance
Methods	977,22	5	195,44400	26,77	2,27	+
Error	1204,63	165	7,3007	-	-	
Total	2181,85	170	-	-	-	

TABLE V. Influence of various pasteurization methods upon the thermal efflux content/ μ of jelly/

Different pasteurization methods	$\bar{x}$ mean	difference of means	$S_{\bar{x}}$ mean error of mean arit.	t	degrees of freedom	Significance of differences
100/72	10,20					
100/80	13,74	3,54	0,501	6,93	15	statistically highly significant
68/74	8,79					
100/72	9,55	0,76	0,666	1,14	12	statistically unsignificant
52/72	5,38					
100/72	8,21	2,83	0,384	7,35	17	difference statistically highly significant
50/100/80/75	6,52					
100/72	8,23	1,71	0,658	2,60	9	difference statistically significant
60/74	6,43					
100/72	8,74	2,36	0,278	8,5	19	difference statistically highly significant

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TABLE VII.

Difference in the jelly content in products under the investigated pasteurization methods.

method	method $\bar{x}_1$	5 13,51	6 9,28	2 8,02	3 6,52	4 6,43	1 5,41
5 13,51		-	4,43/+/	5,49/+/	6,99/+/	7,08/+/	7,11/+/
6 9,28		0,567	-	1,26/+/	2,76/+/	2,85/+/	2,17/+/
2 8,02		0,886	0,811	-	1,50/+/	1,59/+/	2,38/+/
3 6,52		0,770	0,900	1,137	-	0,09/-/	1,11/-/
4 6,43		0,978	0,675	0,962	1,051	-	1,02/+/
1 5,41		0,797	0,708	0,983	1,064	0,878	-

$\bar{x}_1$

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TABLE VIII.

The influence of the pasteurization method on the degree at which the ham is cooked /definite by the Coretti method/

Method	Nr sample of ham	Result	Method	Nr sample of ham	Result
100/80	6	-	100/72	5	-
	8	-		7	-
	14	-		13	-
	15	-		16	-
	28	-		27	-
	30	-		29	-
68/74	44	-	52/74	37	±
	56	-		39	±
	69	-		2/60	-
	71	-		4/60	-
				6/10	-
				10/60	-
50/100/80/75	61	-	60/74	28/60	-
	63	-		30/60	-
	65	-		63/60	-
	67	-		65/60	-

TABLE IX. Sensoric quality of hams pasteurized under various methods.

Quality factors	Compared methods															
	100/80-100/72				100/72-68/74				100/72-52/74				100/72-50/100-80/75			
	Number of hams				Number of hams				Number of hams				Number of hams			
	1	1a	1	1a	1	1a	1	1a	1	1a	1	1a	1	1a	1	1a
1.Colour :																
a/uniformity	3,2[x]	3,2	3,6	3,6	3,6	3,4	4,1	4,0	3,5	3,6	4,0	3,9	3,1	3,0	3,5	3,2
b/desirability	4,0	4,0	3,9	4,0	4,1	4,2	4,2	4,2	3,8	3,9	3,7	4,0	3,8	3,8	4,0	4,1
2.Intermus-cular fat	2,0	2,0	3,0	3,1	3,3	3,5	2,5	2,7	3,5	3,4	2,8	2,9	2,5	2,7	3,6	3,8
3.Bounding	1,2	2,1	1,5	2,7	2,5	2,8	2,9	2,8	2,3	3,0	2,5	3,2	2,2	3,1	2,4	3,5
4.Odour:																
a/intensity	5,0	4,8	4,6	4,5	4,5	4,3	4,0	3,9	4,5	4,4	4,2	4,4	4,1	3,9	4,0	4,3
b/desirabil.	4,0	4,5	4,2	4,5	4,3	4,5	4,0	4,1	4,0	4,5	4,3	4,1	4,0	3,9	3,9	4,2
5.Succulence	3,1	4,0	3,0	3,9	3,8	3,7	4,0	4,1	3,9	4,1	4,0	4,2	3,8	4,0	4,0	4,4
6.Tenderness	3,5	4,2	4,0	4,2	4,0	4,1	4,0	4,0	3,9	4,0	3,8	3,8	4,0	4,1	4,2	4,1
7. Flavour:																
a/intensity	4,2	4,1	4,1	4,1	3,9	3,9	4,1	4,2	4,1	4,0	3,9	4,1	4,0	4,2	4,0	3,9
b/desirability	4,2	4,5	4,3	4,4	4,3	4,2	4,2	4,2	4,0	4,2	4,2	4,3	4,1	4,1	4,0	4,0
8. Saltiness	4,0	4,0	4,1	3,9	4,0	3,9	4,0	3,9	3,5	3,6	4,0	4,2	4,4	4,0	3,8	3,7

x/ mean of [redacted] 10 individual scores.

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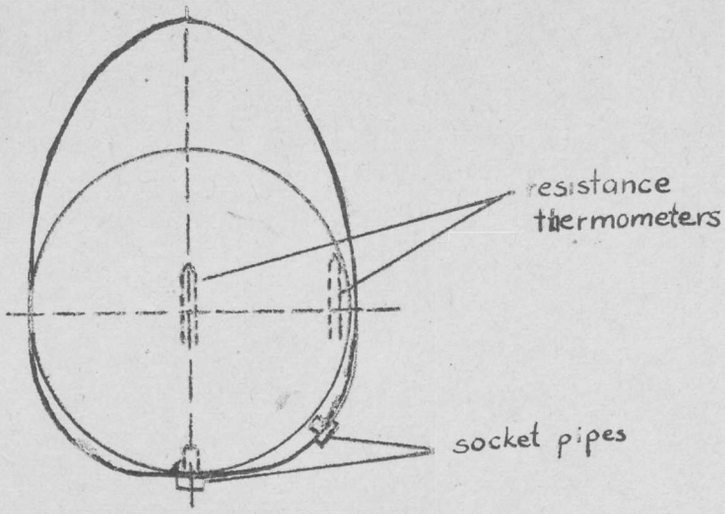


Fig. 1

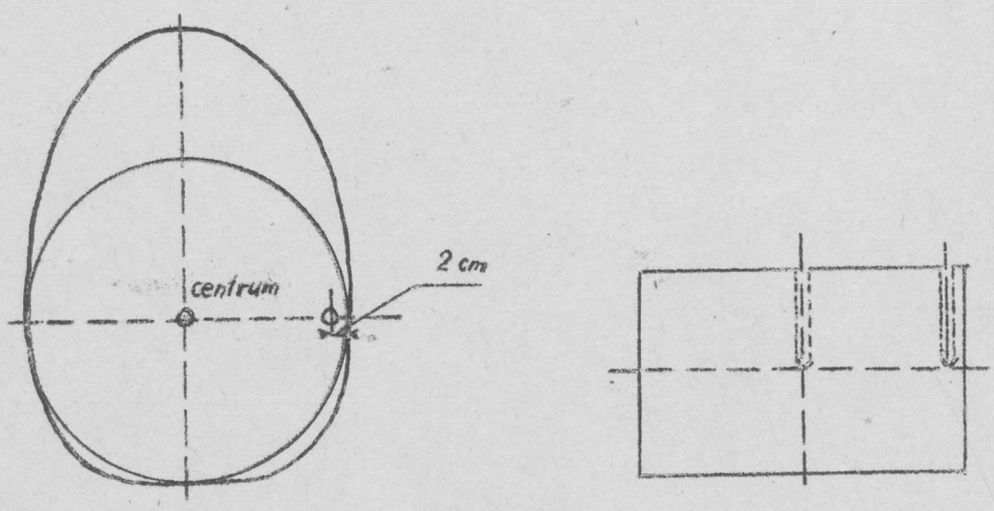


Fig. 2.

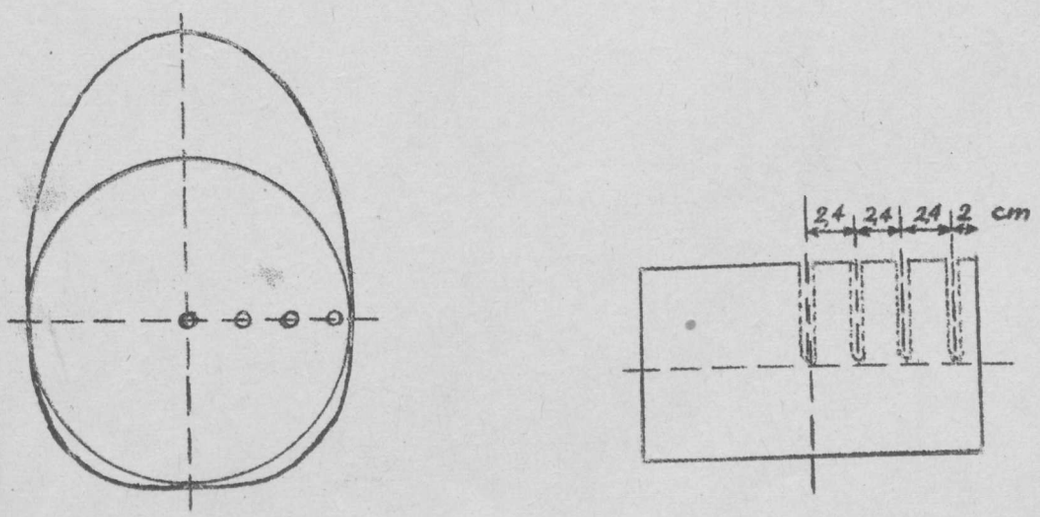
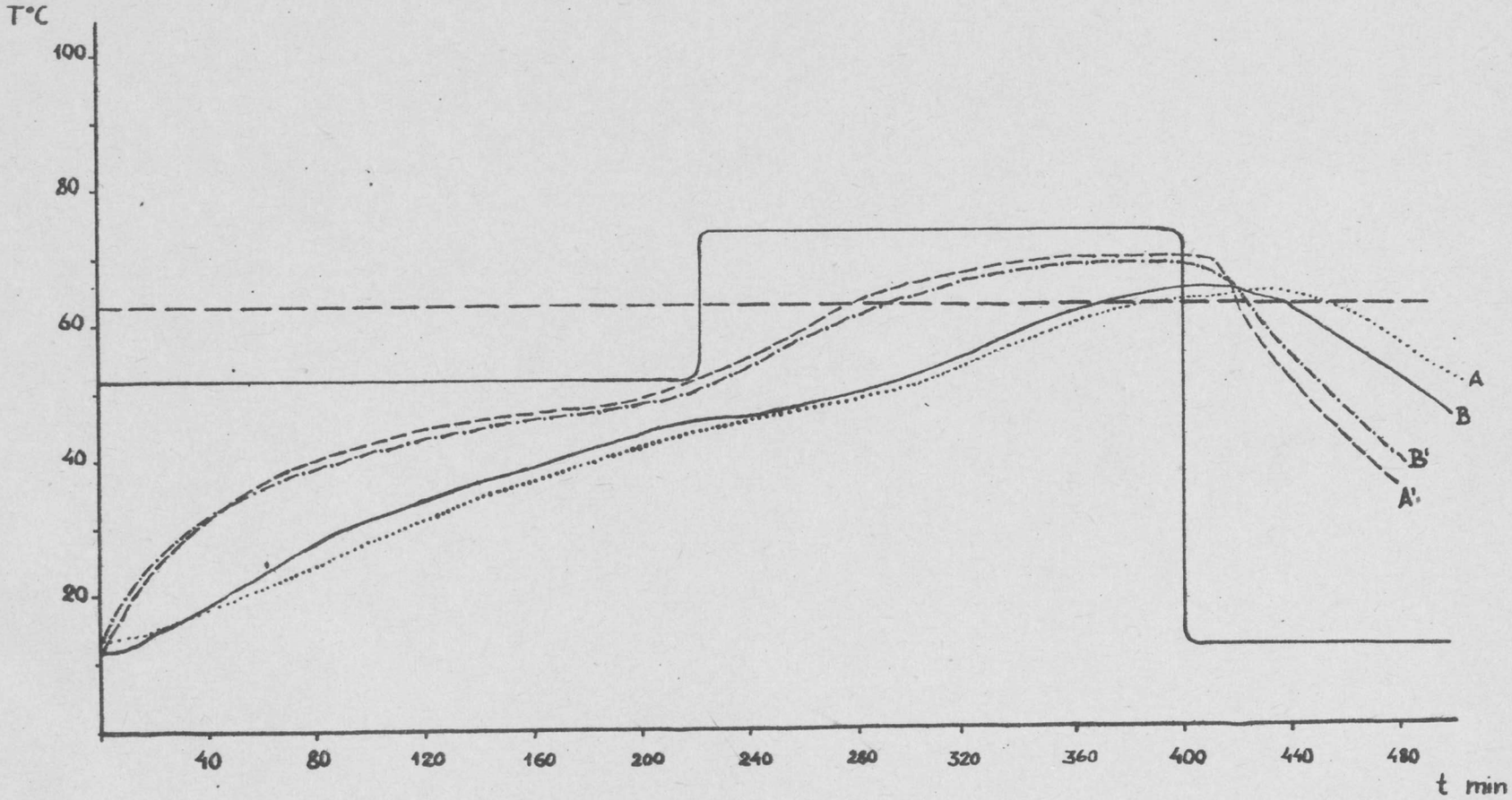


Fig. 3.

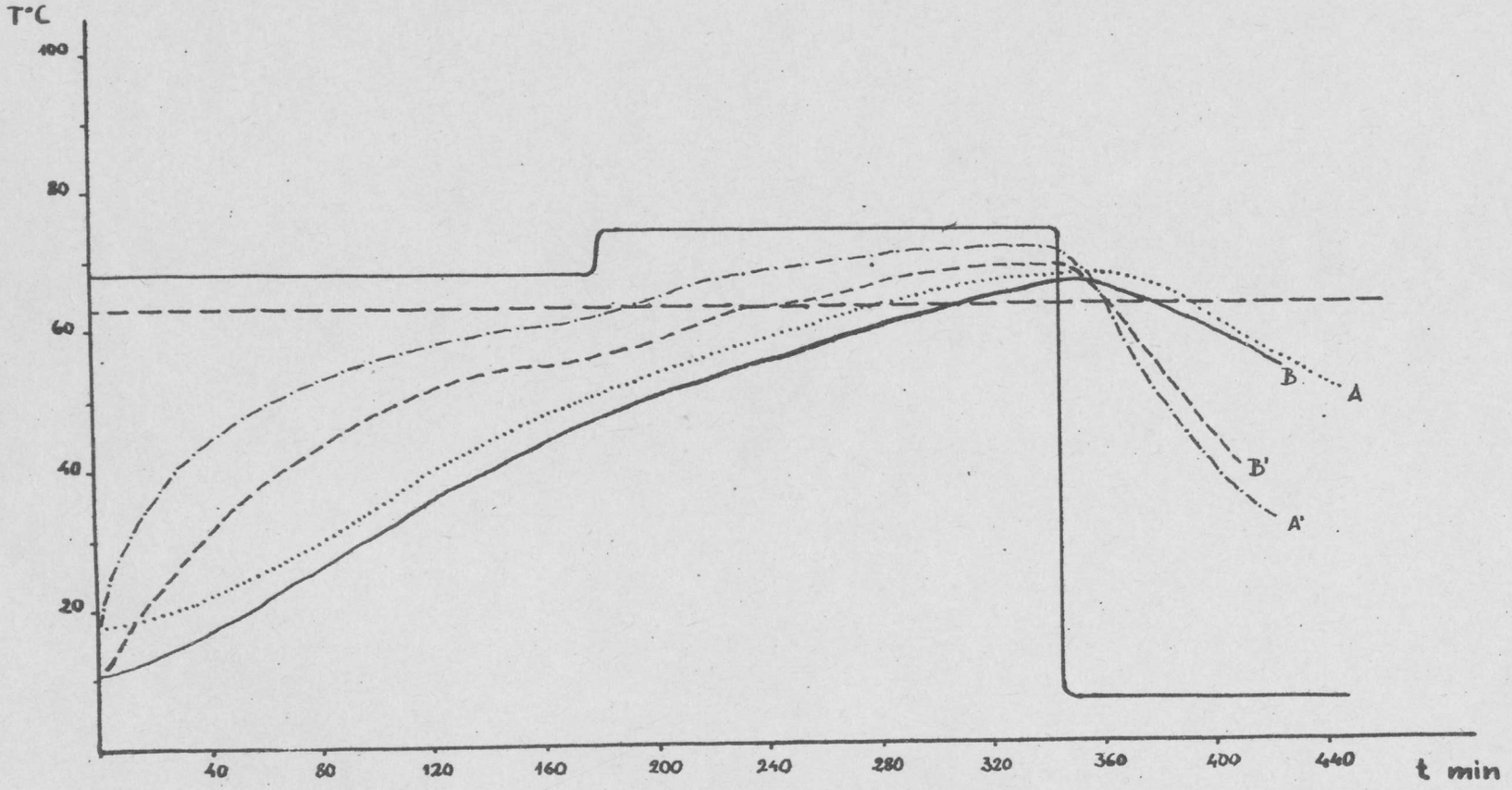
Pasterizacija 52/74



R60

Rys. 5.

Pasteryzator 68/74



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261

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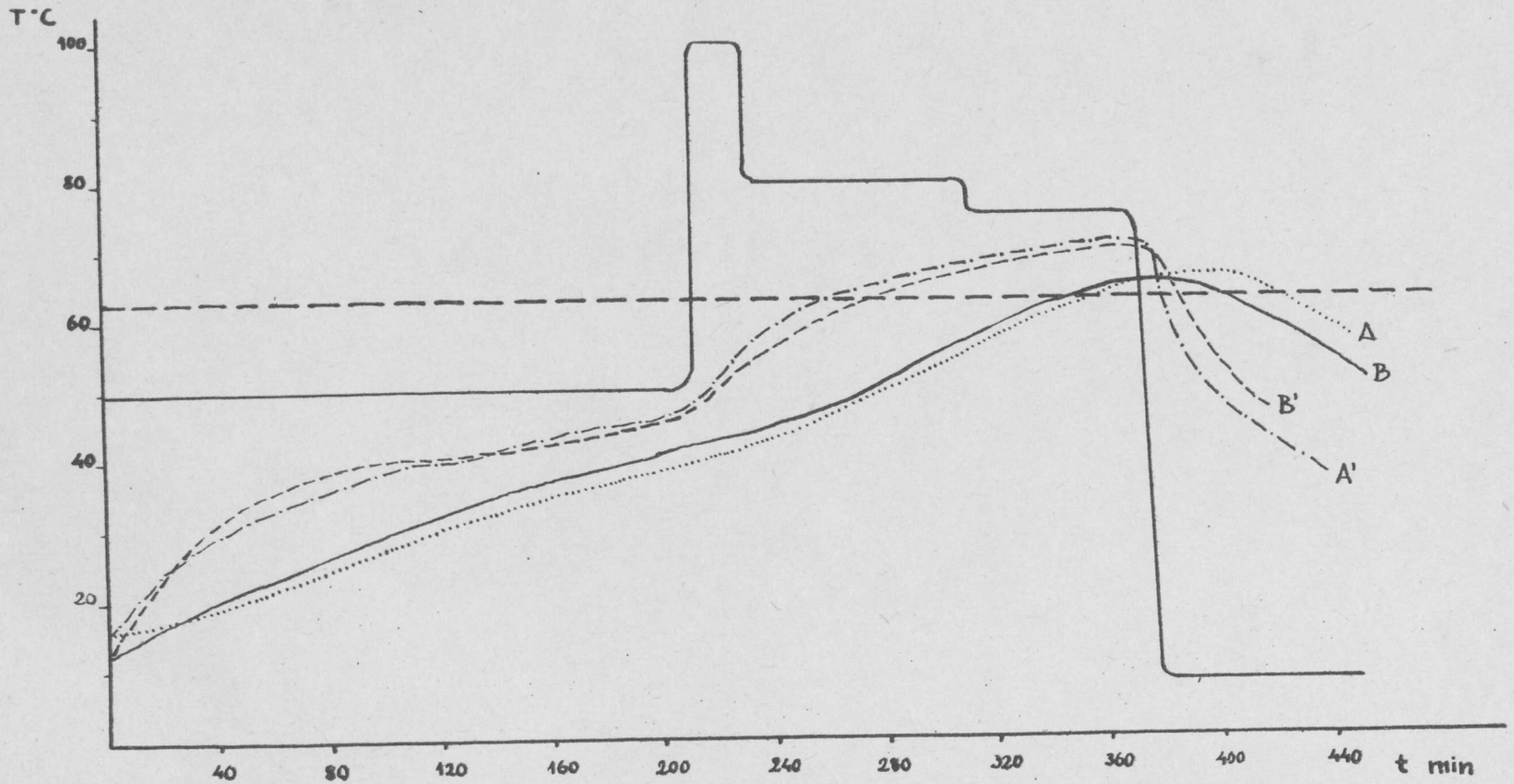

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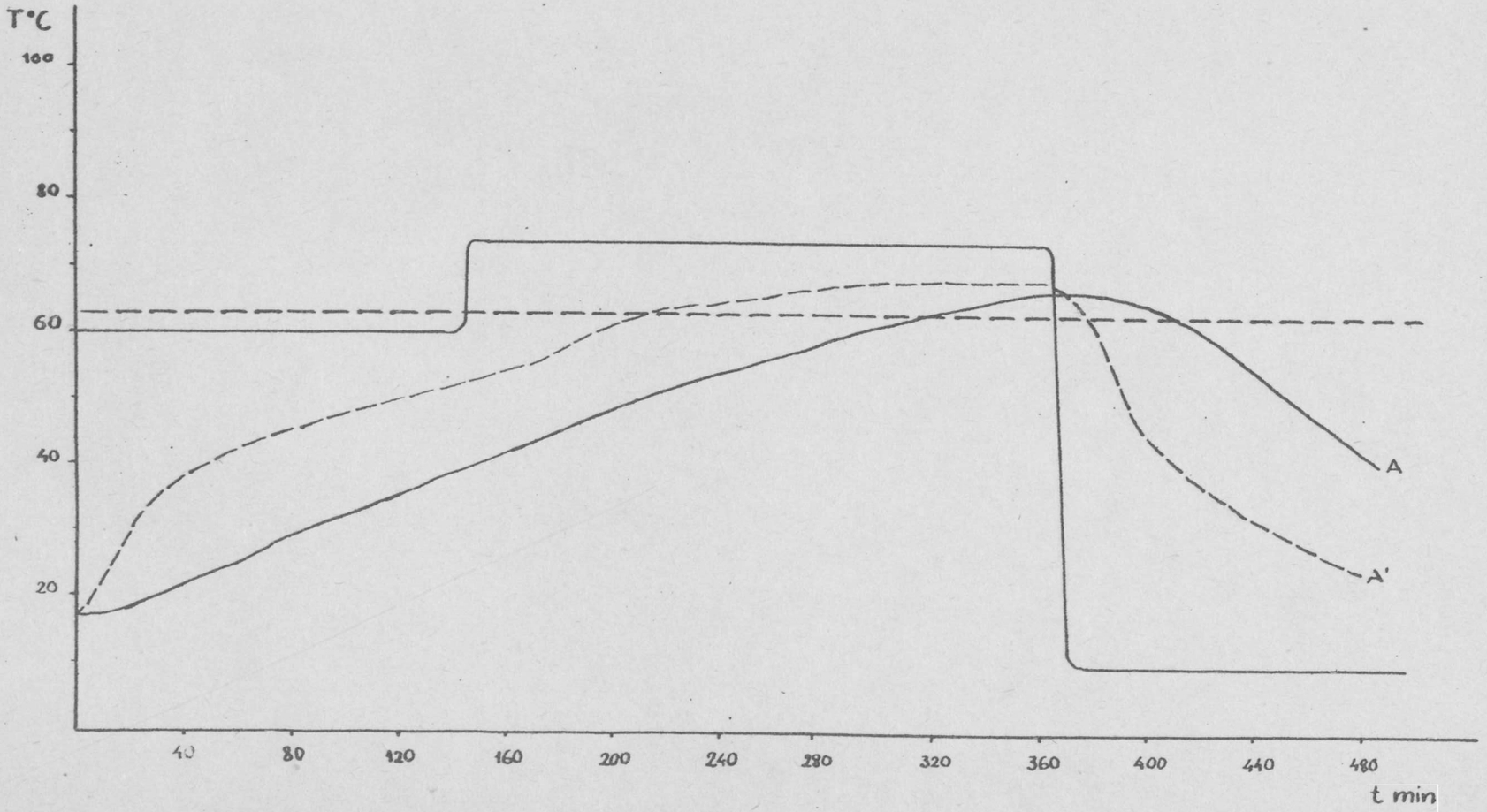
Rys. 7



263

Rys. 8

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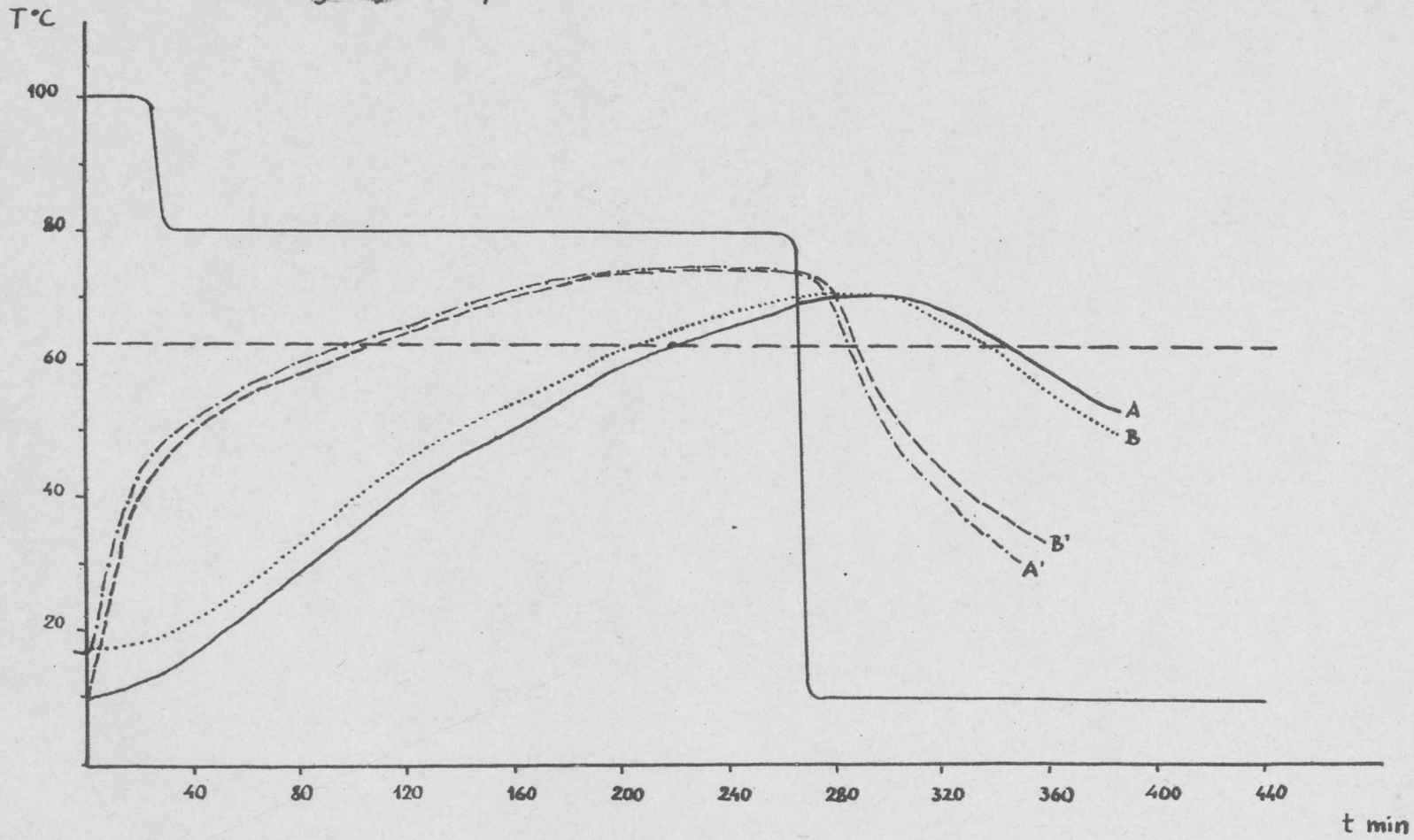
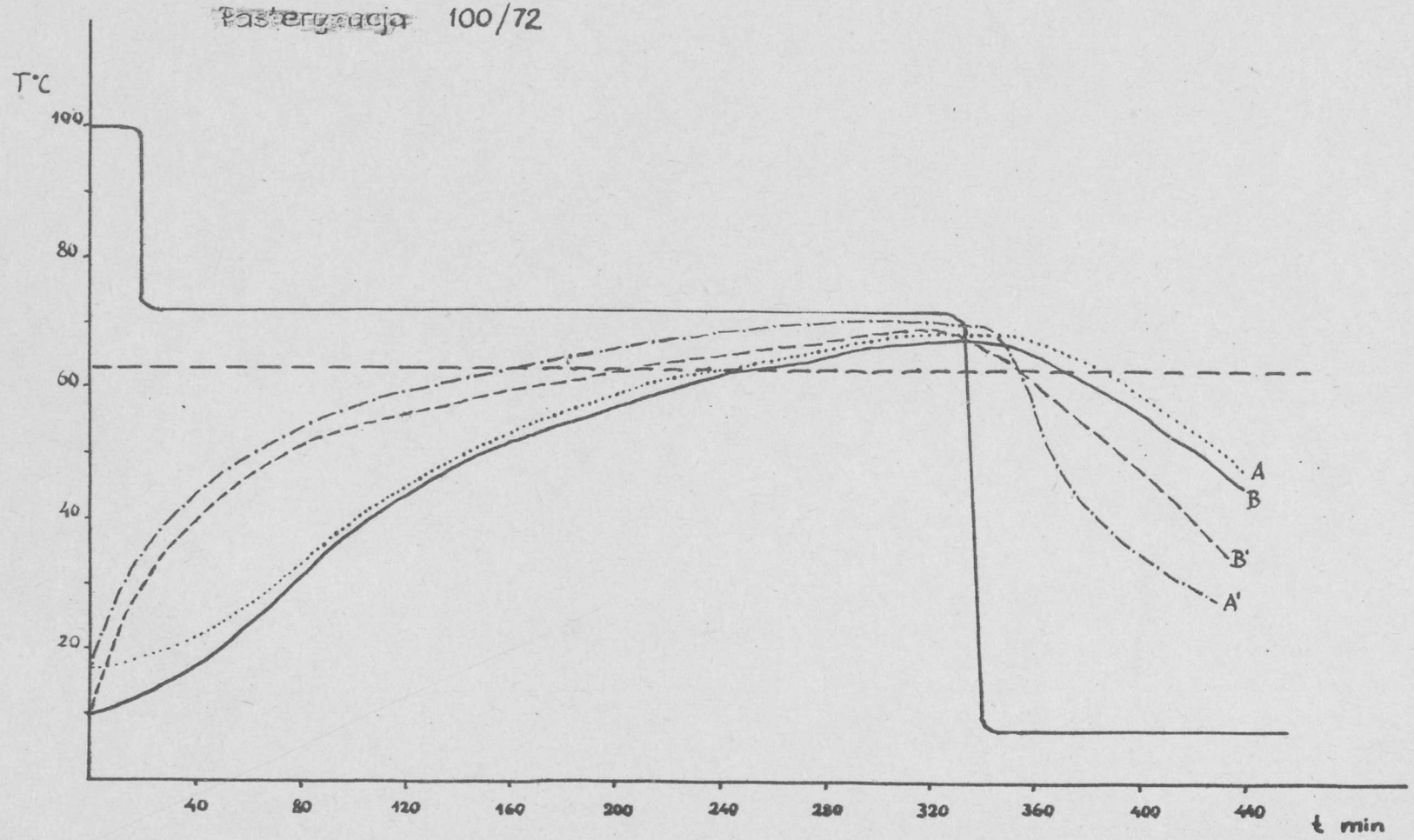


264

Rys. 9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T°C
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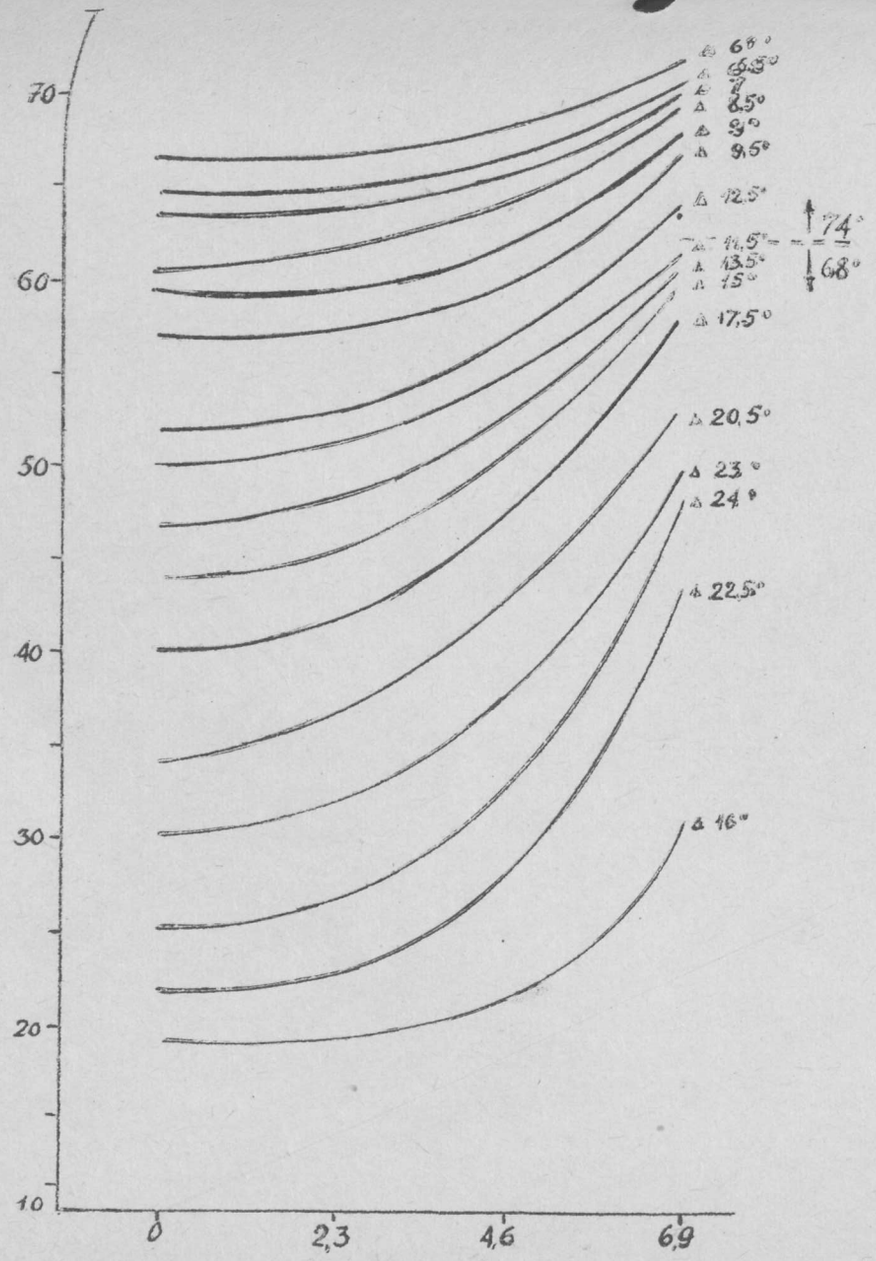

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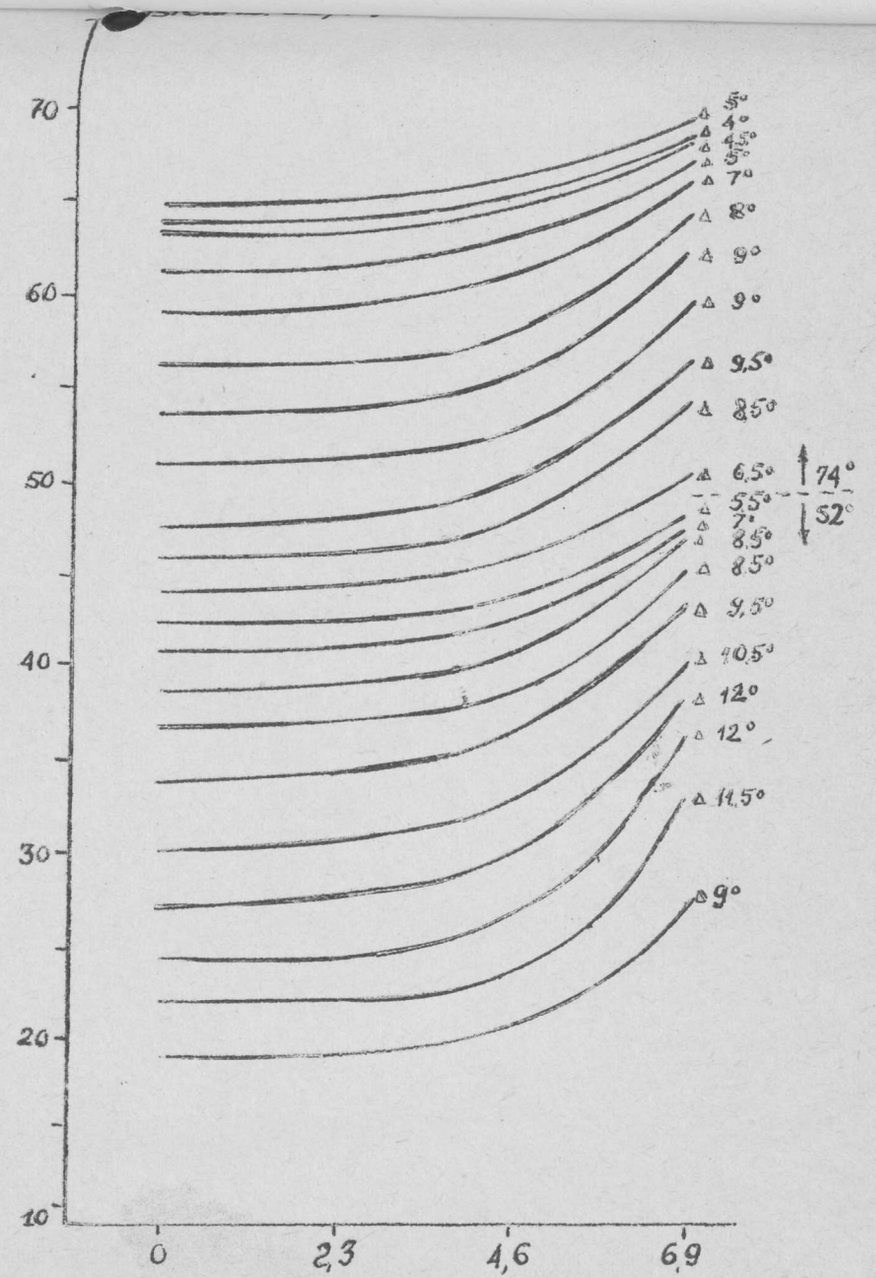
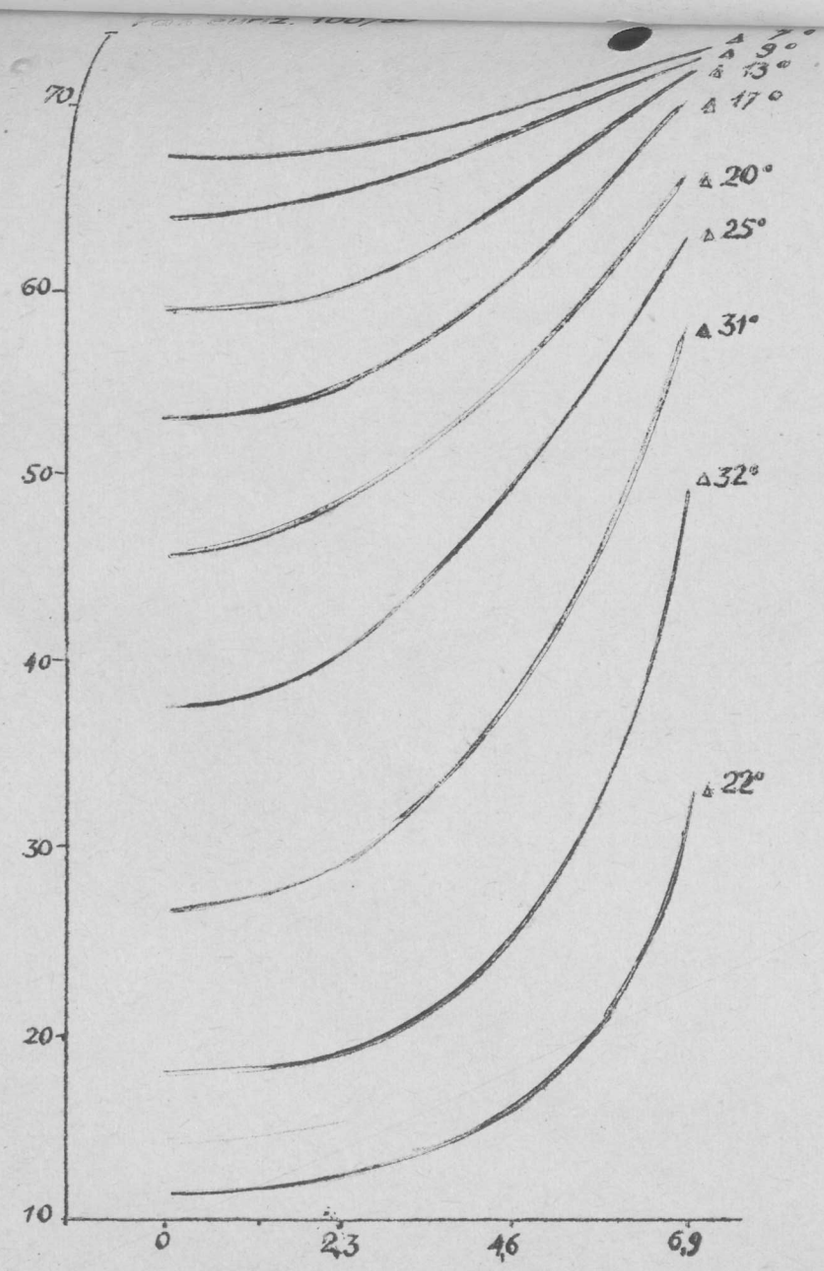


Fig. 11.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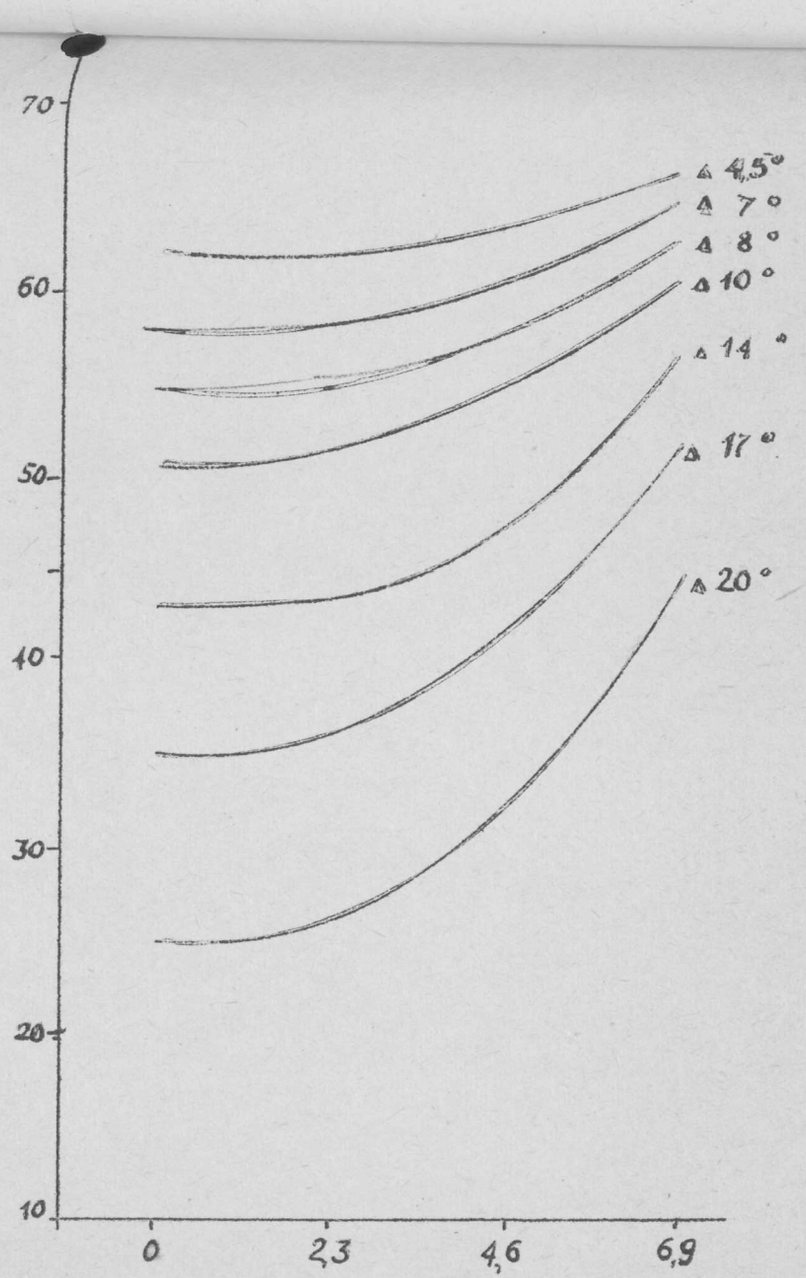
Δ 25°
Δ 31°
Δ 32°
Δ 22°

Fig 12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Δ 7°
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Δ 14°
Δ 17°
Δ 20°

Fig. 13.

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