PhD THESIS

UNIVERSITY OF KAPOSVÁR
FACULTY OF ECONOMIC SCIENCES
Department of Mathematics and Physics

Head of Doctoral School
PROF. DR. GÁBOR UDOVECZ
Doctor of the Hungarian Academy of Sciences

Supervisor
DR. GYÖNGYI BÁNKUTI PhD
Associate Professor

Associate Supervisor
DR. habil. BÉLA CSUKÁS CSc
Associate Professor

SOLVING COST MANAGEMENT, ORGANIZATIONAL AND QUALITY PRESERVATION TASKS ON THE EXAMPLE OF AN AUTOCLAVING CANNING COMPANY

Made by
ZOLTÁN FABULYA

KAPOSVÁR
2010

1. RESEARCH PRELIMINARIES, OBJECTIVES

To increase quality is the primary aspect in food industrial researches. It is the most important aim to lessen the degree of conservation in food processing otherwise the food cannot preserve its original qualities, consuming and nutritional values. Furthermore, consumers claim the possibility to prepare their food more quickly, the safe and hygienic application, longer shelf-life, the constant and checked quality, the usability on wider scale and the solution of unexpected situations. All of them could be utilized by preserved food-makers but for this they have to employ modern work organization which follows the expectations of our time.

Heat-treatment is used to prevent the microbiological danger thus it makes longer conservation-time possible. However, in case of an over-guaranteed heat-treatment there is a deterioration of quality, since sensory features, substance, taste, smell of the food can suffer a serious loss (discolouration on the surface in case of liver pastes, liquid exudation and jelly precipitation in case of meat, transformation into puree etc.)

Heat-treatment of canned food, mainly in case of meat conserves, is a process which needs a lot of energy, since it involves sterilization, heat effect of long time span around 120 °C. In the meantime, the necessity to reduce utilization of natural energy resources appears as an important aspect.

It is worth involving engineering calculations, modelling, computer simulation in the research of this field, for the sake of the quality of products and expense-efficient production. A work organization should be formed which guarantees manufacture of products which are safe from microbiologal aspect; which keeps the regulations more precisely in the interest of higher quality and lower expenses. To do this there should be an informatic background which can provide the necessary assistance, on the basis of research results, to elaborate the suitable work organization. For this aim it provides the user-friendly operation surfaces, which fulfill the claims of our time, the simulating and optimizing technique, the predicting and problem solving services and the flexible enlargement possibilities.

The quality and rentability of preserved food (besides the quality of the basic materials, the good recipe, the features of the production belts) are determined by their heat-treatment and its organization. The production process which was not planned carefully can imply quality problems and considerable increase of expenses. To support work organization with computer has not been in practice in Hungary so far.

My main objective in case of technologies with an autoclave group is to elaborate a program system based on simulation which could help reduce the direct costs of heat-treatment and improve the quality of products. For this objective it is necessary to carry out further sub-tasks and examinations whose results should be utilized in the system:

- I examine the effect of scheduling on the product quality. At present heat-treatment of conserves coming from the production belt is done without a schedule in factories.
- My aim is to analyse with simulation the load-dependent efficiency graph of gas boiler which provides the necessary amount of steam and then to use the results to find the conditions of optimal operation and to calculate costs reduction arising from it.
- I examine the possibilities of costs reduction which are adaptable to the calculation method of how the special gas-fee in case of big consumers is accounted for.

- I form a database to provide the simulating, optimalizing and scheduling program with the necessary data.
- I elaborate a test program which can find and test the algorithm with optimizing function. The other aim is to give the suitable basis for factory adaption with manageable parametres. I develop the software components which can reveal and predict the problems of the weekly production plan.

2. MATERIAL AND METHOD

What basically determined the research and appeared in almost each element of the work was computer modelling. For this reason primarily I utilized the applied methods and techniques of this field from observation and data collection through details of modelling, programming, which often needed considerable creativity, up to the statistic methods of verification and validation of the model and finally, to the statistic processing of results coming from the experiments (simulation) carried out on the model.

Data utilized in the research work formed two groups. Chronologically the first one comes from the former Meat Industrial Company of Szekszárd (Szekszárdi Húsipari Vállalat) where we accomplished measurings to improve quality of heat-treatment effected on meat conserves. For this I developed a data collecting software. Thus, for this present research I had the necessary data in archive files to elaborate and verify the model, to develop the test simulating and optimizing program and finally, to find and test the scheduling algorithm, consequently, to elaborate the examination methods. I needed the other data group, which was provided by another company, for further examinations and research directions (optimization of costs, work organization).

For modelling and optimization with simulation I employed the microsoft Excel and Access 2003 programs both for development of the mentioned program with the built-in Visual Basic for Applications (VBA) service and for function insertion and statistic operations with Solver and Data Analysis functions available as the Excel complements.

During the research work, it was often necessary to accomplish function insertion, which is, to find for the computer model, which depends on parametres, the value combination of parametres where the results from the model precisely approximate the data from observation. For this, I applied the Solver complement of Excel spreadsheet program with the smallest square method. It means that in each cell we indicate the possible initial value of the parametres in question, and form a counting table which, in case of changes of parametres, automatically forms, within the cell, the square amount of difference of the related calculated (simulated) and known value pairs. Then, to operate Solver we set which the cells of the parametres in question, as altering cells, and the cell of square amount, as the value to minimalize, are.

For data analysis I needed the following:

- average
- standard deviation
- correlation
- linear regression
- two-pattern combined t-proof
- random number generator

I needed average and standard deviation to analyse the different model parametres of each shift given by Solver. I employed linear regression and correlation to determine the interconnection between the collected data and its closeness, and to check if the data are sufficient to model gas consumption. I applied two-pattern combined t-proof to verify and validate the models. I simulated boiler-load data of different dispersion with random number generator (Monte Carlo method) in order to be able to analyse the effect of uneven boiler-load on the expenses, on the basis of the results. The essence of the Monte Carlo method is that instead of the measured data we utilize their simulated (generated as random number) value on the input of the computer model, and we evaluate these results instead of the measured effect.

3. RESULTS

3.1. Effect of the lack of schedule on the quality of products

While determing the heat-treatment regulations and sterile-formula of a certain product, with examinations and calculations done in a laboratory environment, great attention is taken to decide which one is the most favourable among heat-treatments that are equivalent in the microbiological destruction, from the aspect of the quality of that product. Provided the heat-treatment of the factory practice did not conform to these regulations, in a serious case the product would not be appropriate for safety reasons, since the microbiological destruction of the necessary degree would not be achieved. Then, the product would get spoilt before its shelf-life having a harmful effect on the judgement of the whole company on the customers' side. In a lighter case of heat-treatment not comformed to the sterile-formula, the quality of the product derivates from the optimal in smaller or larger degree. For these reasons the autoclaves are provided with the suitable instruments and automation so that the heat-treatment process can be guaranteed according to the regulations without human intervention. In case of insufficient steam supply the automation cannot heat up the equipment within the time prescribed, and/or keep the temperature, and/or guarantee the cooling phase because of the lack of cooling water of necessary intensity. These problems arise because phases of heat-treatment processes of more intensive resource-demand running in parallel in more autoclaves meet each other. The task of automation is to guarantee, even in this case, the safety of the product, as the factor with primary priority.

At the beginning of heating the automation states how much the temperature should increase per minute. To do this it measures the initial temperature, then deducts it from the temperature given by the sterile-formula and then divides it by the prescribed time span of heating up. It aims at keeping the raise of temperature lineally with this rise. Failure due to the problems of steam supply cannot be solved by increasing this rise because the intensive increase in temperature is harmful to the quality of products. It means that the time span of the phase can be longer than what is prescribed but not shorter in the interest of the quality. The increasing heating up time results in a product of lower quality which shows a higher cooking equivalent (C-value) than what is prescribed but this quality is not as low as in case of a more intensive raise of temperature which results in surface heat-impairment.

We can start to keep the product heated when the necessary temperature has been reached and it cannot be shorter than what is prescribed even if the time span of heating up has been incresed. Of course, the time span of keeping heated can be shortened if the microbiological destruction is bigger than planned, during heating up, but to a smaller degree than time growth of heating up, while its exact degree can arise only from complex calculations which depend on temperature, too. It is so because it takes longer time to have the same destruction on lower temperature. However, because of the insufficient steam supply the time span of this phase can grow as much as long the prescribed temperature could not be kept.

At time of cooling there are not problems in connection with product safety, though regulation is done in different ways since the autoclave can accomplish cooling with water bath or with water spray, and either the inner temperature of the conserve (core temperature) or the temperature of the cooling environment (space temperature) is measured. With application of water bath the linear reduction of space temperature can be realized to the desired 40 °C, though restricting the rise of cooling analogically to the one in the phase of heating up. Thus, in this case the time span of cooling can increase. At cooling with spraying technique the space temperature is reduced at once, and the phase lasts to the prescribed time span or more until the core temperature is over 40°C. If the core temperature is not measured, the heat-treatment is finished at the prescribed time but perhaps with product of higher temperature.

It can be concluded so far that the automation guarantees the microbiological reliability of the product in case of insufficient energy resource supply but in this case, either with the growth of time spans of the phases or with products of higher temperature. These problems result in deviation of smaller-bigger degree from the optimal quality of the product determined in laboratory environment. If the product is of higher temperature for longer time, it is cooked more and it will have a lower quality (in serious cases it becomes puree, or changes colour etc.)

The only assumption remained to be proved is that the increased time spans of treatment really come from the fact that the parallel processes are not scheduled. For this, at the company which provided the data I chose all heat-treatment per a month of which I examined and chose the problematic ones. I examined all of them and I experienced in each case, without exception, that 3-4 more heat-treatment processes swere tarted with 5-10 minute-long difference in other autoclaves, too. It means that more phases with intensive steam demand manifested at the same time. Synchronizing the starting point of the parallel heat-treatment processes, the automation could guarantee the regulations prescribed in the sterile formula and thus manufacture of products of better quality. All in all, it is necessary to schedule the processes in the interest of higher quality.

3.2. Examination of costs due to the uneven boiler-load

3.2.1. Costs of regulations on gas fee payment

More significant part of the costs spent on heating gas is the expense of the utilized amount, the other is the one of the amount reserved for utilization. This latter one is compulsory for big consumers, they have to indicate, half a year earlier, the upper limit of the gas quantity employed per hour regarding the forthcoming year. However, if they exceed it even with an hour in a month, they have to pay a fairly high fine which is in direct proportion of the highest monthly excess:

extra charge = excess × specific reservation fee for a year and a half

Firstly, I examined the changes in monthly total expenditure as a function of the reserved quantity, in case of a constant, under-limit utilization. Figure 1 shows that 600 m³/h reserved amount, instead of 350, increases the costs from 10,1 million Fts only to 10,7 million. Thus, a more significant (almost the double) reserved quantity causes only an insignificant growth (less than 10%) in the total expenditure. The figure shows a break because in case of reservation over 500 m³/h, the actually utilized amount has a lower standard price, while the rise does not change because the standard price of the reserved amount remains the same.

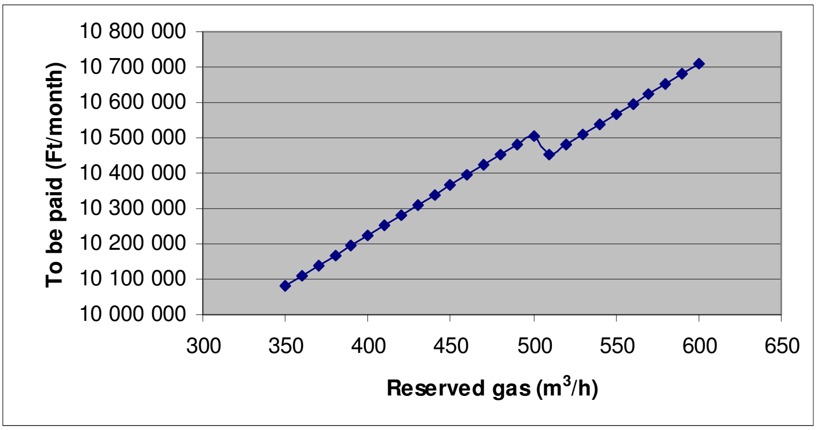


Figure 1. Monthly gas bill as a function of the reserved gas amount with constant utilization

Secondly, I examined the changes of the fine in case of the limit excess, as a function of the degree of this excess. The diagram in Figure2 shows that in case of the totally constant utilization but with uneven boiler-load, if we exceeded the limit only with an hour in a month, how much extra charge it would result in as a function of the excess degree.

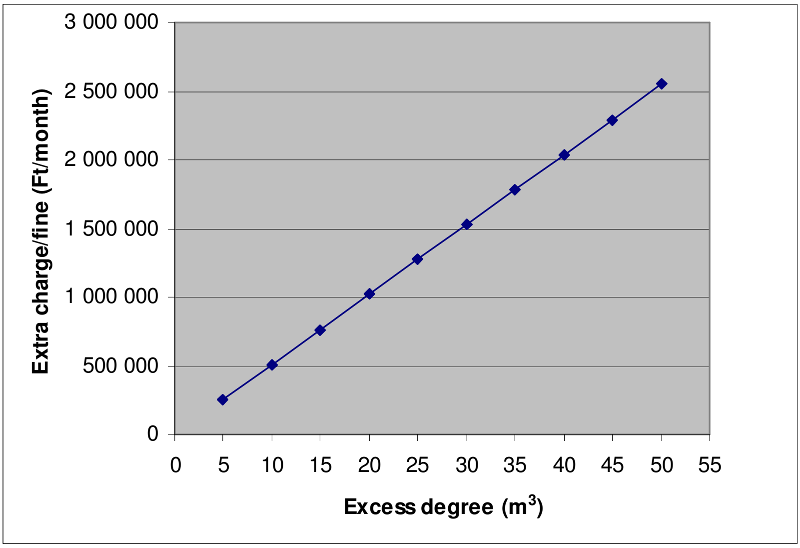


Figure 2. The sum of the extra charge as a function of the excess degree

3.2.2. Analyis of the load-efficiency graph of the boiler

The diagram (Figure 3) which shows the section with a critical, more intensive change in efficiency of the graph, necessary for the examination, was available in documentation of the boiler of the company which provided me with the data. It has a text complement which says that the efficiency continuously increases over the load of 50% and it reaches 90% at the load of 100%. The efficiency on the vertical ordinate of the figure means that how many percentages of the heat amount calculable from the gas amount utilized to heat up the boiler is found in the heat-energy of the steam coming out of the boiler. It means that in case of lower efficiency, the heat-energy necessary for heat-treatment can be provided only by fuel gas of bigger amount. In the figure on the horizontal ordinate the percentage of the boiler- load shows that how many percentages of the heat amount, which can be maximally guaranteed in the unit of time, and which comes out in the form of steam, the boiler is loaded with.

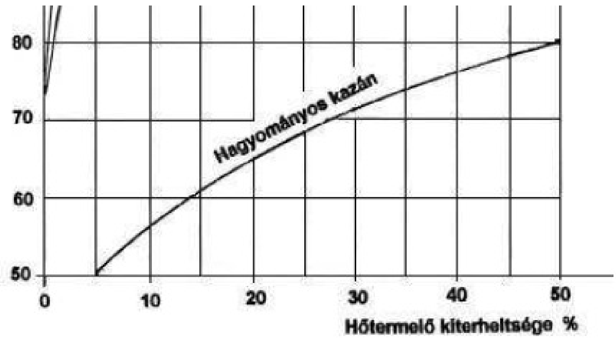


Figure 3. The efficiency of the boiler as a function of loading
(source: documentation of the boiler of the company)

According to my assumption, the boiler-load which is constant in time guarantees the possible maximum average efficiency, while loads of bigger fluctuation and deviation result in lower average efficiency with the same average load, namely with heat-treatment of products of the same quantity.

To get the efficiency automatically for the given load I needed the function of mathematical form which defines the graph. Thus, I aimed to find a function which attaches the efficiency values shown by the chart to the values of [0, 1] interval (corresponds to the [0%, 100%] load domain). I chose the $f(x)=x^n$ power function with exponents between 0 and 1 which adjusts itself to the nature of the graph. It was necessary to dislocate the function downwards (transformation) by 10%, so it is regarded as a parametre to find the precise value. All in all, the function which shows the connection between load and efficiency is the following:

$$y = f(x) = x^n - d, \tag{1}$$

where:

- x – load,
- y – efficiency,
- n, d – parametres in demand.

I used the Solver complement of the Excel program to find the values of the parametres, applying the smallest squares method. Thus, I had the following function:

$$y = f(x) = x^{0,2} - 0,09. \qquad (2)$$

The chart formed, on the basis of the known data, on effeciency and the function used as its model (Figure 4) showed that there is no need to examine the statistic congruency of the two data series. By means of the function, the efficiency can be calculated to the load of any values.

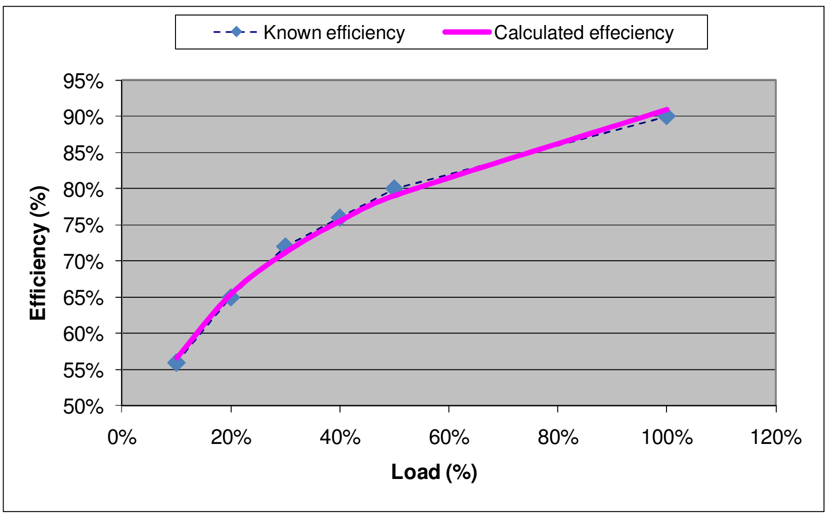


Figure 4. Graphs of known and calculated efficiency as a function of loading

During analysis I tried to find out what efficiency of average value the boiler loads of a given average value but of different deviation, dispersion result in (Table 1). It can be calculated from this that the heat-treatment of the given amount of products can be guaranteed by what degree of efficiency and thus, by what gas consumption depending on the eveness of loading. The relative loss of efficiency shows that what loss can be experienced in percentage with the given average load, as compared to the maximum available efficiency. Dispersion of load means the value domain the boiler load moves in.

Table 1. Analysis of the boiler efficiency with different loads

Average load	Dispersion of load	Average efficiency	Relative loss of efficiency
70%	70%-70%	84,11%	0,0%
	65%-75%	84,06%	0,1%
	40%-100%	82,66%	1,8%
50%	50%-50%	78,06%	0,0%
	30%-70%	75,83%	2,9%
	20%-80%	75,39%	3,5%
	10%-90%	74,39%	4,9%
30%	30%-30%	69,60%	0,0%
	10%-50%	65,58%	6,1%

To generalize the data of boiler loads in percentage the average values possible in practice and their approximate dispersion were taken into consideration. The average of the boiler load per year is around 50%. One of the main reasons for uneven load is seasonality when certain products need heat-treatment with a fairly big deviation. Of course, in this case there is no posibility to balance the load. The other, a more important case from the aspect of my research, is when different products are made at the same time which need different loading, and it is not taken into consideration while scheduling the production, as I have experienced in the present practice. In this case, for example, instead of the average load of 50% per shift it is typical that average loads of 30% and 70% can be experienced in successive shifts. Nevertheless, there can be big deviations within a given shift when the heat-treatments in parallel autoclaves are not scheduled.

Consequently, dispersion of loads is on a very large scale but it cannot be regarded as a normal one, for example. For this reason, I generalized a data series of even dispersion between different limits which is typical to the uneveness of loading. I determined the average of the efficiencies arising from it and the relative deviation in relation to the balanced position. This relative loss of efficiency is the loss of gas consumption of the boiler, too.

During examination at each efficiency of 30, 50 and 70% I examined that how much the standard deviation effects the efficiency. The last column of Table 1 shows that how much the relative deviation of efficiency and thus, the costs are from the case which can be maximally attained without the standard deviation, in case of the given average load.

It can be seen from the results that in parallel with the growth of uneveness of load the loss increases, too. With smaller average loads the equalization of load has greater importance since in this case the relative loss can reach 6%. With the load of 50% which can be regarded as the annual average there was almost 5% loss in the worst case which means the additional expenditure of 5 million Fts if the annual gas fee is 100 million Fts.

3.3. Reduction of costs with scheduling the production

Companies make a production plan for the forthcoming period in a certain frequency. At the company I carried out my researches at the production plan for the following week is elaborated on a weekly basis the most important element of which is to decide which products should be made in each shift. They have more production belts and it is product-dependent which product which belt can be made on. More products can be manufactured on the same belt, if the size of the can makes it possible, but only one of them can be made in one shift because of the loss of time due to refitting the belt. The weekly plan does not contain which product should be made on which belt because the product clearly determines the belt. However, the plan can have a mistake here since product bump can be experienced on the belts, in spite of the fact that different products are set in a shift. At present, the plan and the data from it are not checked with a computer, thus a problem of this latter kind can happen easily due to the human inadvertence.

The planning mistake that cannot be predicted easily is when products are made in parallel on different belts whose heat-treatment claim great capacity even separately and thus altogether they exceed the limit arising from the number of autoclaves. What is more, this mistake becomes clear only when the products arrive at the heat-treatment unit from the production belt and they form a waiting line which continuously grows. However, a strict regulation prescribes how long the maximum waiting time may be before heat-treatment. If it cannot be kept, a temporary cooling storage should be guaranteed, otherwise the germ number can considerably increase. For security reasons these conditions are calculated in the sterile formula but a germ activity over the level can imply explosion of conserves. It would not happen in the waiting line of some hours but after heat-treatment during the compulsory quarantine storage which lasts for a week or two, or in worse case, in the customers home, because the sterile formula was not determined according to the initial germ number which increased. The financial loss is significant because in this case the whole portion for heat-treatment (about 1 ton) or might as well, the total amount produced in the shift is endangered, so after a laboratory test it needs either further heat-treatment or it is destroyed.

Manufacture of products planned for each shift can cause great deviations in the boiler load, though it is not experienced in the costs so strongly as the above mentioned problem. For this reason, the present practice is not aware of it or the companies neglect it in the lack of calculations and/or because of the complexity of the management of this problem. I have detailed its effect on the costs in a previous part of my thesis.

3.4. System development for a company

3.4.1. Preparation and analysis of data

It was questionable if I had the sufficient amount of data for modelling, so it was necessary to examine the data available, and streams of materials and resources (Figure 5) in details. The conserves not treated arrive at the heat-treatment unit from more production belts in different schedule. Different products are made in each belt, so different regulations on heat-treatment concern them. Heat-treatment is guaranteed by more autoclaves. The heat-treatment process starts in an equipment when it is completely filled with products of the same heat-treatment regulation. Thus, the minimum specific cost can be guaranteed. The heat-treatment equipments are provided with the necessary steam supply by a gas-heated boiler whose other task is to heat the buildings and offices in winter.

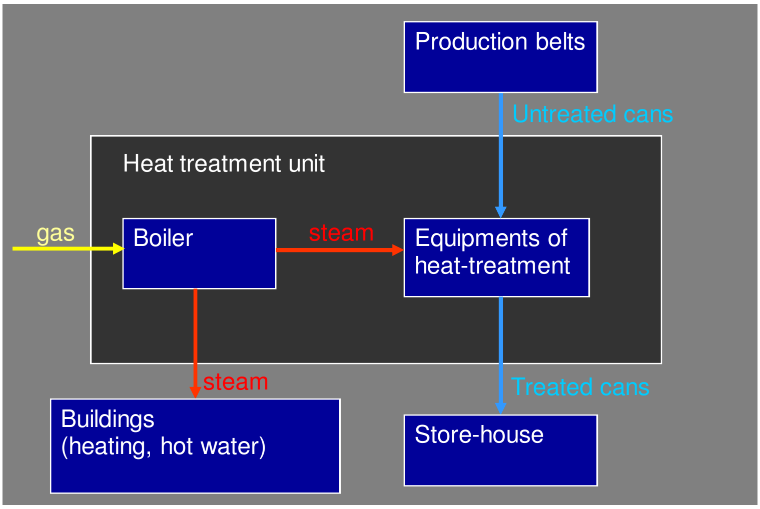


Figure 5. Streams of materials and resources

First of all, I made the data manageable on a common user's area. I found the Excel environment the most convenient for this task. Modelling, correlation and regression analysis all can be done here. I typed the paper-based data in, the text files (Txt) were imported, while I made a text file from the jpg files redirecting the output of the equivalent DOS (dir) direction which then I could import.

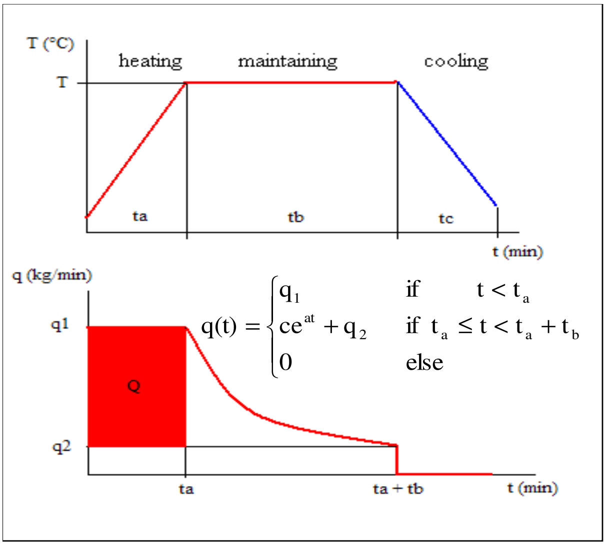
By examing the linear regression and correlation I tried to find the connection with gas consumption as a function of the quantity of products and temperature. I had the necessary amount of data to elaborate the model since I had the appropriate tight connection, so I could interpret the data on linear regression, too:

- Correlation: 91%.
- The coefficients indicated a mistake under 5%.
- Reduction of temperature by 1 °C implies increase in gas consumption by 98 m^3.

- Change in product quantity by 1t causes change in gas consumption by 75 m³.

3.4.2. Modelling the gas demand of a heat-treatment process

On the upper part of Figure 6 the prescribed temperature (provided by the sterile formula of the given product) can be seen, while on the lower part the changes of the necessary steam mass flow in time (unknown, to be determined) are given.



$$q(t) = \begin{cases} q_1 & \text{if} \quad t < t_a \\ ce^{at} + q_2 & \text{if} \ t_a \le t < t_a + t_b \\ 0 & \text{else} \end{cases}$$

Figure 6. The prescribed temperature and changes of the necessary steam mass flow in time

Product-dependent data known from the regulations:

T - temperature to be reached (°C)

t_a - time of heating up (minute)

t_b - time to keep on temperature (minute)

t_c - time of cooling (minute)

Parameters of the q(t) steam mass flow (kg/min):

Q - steam demand (kg) of heating up, value dependent on the product mass

q_2 - loss of the steam mass flow (kg/min), constant non-dependent on the product

c, a - parameters of curvature of the q(t) function, one of them is unrelated to the product and it determines the other.

With knowledge of the model, I can calculate the changes of steam demand of certain equipments in time which is related to the product to be treated (thus to the regulations on heat-treatment) and the starting points in time. Making use of the simulator created in Excel I constituted the daily data series of the total gas demand broken down in hours on the basis of the total heat-treatment in a day. The data of the gas demand should be calculated from these 24 data, but it has to be taken into consideration that a part of the steam produced is turned to the loss. It is unknown, too, and it is indicated as a new parameter (G) of the model, like the gas amount which covers the loss in m^3/h unit of measure. It can be regarded constant in time. It was indicated in the technical description of the boiler that about 80 m^3 of gas is necessary to produce 1 t of steam. Thus, the the total gas consumption per hour based on the model can be calculated both by realizing the steam demand of heat-treatments and from the loss. Then, it can be cross-checked with the measured gas consumption per hour.

I got the values of the model parameters (q_2, k, a, G) with the Solver complement of Excel making use of the smallest squares method. However, the modelling of each day gave different results for the parameters. So the average of the parameters of five days (working days of a chosen week) provided by Solver was regarded as the final result which then I had to check (model verification) if with these parameters the gas consumption of the modelled day can be statistically considered as equal to the measured data. Checking it with the combined t-proof in case of all five days I found it adequate, there was no significant deviation ($p<0,05$). As a next step I examined if the model is adequate in case of days of the week which did not imply determination of the model (model validation). I had a positive answer again by means of a similar method. Consequently, the model and the simulator can be applied in software system, too.

3.4.3. The plan of the software system

3.4.3.1. Software environment

A database manageable with an Excel spreadsheet would serve the user's interest the most. Thus, data processing and tabulation, graph making, which fit to the different demands and cannot be planned in advance, could be done easily. Application of spreadsheet guarantees a simple opportunity to provide program functions for calculations and graph making, besides it can be used as a development environment with the service Visual Basics for Applications (VBA) to elaborate the program. In addition, the database manager program should be used because firstly, it is easier to realize data storage, secondly, the program could have more functions, thirdly, the user-friendly way of data entry can be guaranteed by the technique of forms. Fortunately, both the spreadsheet and database manager can be applied since Excel sheets can be used as attached tables with the database manager program. It means that physically the data storage is realized on Excel sheets, while Access manages these data as if they were stored in its own tables. Thus, data correction done in Access will be stored on Excel sheets.

3.4.3.2. User interfaces, main functions

After starting the program the first thing to appear is the main menu (Figure 7) which shows three submenus, besides log out. If we choose „Data input, modification”, we can find the points shown by Figure 8.

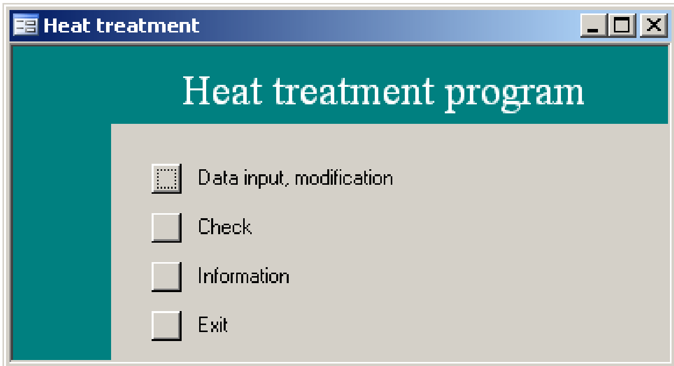


Figure 7. The main menu of Access

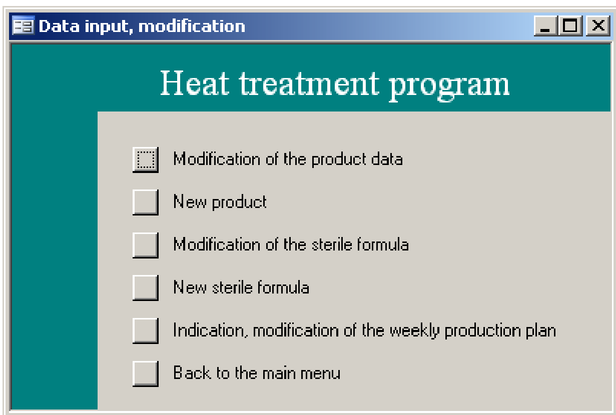


Figure 8. The submenu of „Data input, modification”

First of all, we can fix the data of tables „Product” and „Sterile formula” which can be modified only when a new product is to be manufactured or the regulations on the heat-treatment (sterile formula) of a given product should be modified because of the bigger security or the earlier over-guaranteed regulations. The user will rarely need these functions, the program provides forms of data input to realize them.

Indication of the data of the weekly production plan is used in a weekly frequency in the program which can be done by means of a form. Due to the applied technique of attachment, data manipulations done in Access forms are stored on Excel sheets, so they can be used directly in Excel.

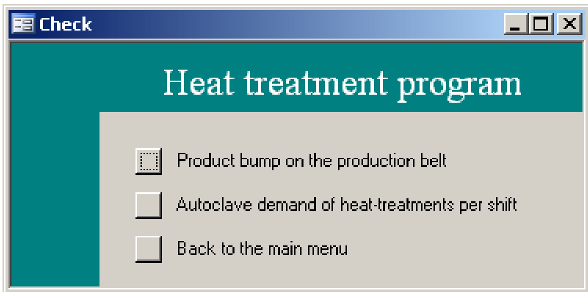


Figure 9. „Check" submenu

Data of the plan should be checked. The submenu „Check" guarantees these functions (Figure 9). The first one examines if the plan contains a mistake in case of which more products would arrive at one production belt at the same time (in the same shift). The list of products bumping on the production belts are provided by a query available on the Access surface which is shown by the program as the view print preview by means of a report. Since the table stores, among the product data, which production belt it can be made on, this result can be obtained without simulation.

The other checking function examines if the heat-treatments can be done in time. We can get the printable report without simulation, since the number of the necessary autoclaves can be calculated from the time spans of heat-treament stored in tables. If the demand of any shifts exceeded the capacity, the plan should be modified. For this, the list shows when the capacity is unemployed in the suitable measure and then we can move the product here with the form which modifies the plan.

Having the checked plan the Excel spreadsheet takes over the work from the Access database manager to do the other tasks. It is the main menu shown in Fugure 10 which helps us reach the functions that should be performed in the order of appearance with weekly frequency.

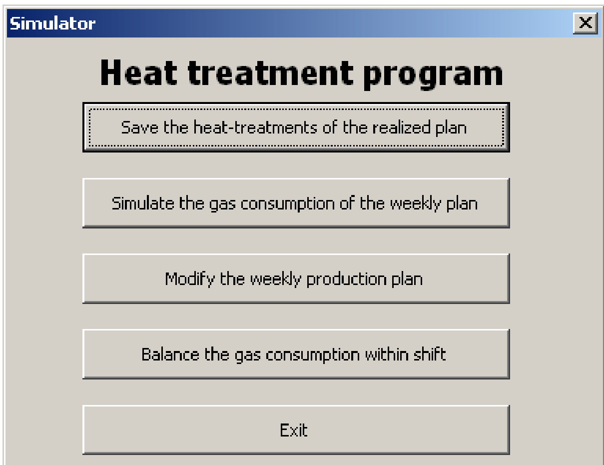


Figure 10. The main menu of Excel

First, we can save heat-treatments of the realized weekly plan, then we can simulate gas consumption of the plan for the following week. Then, the program generates heat-treatment data necessary for the input of the simulator, and makes the calculated data for gas consumption broken down in shifts appear on a diagram. Data generation is done with a VBA (Visual Basic for Applications) operation, while the program switch on the adequate sheet to make the diagram appear. The task of this function is to point out if it is necessary to modify the plan, provided gas consumption of each shift shows a big deviation. The manual data modification can be accomplished with a form made for data input, but plan modification can be done automatically, too, in case of which a VBA operation rearranges the products of the plan within shifts. Modification can be followed by the user in a table of a sheet, and then it can be printed, too.

The last function of the program guarantees that gas consumption within the given shift will be even, evolving the appropriate schedule by delaying the heat-treatment of the products. It is done by a VBA algorithm, together with the simulator, which in every shift of the production week tries to find the value variation of delay of heat-treatments which causes the gas consumption of the lowest standard deviation thus securing the even boiler-load and avoidance of high gas consumption peaks. In this function the maximum waiting time appears as a restriction since it cannot be exceeded to avoid spoilage of canned food. As a final result we can get the optimal value variation of the waiting time for the heat-treatment which then gives the recommended time to start heat-treatments.

Apart from the initial setting functions, the program should be used in a weekly frequency and by storing the data of the accomplished heat-treatments, it makes their registration possible. This registration is compulsory for the company but the stored data can provide an excellent basis for an informational system, too. In our database statements can be made with queries from different points of view, and our data can be displayed even in diagrams. We can easily observe changes, tendencies and seasonalities in the production profile. These functions can be formed in „Information" submenu. Thus, for example, we can have a statement on the weekly summary of production, a diagram of the changes in the produced amount of a certain product per week, production of a selected week per product etc.

4. CONCLUSIONS

Synchronizing the starting points of parallel heat-treatment processes in the autoclaves the automation could guarantee that regulations described in the sterile formula are kept and thus products of better quality are made. The automatic control, very properly, regards the security aspects as of major priority. That is why time spans determined in the sterile formula (heating up, keeping on temperature, cooling) cannot be shorter than what is prescribed, the speed of heating up cannot exceed the measure determined by the regulation, keeping on temperature can be started only when the prescribed temperature has been reached. The temporary insufficient steam supply can be avoided this way, so the time span of the process will not grow which, with its groundless heat load, results in the over-cooked product of lower quality. All in all, the applied method of scheduling has a positive effect on the quality of the product.

Examining the possibilities to reduce the cost of the gas in case of big consumers it can be stated it is not practical either to fix a small gas demand per hour, because of the algorithm on gas payment, or to minimize it, but it is advisable to keep gas consumption under the fixed limit which could be impossible in case of the uneven boiler-load. I think that balancing the boiler-load should be done in two phases. Firstly, by changing, rearranging the products in the weekly production plan between shifts. Secondly, by synchronizing the heat-treatment processes within shifts.

Examination of the load-efficiency graph of the boiler showed that gas fee which determines the direct expenses significantly can be reduced by 6% if the load is balanced. It is typical to the present practice that when different products of different load are made at the same time, it is not taken into consideration when the shifts are planned. Then, for example, instead of the average load of 50% per shift it is typical that even the average load of 30% and of 70% can be observed in the consecutive shifts. However, even within one shift great deviations can be experienced because the production is not scheduled. It can be seen from the results that the increase of the unbalanced feature of the load results in the growth of the loss. With smaller average loads, balancing the load is of a bigger importance since the realitve loss can be even 6% then. Besides the load of 50%, which can be regarded as the annual average, almost the loss of 5% was experienced in the worst case, which, for example in case of the annual gas fee of 100 million Fts means increase of costs by 5 million Fts.

In the simulating, optimizing and scheduling program developed on the basis of archive data the quality of the product can be described by water consumption over capacity while the direct cost by steam consumption. Setting and testing the program it derived that if we deal the optimization of more aspects with the weighted sum of the index-numbers of each purposes (maximum quality, minimum cost), it is advisable to apply the weight value concerning the water of triple value related to the neutral condition. Thus, a solution of approximately Pareto-optimal arises which generates the solution of minimum cost from more solutions of approximately maximum quality (min. excess of the water consumption limit).

Examining the positive effect of software production programming on the costs it can be concluded that with simulation technique the following problems can be avoided: product bump on the production belt due to careless planning, product piling in the heat-treatment unit and thus, product deterioration due to the heat-treatment which was not started in time.

For the software developed for simulation, optimization and sceduling the Excel can be applied, in a user-friendly way, to store, process the data and to represent them in diagrams, to fulfill programming tasks, while the Access to feed data into the computer with forms and to form queries and reports. The developed computer system guarantees an easy possibility for data input and modification, to check product piling on the production belt, to avoid the long waiting lines for the heat-treatment by checking the autoclave capacity, to balance the gas consumption of the shifts and to prevent the gas consumption peaks. All in all, it can guarantee the manufacture of better quality products with lower direct costs.

5. NEW SCIENTIFIC RESULTS

1. I pointed out the relationship between scheduling the heat-treatment processes and the quality of the product. In case of the appropriate schedule the automatism could guarantee the regulations prescribed in the sterile formula, thus avoiding the production of poorer quality product.
2. I elaborated a method to reduce the costs which could be adapted to the calculation relating to the special gas fee in case of big consumers. It would be impossible to keep the gas consumption under a tied down limit with uneven boiler-load. Balancing the boiler-load can be done in two phases. On one hand, with rearrangement of products of the weekly production plan between shifts. On the other hand, with the schedule of heat-treatment processes within shifts. I created a simulating, optimizing and scheduling procedure for these organizational tasks.

3. Analysing the load-efficiency graph of the boiler with the Monte Carlo method I pointed out that if loading is balanced, the gas fee can be reduced. If the dispersion of loading increases, the loss increases, too. With below average and average loads, 5-6% gas charge can be spared.
4. I developed a technique based on database and a calculation procedure to avoid product line collision and product congestion in heat treatment units. Thus, production can be achieved without restructuring costs and product deterioration.

6. SUGGESTIONS

I suggest that the developed software should be used in food processing of autoclave technology to optimize the direct costs of heat-treatment and the quality of the products, and to complement the system with further functions. Apart from the initial setting functions, the program should be used in a weekly frequency and by storing the data of the accomplished heat-treatments it makes their registration possible. This registration is compulsory for the company and its electronic variation guarantees a simpler availability. The stored data can provide an excellent basis for an informational system, too. In our database statements can be made with queries from different points of view, and our data can be displayed even in diagrams. We can easily observe changes, tendencies and seasonalities in the production profile.

PUBLICATIONS IN THE SUBJECT OF THE DISSERTATION

Article in foreign language in a scientific journal

Fabulya, Z. (2008): Cost optimizing of autoclaving in Excel environment. Review of Faculty of Engineering Analecta Technika Szegedinensia 2008, SZTE Mérnöki Kar, Szeged, pp. 19-25. ISSN 1788-6392

Fabulya, Z. (2010): Modelling and optimizing in autoclaving. Review of Faculty of Engineering Analecta Technika Szegedinensia 2010(2-3), SZTE Mérnöki Kar, Szeged, pp. 62-67. ISSN 1788-6392

Proceeding published in a foreign conference publication

Fabulya, Z., Nagy, M. (2007): Developing managerial decision preparing system for food industry enterprises using heat treating autoclave. Proceedings of the 6th Biennal Conference of European Federation of IT in Agriculture, Glasgow, 2007.07.02-05., Caledonian University, Glasgow, ISBN-10: 1-905866-10-0, ISBN-13: 978-1-90-5866-10-6, Proceedings in CD-ROM: EFITA Proceeding CD/monday/1400/business_theme-dss_applications/fabulya_zoltan_20070331151402.pdf

Fabulya, Z., Hampel, Gy., Nagy, M. (2009): Modelling and simulation in heat treating. 12th Symposium of Mathematics and its Applications. „Politechnika" University of Timisoara, November, 5-7, 2009., Bul. St. Univ. „Politehnica" Timisoara – Transactions on Mathematics – Physics, Timisoara, pp. 332-337. ISSN 1224-6069

Abstract published in a foreign conference publication

Fabulya, Z. (2007): Decision support in heat treating. 9th International Symposium Interdisciplinary Regional Research (ISIRR-2007), Novi

Sad, 2007.06.21-23., Fakultet tehničkih nauka, Novi Sad, p. 46. ISBN 978-86-7892-042-4

Article in Hungarian language in a scientific journal

Fabulya, Z. (2007): Autoklávos hőkezelés szimulációja élelmiszeripari vállalatok energia költségének optimalizálására. VI. Alkalmazott Informatika Konferencia. Kaposvár, 2007.05.25., Acta Agraria Kaposváriensis 11(2), Kaposvári Egyetem, Állattudományi Kar, Kaposvár, pp. 125-134, ISSN: 1418-1789, (CD: Disc/14Fabulya.pdf),

Fabulya, Z. (2008): Autoklávos hőkezelés számítógépes modellezése, erőforrásainak optimális felhasználása. Agrár- és Vidékfejlesztési Szemle 3(1), Multifunkcionális Mezőgazdaság nemzetközi tudományos konferencia, Hódmezővásárhely, 2008.04.24., SZTE Mezőgazdasági Kar, Hódmezővásárhely, p. 71., ISSN 1788-5345, Proceedings in CD: SZTE_2008_04/pdf/062_Fabulya.pdf

Fabulya, Z., Bánkuti, Gy. (2008): Adatelőkészítés, elemzés húskonzerv-gyártás gázfogyasztásának modellezéséhez. VII. Alkalmazott Informatika Konferencia. Kaposvár, 2008.05.23., Acta Agraria Kaposváriensis 12(2), Kaposvári Egyetem, Állattudományi Kar, Kaposvár, pp. 71-81., ISSN: 1418-1789, (URL: http://oldportal.ke.hu/msites/atk/UserFiles/File/PDF/VOL12NO2/07Fabulya.pdf),

Fabulya Zoltán, Hampel György (2009): Hőkezelési folyamat számítógépes modellezése. Jelenkori társadalmi és gazdasági folyamatok 4(1), Szegedi Tudományegyetem Mérnöki Kar, Szeged, pp. 117-123., ISSN 1788-7593

Fabulya Zoltán (2009): Hőkezelési folyamat modellezési adatainak előkészítése, elemzése húskonzerv-gyártás gázfogyasztásának optimalizálásához. Jelenkori társadalmi és gazdasági folyamatok 4(2), Szegedi Tudományegyetem Mérnöki Kar, Szeged, pp. 85-90., ISSN 1788-7593

Fabulya Zoltán, Hampel György (2010): Adatbázis alkalmazási lehetőségei autoklávos hőkezelésnél. Jelenkori társadalmi és gazdasági folyamatok 5(1-2), Szegedi Tudományegyetem Mérnöki Kar, Szeged, pp. 239-243., ISSN 1788-7593

Fabulya Zoltán (2010): Adatgyűjtés, adatelemzés hőkezelési folyamat modellezéséhez. Jelenkori társadalmi és gazdasági folyamatok 5(1-2), Szegedi Tudományegyetem Mérnöki Kar, Szeged, pp. 234-238., ISSN 1788-7593

Fabulya, Z., Hampel, Gy., Nagy, M. (2010): Gőzfogyasztás matematikai modellezése és számítógépes szimulációja konzervgyártás során. „Mezőgazdaság és vidék a klímaváltozás és a válság szorításában" c. IX. Wellmann Oszkár Nemzetközi Tudományos Konferencia. Hódmezővásárhely, 2010.04.22., Agrár- és Vidékfejlesztési Szemle 5(1), SZTE Mezőgazdasági Kar, Hódmezővásárhely, pp. 522-527., ISSN 1788-5345, Proceedings in CD: SZTE_2010_04/pdf/Posters.pdf),

Proceeding published in a national conference publication

Fabulya, Z. (2006): A Wonderware InTouch szoftver alkalmazása ipari folyamatok vizualizálására az oktatásban. VII. Nemzetközi Élelmiszertudományi Konferencia, Szeged, 2006.04.20., A VII. Nemzetközi Élelmiszertudományi Konferencia előadásának és posztereinek összegoglalói, SZTE Szegedi Élelmiszeripari Főiskalai Kar, Szeged, pp. 150-151., ISBN 963 482 676 8, Proceedings in CD: 7thicofs/sections/6_Posters/41_Fabulya.pdf

Fabulya, Z. (2006): The educational application of the Wonderware Intouch software for the visualization of industrial process. V. Alföldi Tudományos Tájgazdálkodási Napok. Mezőtúr, 2006.10.26-27., V.

Alföldi Tudományos Tájgazdálkodási Napok, Összefoglalók, Szolnoki Főiskola Műszaki és Mezőgazdasági Fakultás, Mezőtúr, pp. 150-151., ISBN: 963 06 0817 0, Proceedings in CD: LAND MNGMNT-2006/szovegek/Muszaki fejl/poszter_Muszaki/Fabulya Zoltan_The educational.doc

Fabulya, Z. (2007): Autoklávos hőkezelés költség-optimalizálása Excel környezetben. Európai Kihívások IV. Nemzetközi Tudományos Konferencia. Szeged, 2007.10.12., Európai Kihívások IV. Nemzetközi Tudományos Konferencia, SZTE Mérnöki Kar, Szeged, pp. 645-649., ISBN 978-963-482-857-0

Fabulya, Z. (2008): Számítógépes szimuláció alkalmazása konzervek hőkezelésére. International Conference on Science and Technique in the Agri-Food Business. Szeged, 2008.11.5-6., Tudomány és Technika az Agrár- és Élelmiszergazdaságban, ICoSTAF2008 Összefoglalók, SZTE Mérnöki Kar, Szeged, pp. 250-251., ISBN 963 482 676 8, Proceedings in CD: /pdf/MPE/Fabulya_Zoltan_full.pdf

Fabulya Zoltán, Hampel György (2009): Húskonzervek hőkezelésének optimalizálása az erőforrás-felhasználás és a termékminőség jegyében. Heat treatment optimization of canned meats in terms of the resource utilization and the quality of the products. 2nd International Economic Conference, Kaposvár, 2009.04.02-03., Abstract of the 2nd International Economic Conference, Kaposvári Egyetem, Gazdaságtudományi Kar, Kaposvár, p. 83., ISBN 978-963-9821-07-1, Proceedings in CD: /cikkek/Fabulya_Hampel.pdf, ISBN 978-963-9821-08-8