Web-based tool for fast qualitative analysis of the sterilization process for foods with an extended expiry date

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Abstract. A digital calculator algorithm for F-effect calculation in an online environment is presented. The tool gives a value that analyzes the nature of the sterilization process in thermally processed foods. The obtained result is a reference to "F Soft" software for modelling the process with increasing or decreasing the retention time at reaching the required F-effect, ensuring microbiological stability and nutritional value, while preserving the taste qualities of the canned product in real time mode or when reading external data, creating an appropriate mode. The implementation of the web tool is done with PHP programming language and it provides a quick guideline for the quality of the production cycle of the product to be sterilized.

1 Introduction

Sterilization is a conservation method that preserves to the highest degree the microbiological stability, nutritional qualities and high organoleptic quality during storage of the preserved products. This is because the heat treatment takes place after the jars are closed with lids (or after the cans are sealed) in the absence of air, contact with which in open cooking destroys valuable nutritional ingredients and especially vitamin C. All kinds of food can be sterilized like natural vegetables, ready lean dishes and appetizers, natural fruits without and with sugar, compotes, mushrooms, meats, meat dishes, meat-vegetable dishes and fish. In addition, the shelf life of otherwise preserved products for example pickled vegetables, pickles, vegetable juices, marmalade nectars, etc. - can be greatly increased if they are further sterilized.

The correct implementation of sterilization regimes is an important stage in the technological process that guarantees the production of high-quality food. In the sterilization of cans, the achievement of a certain sterilization value (lethality or sterilization effect) is searched. The numerical value of this lethality indicates the "softness" or "hardness" of the sterilization regime used.

In recent years, exports of sterilized foods to European Union countries USA, Canada and Middle Eastern countries have been required to reflect the sterilization value (Fo) in the quality certificate of the cans, which ensures the safety and microbiological stability of the can.

This is an important summary indicator that shows the technological level of production, the level of hygiene, technological methods and means of processing.

The F_o value is one of the most important indicators in the production of sterilized cans in enterprises operating under the HACCP system (Hazard Analysis and Control of Critical Points), whose practical application and implementation in Bulgaria has become mandatory since 2006 in order to improve management of the quality and to ensure with sufficient certainty the safety of the produced cans.

A person's lifestyle and health are directly related to the food they eat. In order to achieve food security and in response to the growing worldwide challenges related to demographic changes, the lack of resources, and the need for energy efficiency, there is an urgent need for food producers to identify adequate and flexible tools for the correct determination and implementation of thermal regimes processing. This is an important stage in the preparation of the technological process to guarantee the production of high-quality food with minimal energy costs.

1.1 Heat sterilization of foods

Heat processed foods must provide microbiological stability, required nutritional value and high organoleptic quality in storage. The safety and quality management systems, implemented in companies for the production of food, require the availability of control measurement systems to monitor, record and archive important process parameters, especially at critical control points for temperature and pressure measurement. The availability of such systems makes it possible to monitor the quality of production, particularly with regard to the sufficiency of heat treatment of individual batches of cans when heat sterilisation of foods with an extended expiry date is involved.

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The way of preserving food, called sterilization, was developed by Nicholas Appert in 1810. It consists in a long heat treatment of food in hermetically sealed containers, submerged in water. The process of preserving food by this method is carried out under tight closure without air access. During the sterilization process, the development of microorganisms, harmful to the products, is stopped. This action makes the products completely safe and at the same time does not change their taste.

Nowadays, the application of periodic heat sterilization in production practice is one of the most widely used methods for long-term preservation of food products. The theoretical foundations of heat sterilization are laid out in the classic monographs of Stumbo [11] and Pflug [6], Holdsworth [4, 5], Peleg [7], Ramaswamy and Singh [8], Richardson [9, 10], Teixeira [3], Flaumenbaum [1].

The monograph on Stumbo presents mathematical model of the death of microorganisms when heated depending on various parameters. One of them is the time for a tenfold decrease in the concentration of microorganisms *D*, expressing the thermal resistance of microorganisms, and after him Bigelow [12, 13] introduces the magnitude Z, which characterizes the thermal resistance on microorganisms. These parameters are important for the theory of sterilization, because they make it possible to calculate the sterilization effect (*F - effect*) for a specific object, applying methods based on the calculation of the effect at the slowest heating point in the package. The lethality value F is calculated in different ways: graphic method (Bigellow, Flaumenbaum [1, 13]), which uses empirical time-temperature curves.

Ball, Flaumenbaum [2] enter the magnitude - relative sterilizing action (transl coefficient) for temperature *t*

$$K_f = 10^{\left(\frac{t-T_e}{z}\right)} \quad (1)$$

where:

t is temperature from the thermogram for the slowest heating point, °C;

T_e - reference temperature against which it is calculated, °C;

z - thermosensitivity of microorganisms, °C.

The value K_f [2] allows to calculate the sterilization effect according to the following dependence:

$$F = \int_0^\tau 10^{\left(\frac{T-T_e}{z}\right)} d\tau \quad (2)$$

where:

F– sterilization effect, min;

$d\tau$- time interval for reading the temperature, min;

τ- time, min;

T_e- reference temperature against which it is calculated, °C;

T- temperature at the slowest heating point of the package, °C;

z - temperature sensitivity of microorganisms, °C.

This method is quite universal and can be used in different sterilization modes, regardless of the shape and size of the packages, as well as the type of heat transfer. In this case, it is necessary to have the empirical time-temperature curve removed.

The frequent change of heat treatment modes of a canned product leads to the following problems:

✓sometimes to application on “harder” modes on thermal processing;
✓difficulties;
✓delay;
✓overspending;
✓energy overspending;
✓increasing the ecological footprint.

Suggested solution to the problem:

One tool to indicate such problems is the web-based F-effect calculator. The online tool that we offer gives a result on the basis of which an assessment can be made whether the sterilization mode needs correction and optimization of the technological modes. If the result shows that it is below or above the reference values, then it is possible to switch to *F-soft* software to optimize the sterilization process.

2 Implemented project (related work)

A calculator has been implemented to calculate F-effect. Because the project was intent for Bulgarian users, the interface was only developed in Bulgarian language.

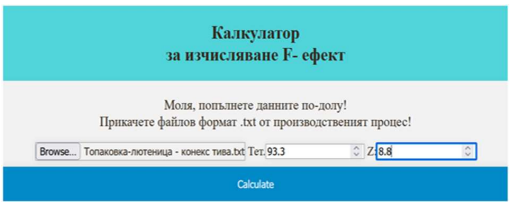

Fig. 1. Illustration on calculator for calculation of F-effect

On Fig.1 is shown window in which the user has to enter input data in file format taken from a manufacturing process.

The implementation was done in a web server, using HTML, CSS and PHP programming language.

The data must be in standard textual format (. txt) and the following sequence must be observed:

"*DD.MM.YYYY hh:mm:ss , XXX.X*".

where:
DD – day,
MM – month,
YYYY – year,
hh – hour, mm – minute,
ss – second,
XXX.X – measured temperature.

```
29.07.2021 00:01:00, 45.94
29.07.2021 00:02:00, 46.00
29.07.2021 00:03:00, 46.19
29.07.2021 00:04:00, 46.31
29.07.2021 00:05:00, 46.44
29.07.2021 00:06:00, 46.69
29.07.2021 00:07:00, 46.88
29.07.2021 00:08:00, 47.13
29.07.2021 00:09:00, 47.38
29.07.2021 00:10:00, 47.69
29.07.2021 00:11:00, 48.06
29.07.2021 00:12:00, 48.38
```

Fig. 2. Illustration on the necessary format of the input data for the calculator

On Fig. 3 visualized result after entering input data.

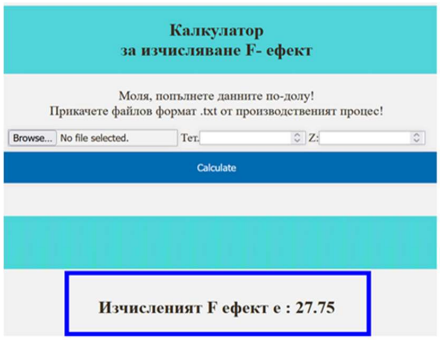

Fig. 3. Illustration at returned result of calculator

2.1 Output code on calculator for calculation of F -effect

The selected implementation method does not require the recording of the submitted data. Therefore, the implementation was made without the use of a database or any other similar method. Following the block diagram, a PHP code was created to initialize the primary data, extract the data from the sent text file following the specified formatting, process it according to the specified algorithm and visualize the result to the user.

Fragment from output code on calculator for calculation of F -effect

Data submission form

```
<form action="<?php echo $_SERVER['PHP_SELF'];
?>" method="post" enctype ="multipart/form-data">
    <input type="file" name="file" size="60" />
  Tem.<input type= "number" name="secondtemp"
step=".01">/)
  Z:<input type= "number" name="NumberZ"
step=".01"/>
    <input type="submit" name="submit"
value="Calculate">
    </form>
```

where:

$_ SERVER ['PHP_SELF'] is used to automatically extract the name of the file the form is send from, so when changed the form will work correctly and send the data to itself for processing;

step =".01" specifies the increment step of the numeric value of the field using the arrows.

Temperature data processing

```
$F0=0;
foreach ($array as $key => $value) {
  if(strlen($value[0])>0)
    $exp=($value[2]-$T0)/$Z;
   $F0=$F0+pow (10, $exp);
}
   fclose($file);
```

strlen() returns the length of the string;

pow() is used for exponential expression;

fclose($file) - closes an open file pointer.

The algorithm by which the calculator for calculating *F effect* e is implemented programmatically:

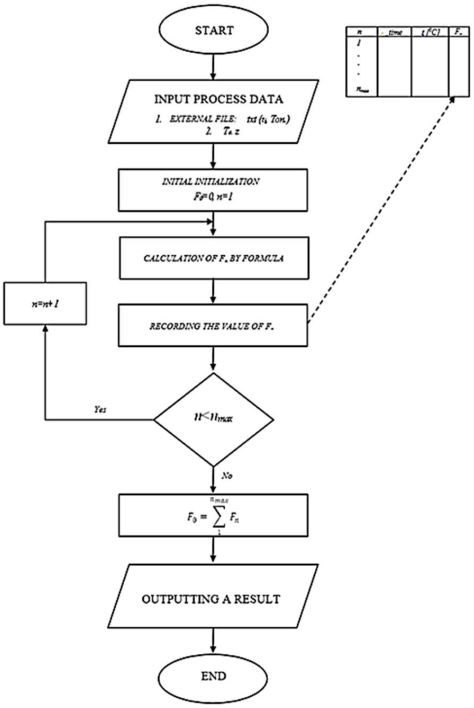

Fig. 4. Block diagram of a web-based calculator for calculating the *F effect*

3 Calculation accuracy of online *F effect* calculator

The calculation accuracy of an online calculator for calculating the F-effect has been proven in an experiment (comparative study). From three products "Peas," "Grilled Zucchini" and "Zucchini Caviar" calculation of the

accuracy of the result in measured sterilization process parameters and adhering to the recommended input data format. The data and results obtained in MS EXCEL and compared with the same results when calculating on an online calculator for the same products and the same inputs.

Product: Peas: "Peas" in jars TO 0.7 kg. with pH = 5.6, z = 10°C and $T_{et.}$ = 121.1°C. Results:

Table 1. Error data for calculation of F effect when calculated in MS Excel and online calculator for *F effect* in actual sterilization process of "Pea" product

MS Excel	Online calculator *F effect*	Difference in results	Reference temperature, °C	Temperature sensitivity of the microorganism, °C *Cl. botulinum*
F_0, min	F_0, min		$T_{et.}$	z
3.76	3.76	0	121.1	10

The table shows the results of a real experiment, from which it is clear that there is no deviation from the results of MS Excel and an online calculator for calculating the sterilization effect F_0. The difference of the two values obtained is 0.

Experimental data are published at: http://cloud1.acci-bg.com/index.php/s/HCcBZ9arMQznbXR and the experiment can be verified. The downloaded resource with file format "T pack-pea. txt" or "T_packing_peas. txt", is attached to the calculator in address https://www.f-efect3.acci-bg.com/, and Tet parameters. and z from Table 3 is added, and the calculator returns the result F_0 = 3.76 min. The reference values of this product are in the range of 6 to 11 notional min. The conclusion that can be made is that it is necessary to correct the thermal regimes in order to avoid problems, difficulties, such as delays, overspending of funds, overspending of energy, etc. in the production and use of the can. Danger of spoilage of the product or inability to inactivate the harmful microorganism in it, which can lead to poisoning from the can. In this particular case, the microorganism to be deactivated is *Cl. botulinum*.

Product: Grilled zucchini: "Grilled Zucchini" in jars TO 0.580 kg. with pH = 5.6, z = 10°C and $T_{et.}$ = 121.1°C.

Table 2. MS Excel *F-effect* calculation comparison results data and sterilization effect calculation online calculator

MS Excel	Online calculator *F effect*	Difference in results	Reference temperature, °C	Temperature sensitivity of the microorganism, °C *Cl. botulinum*
F_0, min	F_0, min		$T_{et.}$	z
0.25	0.25	0	121.1	10

Experimental data are published at: http://cloud1.acci-bg.com/index.php/s/YXYy4fRYzfHZXbe and the experiment can be verified. The downloaded resource with the file format "Grilled Zucchini Wrap. txt" or T_grilled zucchini.txt, is attached to a calculator for calculating the *F-effect* https://www.f-efect3.acci-bg.com/, the $T_{et.}$ parameters are added, and z as reference values from Table 2 and the calculator returns a result of F_0 = 0.25 min.

The results of Tables 1 and 2 are showing accuracy. This confirms the accuracy of the calculator that if the process data is entered in the recommended input format to the online calculator its accuracy is guaranteed.

There is no difference in the experimental comparison of results for both products. It is evident from the experimental data that the accurate result can be trusted and it can be said that the online F-effect calculator works correctly and can be provided for use by manufacturers and regulatory authorities. The data and results obtained in MS EXCEL are compared with those obtained from the purpose-built digital reference calculator and displayed in the developed platform.

The advancement of new technologies and, in particular, the development of web development leads to a new way of thinking. Many software tools that we use are being transferred in a convenient form to the Internet, accessible from anywhere in the world. One such tool is presented and is offered for guidance and possible actions to improve and eliminate the problems caused by incorrect thermal regimes.

The implemented web calculator provides the possibility for each user to calculate the value of the F effect. This value is a reference for canning industry professionals, inspection authorities, manufacturers of thermally processed foods as well as the ordinary consumer. A very simple and quick tool that shows the quality of a sterilized product.

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