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IMPACT OF HIGH VAPOR PRESSURE PARAMETERS ON THE MICROBIOLOGICAL SAFETY OF EGG OMLETS IN THE PROCESS OF TREATMENT

V. SUKMANOV, Doctor of Technical Sciences, Professor;
N. HERMAN, Associate Professor;
D. MIRONOV, CandidateTechnicalScienxes
(Poltava University of Economics and Trade);
A. PALASH, CandidateTechnicalScienxes
(Poltava College of Food Tehnology National University of Food Technologies)

Summary. Purpose. *Egg omelet is one of the most valuable human foods. Unfortunately, this product is not intended for long-term storage. The purpose of the study is to establish the nature of the influence of high-pressure processing parameters on mixed egg omelets with various fillers in order to ensure its microbiological safety during long-term storage. The research method is high-pressure processing of egg omelets with fillers and investigation of their microbiological safety. The process of producing egg omelets with various fillings (cheese, bacon, fried mushrooms) for long time storage consists of mixing the liquid chicken egg with grated or finely chopped cheese (or other ingredients), xanthan gum, water or milk, adding spices (salt, pepper), after which the resulting mixture is packaged in a sealed resilient packaging material; then it is heated, immersed in a working chamber, that is a high-pressure unit.* ***Methods.*** *The samples were treated in the range of the following process parameters: preliminary heating of the mixture – to 85-95 °C, pressure – 650-750 MPa, processing time is – up to 8 min.* ***Results.*** *As a result, the dependence of microbiological contamination of egg omelets (E. coli, Pseudomonas fluorecens, Paenibacillus polymyxa and Listeria seeligeri) on the parameters of the process of their high-pressure treatment (pressure value, temperature and duration of the process) has been established. It has been suggested and experimentally established that it is expedient to use kinetic models of the second order to describe the process of inactivation of E. coli. Dependences for the second-order kinetic models in terms of the change in the rates of inactivation of ln (k_1) and ln (k_2) constants on the pressure have been obtained.* ***Conclusions.*** *The values of microbiological contamination (E. coli, Pseudomonas fluorecens, Paenibacillus polymyxa and Listeria seeligeri) have been determined for long-term storage of egg omletes processed with HP.*

Keywords: *egg omelets with fillers, high pressure, shelf life, microbiological safety.*

The statement of the problem in general form and its connection with the most important scientific and practical tasks. Chicken eggs are one of the most valuable human foods used in cooking of a large number of dishes, among which the leading place is occupied by egg omelets (EO). Unfortunately, this product is not intended for long-term storage, it is prepared at mass catering enterprises when ordered. At the same time, given the high nutritional value of this product, in case it is provided with its high food and consumer properties for a long shelf life, it can be recommended for use in expeditions and hikes, difficult to access regions of the country, in the formation of strategic reserves for the armed forces and navy as well as in the egg-processing industry, food industry and mass catering enterprises.

Analysis of recent research and publications. The influence of high pressure (HP) on egg protein was first described in the work [1].

Currently, research into the production of long-shelf omelets is being conducted in several countries in Europe and the United States. It has

been established that it is most expedient to use HP to ensure the microbiological purity of the processed products in the course of storage while preserving the entire enzyme-vitamin complex, to develop a process for the production of mixed egg omelets with various fillers of a long shelf life [2, 3].

Research in this area is focused on establishing the conditions for preserving the nutritional value of a chicken egg treated with HP [4], studying the changes in the physico-chemical properties of eggs treated with HP and the kinetics of these changes [5, 6].

Considering the fact that for consumers of egg omelets produced with the use of HP technology it is a relatively new product, a number of studies are aimed at studying the consumer properties of these products [7].

The study of the consumer market has confirmed the prospects of using HP technologies in the production of egg omelets with cheese both for their subsequent long-term storage and for use as fillers in the production of various culinary products, such as pies [8].

In connection with the fact that when using the technology of HP practically there is no traditional high-temperature processing of egg omelets, so, it is of undoubted interest to determine the parameters of the process of HP processing of egg omelets with various fillers and to study their microbiological safety.

Formulation of the article objectives. The purpose of the study was to investigate the influence of the parameters while processing egg omelets mixed with various fillings with HP in order to ensure its microbiological safety during long-term storage.

Statement of the main material of the study with full justification of the scientific results obtained. *Object and subject of research. The object of research* is egg omelet with various fillers produced for long-term storage. *The subject of the research* is the technological parameters of the process of treatment of egg omelets with fillers with high-pressure and the microbiological safety indicators of the received product.

Used research methods and equipment, organization of research. To investigate the influence of HP on egg products it was developed a process based on liquid chicken eggs for producing egg omelets with cheese, bacon and fried champignons for of long-term storage. The process consists of several stages: mixing the liquid chicken egg with grated or finely chopped cheese (or other ingredients), xanthan gum which gives the finished product a form-retaining capacity, water or milk, then adding spices (salt, pepper), as a result a given mixture is packed in a sealed resilient packaging material, heated, and finally placed in a working chamber – a HP installation. The obtained product in hermetically sealed package is intended for long-term storage; therefore the investigation of its microbiological safety during storage is a priority task in determining rational parameters, both the process of its production and the storage regimes of the produced product.

The processing of hermetically sealed samples of egg omelets was carried out in a high-pressure installation (HPI) [9,10] in the range of process parameters: preliminary heating of the mixture by 85-95 °C, pressure of 650-750 MPa, processing time is up to 8 min.; microbiological studies were performed on the regional sanitary-epidemiological stations.

As a result of the fact that the product loaded into the HP working chamber, according to the developed technology, has a temperature of 85-95 °C, and the subsequent increase in pressure in the working chamber, the temperature of processing the product with HP was 110-130 °C.

An analysis of earlier studies of the HP effect on the microbiological purity of liquid eggs and egg products has made it possible to determine the field of experiment and to organize an analysis of the results of experiments [11–21].

The culture of Escherichia coli was used to carry out experimental studies for assessment of the microbiological sterility of the product samples treated with HP. The process was as follows.

The E. coli which was found in one of the samples of a liquid chicken egg and assigned to the group of K12DH5α was transferred to 20 ml of standard broth and grown in a vibrating incubator for 24 hours at 30 °C. After 24 hours of incubation, 50 ml of the suspension was transferred to 20 ml of fresh broth, and the cultivation continued for another 24 hours. Subsequently, 1ml of a suspension of microorganisms with E. coli was grafted to 100 ml of the whole egg which was used in the production of egg omelets. The initial concentration of E. coli was approximately 10^7 CFU/ ml. The initial concentration of other microorganisms used in microbiological studies was approximately 10^7 CFU/ ml.

In addition, it should be noted that some microorganisms are sufficiently resistant to pasteurization and are capable of spoiling the liquid chicken egg even when stored in chilled conditions. Thermal pasteurization often reduces by one or two orders of magnitude the number of microorganisms and the liquid pasteurized egg contains 10^2 or more than 10^3 of microbial cells per gram. The main pathogenic microorganisms found in pasteurized liquid eggs are: *Alcaligenes, Bacillus, Proteus, Escherichia coli*, *Pseudomonas* and Gram positive cocci.

The procedure for carrying out experimental studies on the influence of the parameters in the process of treating egg omelets included the following stages:

1. Formation of a bank of microbiological cultures for their subsequent introduction into egg omelet samples.
2. Preparation of samples of egg omelets with cheese, bacon and champignons according to technology and introduction of a pre-prepared microbiological culture.
3. Packing of samples of egg omelets in sterile sealed containers and treating them at the HPI.
4. Microbiological analysis of egg omelet samples, both immediately after treatment with HP and during their long-term storage at +4±0,5 °C.

The microbiological analysis of processed samples of egg omelets treated with HP was performed according to the standard methods of ISO-4833:2003 (Microbiology of food and animal feeds: Horizontal method for counting microorganisms: Method for the detection and enumeration of colonies at 30 °C (ISO 4833: 2003, IDT)) Microbiology of food and animal feeding stuffs – Horizontal method for the enumeration of microorganisms – Colony-count technique at 30 degrees C), ISO-21528-2004 (ISO 21528-1:2004 "Microbiology of food and animal feeding stuffs – Horizontal methods for the detection and enumeration of Enterobacteriaceae – Part 1: Detection and enumeration by MPN technique with pre-enrichment), ISO 4833:1991 "Microbiology – General guidance for the enumeration of micro-organisms – Colony count technique at 30 degrees C", ISO-6579:2002-07, ГОСТ 10444.15-94 Microbiology of food and animal feeding stuffs – Horizontal method for the enumeration of microorganisms – Colony-count technique at 30 degrees C, ISO-21528-2004 (ISO 21528-1: 2004) For the detection and enumeration of Enterobacteriaceae – Part 1: Detection and enumeration by MPN technique with pre-enrichment), ISO 4833: 1991 "Microbiology – General guidance for the enumeration of micro-organisms" –6579: 2002-07, GOST 10444.15-94 "Food products. Methods for determining the amount of mesophilic aerobic and facultative-anaerobic microorganisms" and GOST (State Standard) 10444.12-88 "Food products. Method for determining yeasts and moldy fungi".

According to the "Uniform Sanitary and Epidemiological and Hygienic Requirements for Goods Subject to Sanitary and Epidemiological Supervision (Control)", the following safety and nutritional requirements are stipulated for "omelets from eggs (mélange, egg powder) natural and with the additives of vegetables, meat products, etc., fillings including eggs":

- QMAFAnM, CFU/g – $1 \cdot 10^3$;
- CGB (coliforms) in 1,0 g – not allowed;
- pathogenic, incl. Salmonella in 25g – not allowed;
- S.aureus in 1,0 g – not allowed;
- Proteus in 0,1 g – not allowed.

Considering the fact that several ingredients are used in the production of egg omelets including milk, without its thermal sterilization, the safety requirements for each component of egg omelet were analyzed.

Requirements common for all the raw ingredients making up egg omelets are the following:

- CGB (coliforms) in 0,1 g – not allowed;
- sulfite-reducing clostridia in 0,01g – not allowed;
- S.aureus in 1,0g – not allowed;
- pathogenic incl. Salmonella in 25g – not allowed;
- E.coli in 1g – not allowed;
- L.monocytogenes in 25g – not allowed;
- for bacon: QMAFAnM, CFU / g, not more than $1 \cdot 10^3$;

or a mixture of egg for an omelet: QMAFAnM, CFU / g, not more than $1 \cdot 10^5$;

for mushrooms:

- QMAFAnM, CFU / g – not more than $1 \cdot 10^4$;
- yeast, CFU / g – not more than $1 \cdot 10^2$;
- mold, CFU / g – not more than $1 \cdot 10^2$

for xanthan gum:

yeast, mold, CFU / g – not more than 500 in total;

for raw milk of the highest grade - QMAFAnM, CFU / g – not more than $1 \cdot 10^5$:

the content of somatic cells in 1 cm^3(g) – not more than $4 \cdot 10^5$;

raw milk of the 1-st grade - QMAFAnM, CFU / g – not more than $5 \cdot 10^5$:

the content of somatic cells in 1 cm^3 (g) – not more than $1 \cdot 10^6$;

raw milk of the 2-nd grade-QMAFAnM, CFU / g – not more than $4 \cdot 10^6$:

− the content of somatic cells in 1 cm^3(g) – not more than $1 \cdot 10^6$;

raw skimmed milk of the highest grade – QMAFAnM, CFU / g – not more than $1 \cdot 10^5$;

raw skimmed milk of the 1-st grade – QMAFAnM, CFU / g – not more than – $5 \cdot 10^5$;

raw skimmed milk of the 2-nd grade – QMAFAnM, CFU / g – not more than $4 \cdot 10^6$.

In addition to the above indicators, the effect of HP on three species of psychrophilic bacteria was studied: Listeria seeligeri (Listeria innocua), Pseudomonas fluorecens, Paenibacillus polymyxa, which are often the cause of food spoilage when stored in a cooled state.

The indicator of "colibacillus bacteria" (CGB) has been chosen in accordance with the accepted international nomenclature as it is almost identical to the indicator of "coliform bacteria". The study included both citrate-negative and citrate-positive variants of CGB, including the following genera: *Escherichia, Klebsiella, Enterobacter, Citrobacter, and Serratia.*

All the above samples of cultures were obtained as a result of inoculation and subsequent dilution to the required concentration of microflora samples found during various microbiological analyzes and further identified.

Statistical evaluation of the obtained results. To carry out statistical processing of the experimental results and kinetic analysis of the process of inactivation of Escherichia coli, the program STATISTICA V5.5A was used. When analyzing the dependencies obtained, the correlation coefficient (R^2), the Fisher test (F_{stat}) and the standard error (Str. Err) were used. The confidence interval was 0,95.

Analysis of the results. Table 1 and Fig. 1–3 show the results of experimental studies on the inactivation of Escherichia coli in egg omelets.

Table 1

The results of experimental studies on the inactivation of Escherichia coli in egg omelets and cheese samples treated with HP

Temperature 110 ˚C					
650 MPa		700 MPa		750 MPa	
τ, c*	$lg(N/N_0)$**	τ, c	$lg(N/N_0)$	τ, c	$lg(N/N_0)$
0	0	0	0	0	0
30	-0,55	30	-0,62	30	-1,52
60	-0,89	60	-0,89	60	-3,12
120	-1,52	120	-1,99	120	-2,99
180	-2,09	180	-2,48	180	-4,62
240	-3,18	240	-3,13	240	-5,48
300	-3,49	300	-3,78	300	-5,79
360	-3,65	360	-4,44	360	-6,62
420	-4,49	420	-5,25	420	-7,21
Temperature 120 ˚C					
650 MPa		700 MPa		750 MPa	
τ, c	$lg(N/N_0)$	τ, c	$lg(N/N_0)$	τ, c	$lg(N/N_0)$
0	0	0	0	0	0
30	-0,65	30	-0,68	30	-1,10
60	-1,04	60	-1,49	60	-2,00
120	-1,82	120	-3,42	120	-3,97
180	-3,12	180	-4,68	180	-5,12
240	-4,62	240	-5,31	240	-5,73
300	-4,958	300	-6,22	300	-6,56
360	-5,85	360	-7,36	360	-7,42
420	-6,49	420	-8,00	420	-7,85

Contin. of table 1

Temperature 130 °C					
650 MPa		700 MPa		750 MPa	
τ, c	$lg(N/N_0)$	τ, c	$lg(N/N_0)$	τ, c	$lg(N/N_0)$
0	0	0	0	0	0
30	-0,85	30	-1,31	30	-1,99
60	-1,68	60	-2,24	60	-3,18
120	-2,97	120	-3,71	120	-4,44
180	-4,32	180	-4,80	180	-5,82
240	-5,94	240	-6,36	240	-6,65
300	-6,56	300	-7,26	300	-7,50
360	-7,15	360	-7,59	360	-7,99
420	-7,59	420	-8,00	420	-8,00

** τ is processing time, c;*
*** N_0 – initial concentration of microorganisms;*
N is the final concentration of microorganisms.

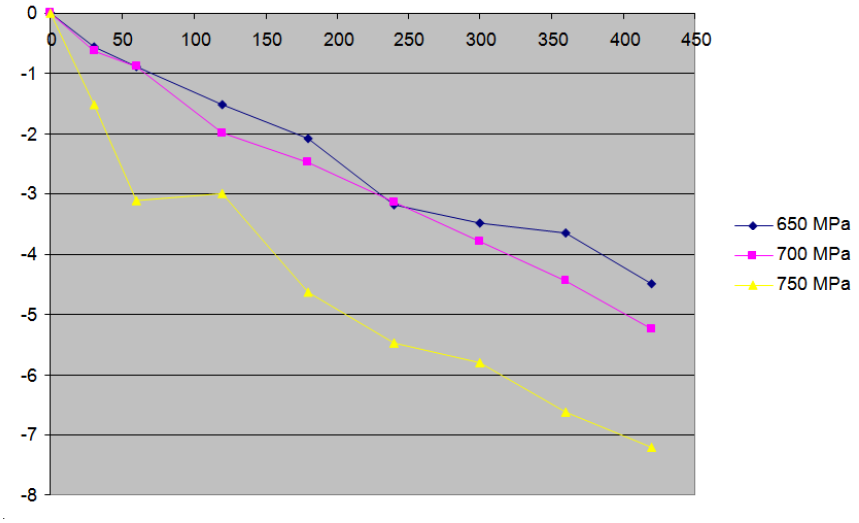

Fig. 1. Experimental points of decrease in the relativeconcentration of Escherichia coli at t = 110 °C

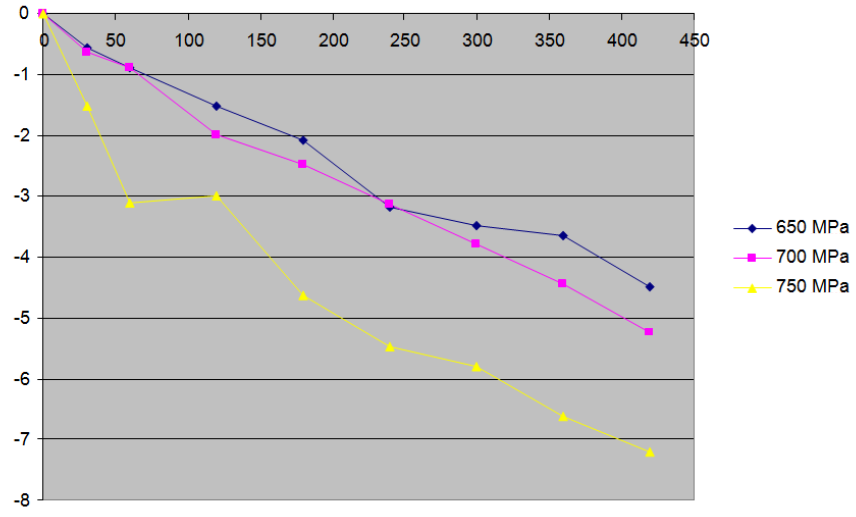

Fig. 2. Experimental points of decrease in the relative concentration of Escherichia coli at t = 120 °C

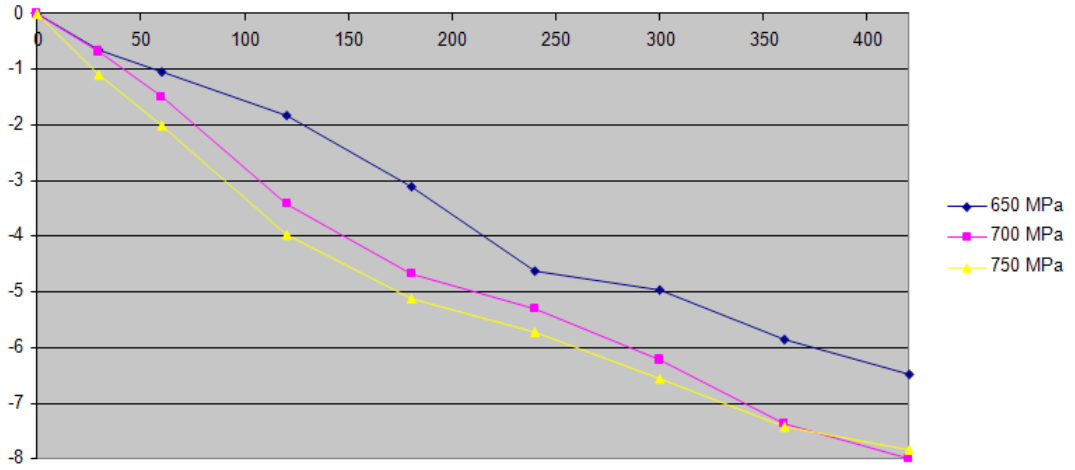

Fig. 3. Experimental points of decrease in the relative concentration of Escherichia coli at t = 130 °C

Inactivation of microorganisms under HP, as well as denaturation of proteins, is often described by kinetic equations of the first order, as a result a logarithm of the concentration of microorganisms surviving after pressure treatment decreases linearly with increasing processing time t as $-kt$, where k is the constant of inactivation rate.

$$-\frac{dN}{dt} = k\ N \quad , \qquad (1)$$

where N – the number of viable organisms;

k – the constant of inactivation rate.

The integral equation (1) taking into account the initial conditions $N=N_0$ at t = 0 was presented in the form:

$$\ln(\frac{N}{N_0}) = -k\,t \quad . \qquad (2)$$

Equation (2) suggests a linear dependence of N on t on a semi-logarithmic scale and it was expressed in terms of the decimal logarithm:

$$\ln(\frac{N}{N_0}) = 2{,}303\log(\frac{N}{N_0}) \quad . \qquad (3)$$

The inactivation rate constant (k) is the most commonly used term to describe the thermal inactivation of microorganisms.

The literature often contains data with significant linear variations which are usually described by a combination of two first-order reactions as a two-phase kinetics with different inactivation rates [22, 23]. The two-phase kinetics is often found both for vegetative and spore forms of bacteria. In such cases, the slope of the logarithm of the concentration over time is observed, the rate of drop for small and large values for t is k_1 and k_2 respectively, and more often, $k_1 > k_2$. A similar form of inactivation curve indicates the existence of a small part of the population with increased resistance to high pressure.

The analysis of the results of the experimental studies made it possible to fix the decrease in the relative concentration of the coliform depending on the parameters of the process.

Similar studies were carried out for samples of egg omelet with bacon and mushrooms, which resulted in the determination of the parameters in the process of egg omelets treatment with HP to ensure the microbiological safety of the product for a long period of storage:

An analysis of the experimental data (Table 1) on the coliform inactivation shows that at given parameters of the process it is advisable to use a two-phase model of the first order to describe the kinetics of the coliform inactivation. This model consists of two parts which follow an independent kinetics of the first order (Fig. 4).

The surviving microorganisms during t are the sum of the separate parts:

$$N(t)= N_1(\tau) + N_2(\tau)\ . \qquad (4)$$

The analytical solution of the above equation is presented as:

$$N(t) = N_0(f\ e^{-k_1 \cdot t} + (1 - f)\ e^{-k_2 \cdot t}), \qquad (5)$$

where N_0 is the initial number of microorganisms and f is the initial proportion of the first part (N_{01}/N_0).

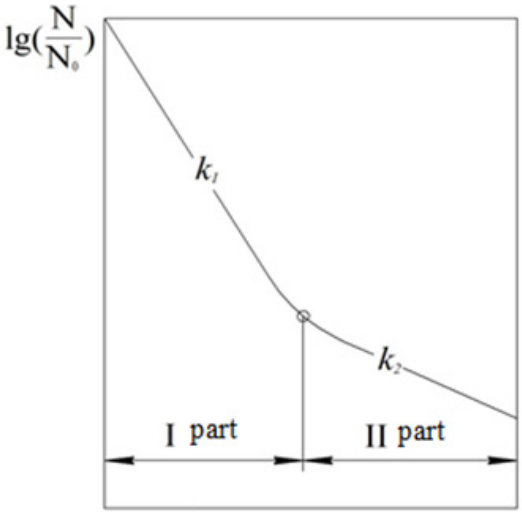

Fig. 4. Typical curve of two-phase inactivation

Each part of the inactivation model is expressed as:

$$\frac{dN_1}{dt} = -k_1 N_1(t), \quad N_1(0)=N_{01}, \tag{6}$$

$$\frac{dN_2}{dt} = -k_2 N_2(t), \quad N_2(0)=N_{02}, \tag{7}$$

where N_1, N_2 – the number of microorganisms in the first and the second part;

τ – the time of processing;

k_1 and k_2 – a constant of inactivation rate.

The dependence of the inactivation rate constants on pressure was analyzed using the Arrhenius-type model. The dependence of pressure and inactivation rate constant k was described by the following equation (8):

$$\left(\frac{\partial \ln k}{\partial P}\right)_T = \frac{-\Delta V^*}{RT}, \tag{8}$$

where k is the first-order inactivation rate constant in c^{-1};

P is the pressure in MPa, ΔV* is the visible activation volume in $м^3 \cdot mol^{-1}$;

R is the gas constant $8{,}314 \cdot 10^{-6}$ $\cdot м^3$ $\cdot$MPa $mol^{-1} \cdot K^{-1}$;

T is the temperature in Kelvin degrees, K.

Equation (8) shows that the dependence of ln (k) on pressure at constant temperature is described by a straight line with a slope $\frac{-\Delta V^*}{RT}$.

In connection with the fact that the second-order kinetic model cannot be adequately estimated by a linear model, a nonlinear estimation was performed using piecewise linear regression and the values of the points of breaking the curves of the second order were obtained (Table 2).

As a result of the experimental data statistical analysis, the inactivation process of the E. coli for all its parameters was described by the following function:

$$\begin{cases} y = a + c\,(x-b) & x < b \\ y = a + d\,(x-b) & x > b \end{cases}. \tag{9}$$

Table 2 shows the numerical values of the coefficients of the model for different values of the process parameters and the statistical characteristics of these dependencies.

Table 2

Results of statistical processing of experimental data

Pressure MPa	*a*	*c*	*d*	*b* inflection point	R^2	F stat	Str. err
Temperature 110 °C							
650 MPa	-3,005	-0,0121	-0,0074	240	0,987	188,9	0,185
700 MPa	-1,877	0,0152	-0,0108	120	0,99	772,1	0,106
750 MPa	-4,476	0,0224	-0,0101	180	0,94	39,5	0,930

Contin. of table 2

Pressure MPa	*a*	*c*	*d*	*b* inflection point	R^2	F stat	Str. err
Temperature 120 °C							
650 MPa	-4,341	-0,0183	-0,012	240	0,99	319,94	0,219
700 MPa	-3,498	-0,0304	-0,015	210	0,99	624,38	0,190
750 MPa	-4,157	-0,0346	-0,013	120	0,99	732,61	0,170
Temperature 130 °C							
650	-6,913	-0,0223	-0,0053	300	0,99	315,94	0,262
700	-6,543	-0,0255	-0,0085	240	0,99	249,24	0,303
750	-6,092	-0,0296	-0,0093	180	0,96	162,72	0,579

Fig. 5 shows graphical relationships that correspond to the data in Table 2.

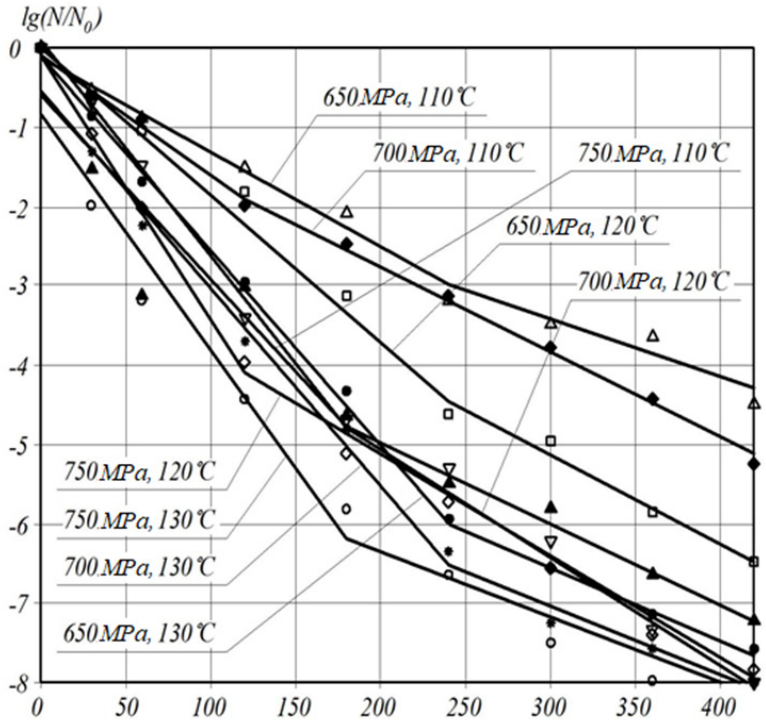

Fig. 5. Graphic dependencies of reduction in relative concentration of the coliform bacteria in the samples of egg omelets with cheese

Mathematical description of the process of inactivation of the coliform at different values of the process parameters has been obtained and analyzed the dependence of the inactivation rate constants of ln (k_1) and ln (k_2) on the pressure for the functions described by the kinetic models of the second order of (Fig. 6).

Graphic interpretation of the dependence of the constant rate of reactions on the process parameters (pressure and temperature) presented in Fig. 6 allowed to analyze the dynamics of the constant reactions rate at different phases of the process.

Table 3 presents the results of experimental studies of the influence on the parameters of the process of egg omelets treatment with HP on the maintenance of microbiological sterility in relation to such microorganisms as mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM); pathogenic microorganisms including salmonella; Psychophilic bacteria *Listeria seeligeri (Listeria innocua), Pseudomonas fluorecens, Paenibacillus polymyxa.*

The analysis of the presented results allows to state that these process parameters provide the necessary level of sterility of the product.

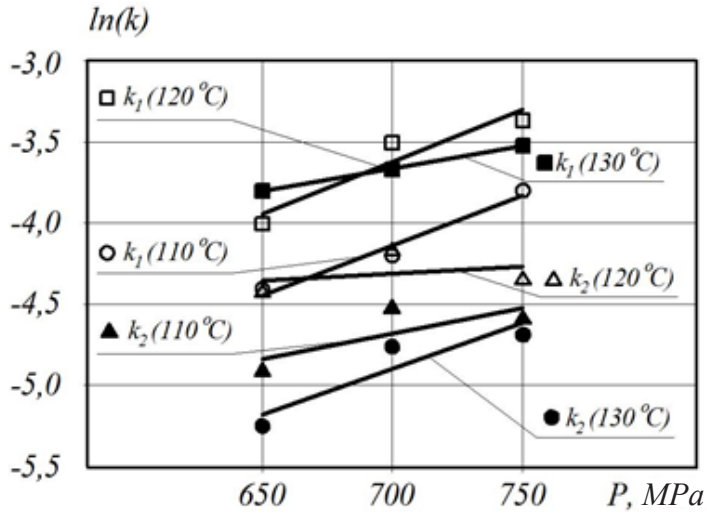

Fig. 6. The dependence of the inactivation rate of ln (k_1) and ln (k_2) constants on the pressure

Table 3

Values of microbiological contamination in egg omelets samples at different values of the processing parameters

Process parameters			CGB (coliforms) in 1,0 g	Pathogenic incl. Salmonella in 25 g	S.aureus in 1,0 g	Proteus in 0,1 g	QMAFAnM, CFU/g
Temperature, ˚C	Pressure, MPa	Time of processing, c					
EOCh.							
121	700	420	n/d*	n/d	n/d	n/d	n/d
EOB							
121	700	420	n/d	n/d	n/d	n/d	n/d
EOCham.							
121	700	420	n/d	n/d	n/d	n/d	n/d

** n/d – not detected.*

Thus, for the first time, we have obtained functional dependences of the change in the relative concentration of E.coli in the treatment of EO with HP with different process parameters. It was first proved experimentally and explained that for different parameters of processing, it is expedient to use kinetic models of the second order.

The dependences of the change of the inactivation rate constants ln (k_1) and ln (k_2) depending on the pressure for kinetic models of the second order have been obtained. The values of microbiological insemination of E. coli were determined depending on the parameters of the processing the egg omelet with high pressure as well as the technological parameters of the process that ensure the microbiological safety of the egg omelet in relation to *Pseudomonas fluorecens, Paenibacillus polymyxa and Listeria seeligeri.*

The samples produced at the process parameters of 700 MPa – 121 °C – 6 min were used to study the dynamics of microbiological safety indicators of EO samples with cheese, bacon and champignons processed with HP under storage. The test specimens were stored in a sealed package in which they were treated with HP at a temperature of 4±0,5 °C with a relative humidity of 85 % to 88 %. The repetition of measurements at this point is threefold. Monitoring of microbiological parameters was carried out every 30 days of their storage. The repetition of measurements at this point is threefold. Analysis of microbiological safety according to the above 5 indicators showed that during 6 months of storage in the samples of EO were not detected: CGB (coliforms) in 1,0 g, pathogenic including Salmonella in 25 g. S.aureus in 1,0 g. Proteus in 0,1 g. At the 5th and 6th

months of storage were discovered QMAFAnM, CFU/g in the amount of $1 \cdot 10^5$ и $1 \cdot 10^4$ which is significantly lower than the allowable values for this indicator. Also, psychophilic bacteria of the species *Listeria seeligeri (Listeria innocua), Pseudomonas fluorecens and Paenibacillus polymyxa* were not detected.

Conclusions on the indicated problems and prospects of further research in this direction. The conducted studies allowed to determine the dependence of microbiological insemination (E. coli, Pseudomonas fluorecens, Paenibacillus polymyxa and Listeria seeligeri) of EO on the parameters of the process of their HP treatment (pressure, temperature and duration of the process). For the first time, the fact that it is expedient to use kinetic models of the second order to describe the process of inactivation of the E. coli has been proposed and experimentally established. The dependences of the change of the inactivation rate constants ln (k_1) и ln (k_2) on the pressure of kinetic models of the second order have been obtained. The values of microbiological contamination (*E. coli, Pseudomonas fluorecens, Paenibacillus polymyxa and Listeria seeligeri)* have been determined for long-term storage of egg omletes treated with HP.

Further research is advisable to focus on the study of the consumer properties of egg omelets produced with using HP.

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В. А. Сукманов, *доктор технических наук, профессор;* ***Н. В. Герман,*** *доцент;* ***Д. А. Миронов,*** *кандидат технических наук (Высшее учебное заведение Укоопсоюза «Полтавский университет экономики и торговли»);* ***А. А. Палаш,*** *кандидат технических наук (Полтавский техникум пищевых технологий Национального университета пищевых технологий).*

Влияние параметров процесса обработки яичных омлетов високим давлением на их микробиологическую безопасность.

Аннотация. Цель *работы – получение зависимостей микробиологической обсемененности (E. coli, Pseudomonas fluorecens, Paenibacillus polymyxa и Listeria seeligeri) яичных омлетов с различными наполнителями от параметров процесса их обработки высоким давлением*

(величина давления, температура и продолжительность процесса). ***Методика исследования.*** *Образцы обрабатывали в диапазоне таких параметров процесса: предварительный нагрев смеси – до 85-95 °С, давление – 650-750 МПа, время обработки – до 8 мин.* ***Результаты.*** *Впервые предложен и экспериментально установлен тот факт, что для описания процесса инактивации кишечной палочки целесообразно использовать кинетические модели второго порядка. Установлены зависимости изменения констант скорости инактивации ln (k_1) и ln (k_2) в зависимости от величины давления для кинетических моделей второго порядка.* ***Выводы.*** *Получены значения микробиологической обсемененности яичных омлетов, обработанных высоким давлением E. coli, Pseudomonas fluorecens, Paenibacillus polymyxa и Listeria seeligeri при их длительном хранении.*

Ключевые слова: *яичные омлеты с наполнителями, срок хранения, микробиологическая безопасность, высокое давление.*

В. О. Сукманов, *доктор технічних наук, професор;* ***Н. В. Герман,*** *доцент;* ***Д. А. Миронов,*** *кандидат технічних наук (Вищий навчальний заклад Укоопспілки «Полтавський університет економіки і торгівлі»);* ***А. А. Палаш,*** *кандидат технічних наук (Полтавський технікум харчових технологій Національного університету харчових технологій).* ***Вплив параметрів процесу обробки яєчних омлетів високим тиском на їх мікробіологічну безпечність.***

Анотація. Мета *роботи – отримання залежностей мікробного обсіменіння (E. coli, Pseudomonas fluorecens, Paenibacillus polymyxa і Listeria seeligeri) яєчних омлетів із різними наповнювачами від параметрів процесу їх обробки високим тиском (величина тиску, температура та тривалість процесу).* ***Методика дослідження.*** *Зразки обробляли в діапазоні таких параметрів процесу: попередній нагрів суміші – до 85-95 °С, тиск – 650-750 МПа, час обробки – до 8 хв.* ***Результати.*** *Уперше запропоновано і експериментально встановлено той факт, що для опису процесу інактивації кишкової палички доцільно використовувати кінетичні моделі другого порядку. Установлено залежності зміни констант швидкості інактивації ln (k_1) і ln (k_2) залежно від величини тиску для кінетичних моделей другого порядку.* ***Висновки.*** *Отримано значення мікробного обсіменіння яєчних омлетів, оброблених високим тиском E. coli, Pseudomonas fluorecens, Paenibacillus polymyxa і Listeria seeligeri за їх тривалого зберігання.*

Ключові слова: *яєчні омлети з наповнювачами, термін зберігання, мікробіологічна безпека, високий тиск.*