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The application of statistical modeling tools to predict the growth evolution of food born moulds

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Abstract

The prevention of the food product contamination with toxinogenic moulds depends mainly on the understanding of the fungal alteration phenomenon during the processing, conditioning and keeping. Consequently it is necessary to have precise diagnostic methods in order to predict and describe in detail the dynamic of the alteration. One of the useful tools in the predictive mycology is the statistical modeling, used in this paper in order to describe the mycelia growth of two moulds isolated from Romanian food.

This article presents aspects of using mathematical and statistical modeling in predictable microbiology. They are listed as found in literature, theoretical concepts relating to current mathematical models used in the study of biological processes, statistical analysis techniques involved in establishing the model primary by mycelia growth, examples are presented for some experimental data, calculations been made using Excel software and Slide Writer.

Keywords: food born moulds, statistical modeling, predictive models, growth, toxinogenesis

Introduction

The prevention of the food product contamination with toxinogenic moulds depends mainly on the understanding of the fungal alteration phenomenon during the processing, conditioning and keeping. Consequently it is necessary to have precise diagnostic methods in order to predict and describe in detail the dynamic of the alteration. One of the useful tools in the predictive mycology is the statistical modeling, used in this paper in order to describe the mycelia growth and mycotoxin production of two moulds isolated from Romanian food of intermediary humidity.

This research belongs to a national project regarding the prevention of the mycotoxin contamination in feed and food.

At the very beginning of the project there have been isolated and identified the main species involved in the alteration of food products of intermediary activity.

Finally, 54 moulds strains have been identified, belonging to the following genders: *Aspergillus, Alternaria, Fusarium, Penicillium, Rhizopus, Cladosporium, Macrosporium.*

The strains have been screened for their toxinogenic activity (aflatoxins, ochratoxin A and deoxynivalenol production) by on-plate method and the toxins were quantified by Elisa Immunologic tests. 38 of those moulds showed toxinogenic activity under laboratory tests.

From this toxinogenic collection, four strains (*Fusarium graminearum MI* 107 and *MI* 113 and *Penicillium crysogenum MI* 208 and *MI* 210*)* have been studied for their growth and

mycotoxin (DON and OTA) production from a predictive point of view, depending on the environmental conditions.

Former studies showed that the decisive models usually involved in the study of physical, chemical and biological processes, are characterized by certain equations with partial derivatives [2], [6] and [8].

However, these models are only a first step in studying the biological process of determining the mycelia growth rate, because the analysis of such a phenomenon should be taken and random physical aspects involved, which argues about the character of these models. It is logical for this purpose and involvement stochastic models, in which certain elements of equations are partially known, doubtful or fluctuating. It is known that the value of a given model is the extent to which it tallies with reality. Therefore, since the stages of preparing a model, should be taken to maintain a rational balance between the precision required and the information held primary.

Any model contains a number of parameters to be estimate, to compare the data with empirical prediction. It is important that the parameters of the model to be studied in conditions close to those of nature or the existing laboratory. A strategy review process includes the formulation of the problem, objectives and criteria of appreciation and recognition for the preliminary classification process elements.

In an effort to find some adjustments as the best of graphs, which represents the mycelia growth rate growth curve at different temperatures were called and other statistical analysis techniques, such as estimating the parameters by the method of confidence intervals, hypothesis and statistical tests, but also elements correlation of theory and regression.

Material and Method

1. Microorganisms

Strains: toxinogenic filamentous fungi *Penicillium chrysogenum* MI 208 and MI 210; *Fusarium graminearum* MI 107 and MI 113.

Before use, all strains were activated by successive passages on the average PDA for 7 days of culture at 27 ° C. The spores were harvested in a solution of water physiologic sterile (9 g / l of NaCl) going from the two strains of *Penicillium sp*. and *Fusarium sp*., through the scraping light area of colonies with a Pasteur pipettes.

The inoculation was done in the center of boxes with Petri Czapek-Dox in duplicate for each strain taken in work. On Czapek-Dox medium it have been measured the mycelia growth (diameter of the colony in cm).

The samples have been studied in triplicate, under different temperature conditions ((4°C, 12°C, 16°C, 20°C, 26°C, 30°C, 33°C, 36° C).

2. Statistical analysis of experimental data

2.1. Collecting and processing data poll

As noted above, any mathematical model contains a number of parameters to be estimate, to compare the data with empirical prediction. This estimate takes place after the collection and processing of experimental data. Synthetic are presented below, the mathematical elements that characterize this process. The purpose of introducing the mathematical processes in an experimental research is to find a convenient result, allowing the phenomenon analyzed forecasts.

The collection of experimental data is done in most cases on a population of selection. Because the results from the survey research data to be relevant to the entire population statistics, the poll must be representative, that is, must meet the following conditions:

- the statistical units which consists of evidence are chosen through a random process;
-each individual statistical population must have the same opportunity to participate in the survey;
-the selection structure to be as closer to the general population;
-the volume selection to be higher.

In this case, the experimental data that are the subject of statistical analysis that follows so conduct, it refers to evolution (growth in cm.) Over 14 days for a strain of *Penicillium crysogenum*, one of *Fusarium graminearum*.

The appropriation of quantitative studied *X*, stalk growth is measured in moments of time equidistance (measurements are made at a time of 24 hours). In these circumstances, we calculate:

1. The chronological mean:

$$\overline{X_C} = \frac{x_1 + ... + x_{n-1}}{n-1}, \quad (1)$$

where $x_1, ..., x_n$ are the values of survey recorded.

2. The pace of evolving environmental value:

$$D = \frac{x_n - x_1}{n-1}. \quad (2)$$

In the case of multiple measurements (2 when analyzed for *Penicillium crysogenum* and 2 for *Fusarium graminearum*), these indicators are calculated sampling progress for each temperature, which was conducted experiment. If $\overline{X_{C_1}}$, $\overline{X_{C_2}}$ are the chronological means for the first copy studied respectively for the second, *Penicillium crysogenum*, then,

3.The timeline global mean is determined by the formula:

$$\overline{X_C} = \frac{\overline{X_1} + \overline{X_n} + 2\left(\overline{X_2} + ... + \overline{X_{n-1}}\right)}{2(n-1)}, \quad (3)$$

which $\overline{X_i}$ means the arithmetic averages of data obtained from observation points *i*, $1 \le i \le n$, ie.

$$\overline{X_i} = \frac{x_{1i} + x_{2i}}{2}, \quad 1 \le i \le n.$$

4. The global average rate will be calculated in this case by the formula:

$$D = \frac{\overline{X_n} - \overline{X_1}}{n-1}. \quad (4)$$

5. The mean overall poll is determined by applying the formula:

$$\overline{X} = \frac{1}{n}\left(\overline{X_{C_1}} + ... + \overline{X_{C_n}}\right). \quad (5)$$

6. The global standard deviation is calculated by applying the formula:

$$S = \sqrt{\frac{1}{n}\left[\left(\overline{X_{C_1}} - \overline{X}\right)^2 + ... + \left(\overline{X_{C_n}} - \overline{X}\right)^2\right]}. \quad (6)$$

2.2. The estimation of population parameters through the confidence interval method

It is a statistical method frequently used in the study of many phenomena in biology, agriculture, technical, economics, etc.. The method consists in determining an interval that covering the parameter (*the mean* of studied nature, noted with μ, and the *variance*, noted with σ^2), with a probability higher. This probability (noted with the *p*), is called the probability of confidence, and is a risk that what you anticipate not take place.

It uses the following notations:

X - is random variable, representing the studied character;

$x_1,...,x_n$ - taken by the variable *X*, following *n* observations;

$n_i, i=1,...,n$ -the absolute nature frequency (the number of occurrences value);

$\bar{x}$ - *the selection mean*, calculated by:

$$\bar{x}=\frac{\sum_{i=1}^{n} n_i x_i}{n}, \tag{7}$$

s^2 - *the selection dispersion*, which is determined by the formula:

$$s^2=\frac{1}{n-1}\sum_{i=1}^{n} n_i\left(x_i-\bar{x}\right)^2, \tag{8}$$

s - *the standard deviation*, representing the square root of dispersion.

a) *The confidence interval for the average value* μ of a character *X*, normally distributed. If σ^2, the *X* 's dispersion character for population is unknown, then the confidence interval for μ is:

$$\mu\in\left(\bar{x}-\frac{s}{\sqrt{n}}t_{\alpha/2;n-1};\bar{x}+\frac{s}{\sqrt{n}}t_{\alpha/2;n-1}\right), \tag{9}$$

where $t_{\alpha/2;n-1}$, it is a table value, which is the critical value to the Student distribution which is determined according to the risk α and $n-1$ degrees of freedom.

b) *The confidence interval of dispersion* σ^2 of a character normally distributed is determined by the formula:

$$\sigma^2\in\left[\frac{(n-1)s^2}{\chi^2_{\alpha/2;n-1}};\frac{(n-1)s^2}{\chi^2_{1-\alpha/2;n-1}}\right], \tag{10}$$

where $\chi^2_{\alpha/2;n-1},\chi^2_{1-\alpha/2;n-1}$ are table values, which means the critical distribution χ^2, calculated for the risks $\alpha/2$, and $1-\alpha/2$, $n-1$ degrees of freedom.

c) *The confidence interval for the averages differences* $(\mu_2-\mu_1)$ of a quantitative character in two normal populations.

If the variances are unknown, then the confidence interval is given by the formula:

$$\mu_2-\mu_1\in\left[\overline{x_2}-\overline{x_1}-s\sqrt{1/n_1+1/n_2}\,t_{\alpha/2;n_1+n_2-2};\overline{x_2}-\overline{x_1}+s\sqrt{1/n_1+1/n_2}\,t_{\alpha/2;n_1+n_2-2}\right], \tag{11}$$

where

$$s^2=\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}, \tag{12}$$

d) The confidence interval for the standard deviations report $\left(\frac{\sigma_2}{\sigma_1}\right)$ of the same character in two normal populations, are determined by the formula:

$$\frac{\sigma_2}{\sigma_1} \in \left[0, \frac{s_2}{s_1}\sqrt{F_\alpha}\right], \tag{13}$$

where F_α, is the table value representing the critical distribution Fisher, for the risk α.

2.3. Analysis of the correlation and regression.

It is a technical mathematical statistics, which highlights the influence of certain factors, the characteristics of the population. By this method, are established the links between certain phenomena, the degree of intensity, and weighting various factors to a mass phenomenon.

The correlation theory based on investigative methods of statistical data, to determine the wishes of equations, which gives value of a variable, depending on the other, finding the correlation coefficient, error estimation. One of the immediate consequences of this finding equations between variables, is the establishment of forecasts of a variable when it has been awarded the other values.

The regression is a way to research a relationship that has previously been established between a variable *y*, called the dependent variable and one or more variables $x_1, ..., x_n$, known as independent variables.

If this dependency is characterized by a linear equation, then the right line corresponding to this relationship is called the right line of regression.

Below, will be presented several theoretical issues relating to the correlation simple. If deemed two variables *x* and y, then, the correlation coefficient, noted by ρ_{xy}, expressing the intensity of the link between the two variables, indicating the table dispersion of *y*, table around the right line of regression.

This factor is calculated by:

$$\rho_{xy} = \frac{\overline{xy} - \overline{x}\,\overline{y}}{s_x s_y}, \tag{14}$$

the terms that appear in formula were defined before.

In the case of linear correlation, if the experimental data were collected from a sample by volume n, then the correlation coefficient of linear, noted with r_{xy} and is determined by the formula:

$$r_{xy} = \frac{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)\left(y_i - \overline{y}\right)}{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2 \sum_{i=1}^{n}\left(y_i - \overline{y}\right)^2}. \tag{15}$$

The correlation coefficient is compared with ± 1 values and how this factor is closer to these values, the dispersion of values and spreading around the right line of regression is less, may be easily determined values of *y*, according to the known values of *x*. If $\rho_{xy} = 0$ then there isn't a correlation between those two variables.

If the dependence of the two variables is not linear, it is replaced with the correlation coefficient *report correlation*, calculated by:

$$\eta = \sqrt{\frac{SPA_A}{SPA_T}} \ , \tag{16}$$

where SPA_H is the sum of squares standard deviations between the variants, calculated as follows:

$$SPA_A = \sum_{i=1}^{k} S_i^2 / r - S^2 / kr \ , \tag{17}$$

k, is the variations number of x factor, acting on his y, r is the number of rehearsals,

$S_i^2 = \sum_{j=1}^{r} x_{ji}$ $S^2 = \left(\sum_{i=1}^{k} S_i \right)^2$, and the sum of squares irregularities,

$$SPA_T = \sum_i \sum_j x_{ij}^2 - S^2 / n \ . \tag{18}$$

It is calculated an experimental value noted with F as the following formula:

$$F = \frac{n-k}{k-1} \frac{\eta^2}{1-\eta} , \tag{19}$$

which compares the table value of Fisher test, determined according to α and $(k-1, n-k)$ degrees of freedom, and if $F_{\text{exp}} < F_{tab}$, then the dependence between the two variables is insignificant, if not as significant.

Analogously, the meaning linear correlation coefficient r_{xy}, is specified by comparing it with the table value of correlation coefficient linear simple, calculated on the basis of α and $n-2$ degrees of freedom. As in the previous case, if the amount is less experimental than the table value, then the dependence of x and y is insignificant.

An interesting problem of the correlation theory is comparing the two coefficients of correlation. They are calculated values

$$z_i = \frac{1}{2} \ln \frac{1+r_i}{1-r_i}, \quad i = 1,2 \ , \tag{20}$$

where r_1, r_2 are the correlation coefficients, obtained as a result of the n_1, n_2 observations. It then calculated the amount of experimental

$$t_{\text{exp}} = \frac{z_1 - z_2}{\sqrt{\frac{1}{n_1 - 3} + \frac{1}{n_2 - 3}}} \ , \tag{21}$$

to be compared to the table value of Student test, determined on the basis of α and $n-2$ degrees of freedom

If $t_{\text{exp}} < t_{tab}$, than the difference between the two coefficients of correlation is insignificant.

Provisions for the evolution of a phenomenon may be obtained by applying statistical tests. Thus, in addition parametrical tests in the normal population (tests for the mean and dispersion of a quantitative character in a normal population, to mean's different and dispersion's report), are extremely efficient and nonparametric tests (test "hi square," dependency the two characters X, Y, accuracy of the survey tests, normality test a population in relation to a character, etc.). They, together with the methods listed above, are just some of

the most important tools of mathematical statistics used in determining the forecasts on the evolution of a particular phenomenon.

Results and Discussions

1. Primary model of the mycelium growth of *Penicillium chrysogenum* and *Fusarium graminearum* toxinogenic strains

The primary results have been obtained as a result of daily measurements of the growth rate and of the mathematical equations applied on biological parameters. It has been considered *X*, the growth rate (in cm) for the strain of *Penicillium crysogenum* and *Y*, the growth rate (in cm) for the strain of *Fusarium graminearum*. There are 14 equidistance measurements, the statistical indicators are determined for each temperature in part. Below are presented the values obtained for the temperature of 26°C (table 1).

Table 1 - The statistical indicators at T = 26 °for *Penicillium crysogenum*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	$\overline{X_{C_i}}$
1	1,4	1,8	2,5	2,8	3,5	3,9	4,4	4,7	4,9	5	5,2	5,2	5,3	5,3	4,04
2	1,4	1,6	2,1	2,7	3,1	3,5	3,8	4	4,2	4,2	4,3	4,5	4,5	4,5	3,49
$\overline{X_j}$	1,4	1,7	2,3	2,75	3,3	3,7	4,1	4,35	4,55	4,6	4,75	4,85	4,9	4,9	3,76 3,76

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	$\overline{Y_{C_i}}$
1			0,5	1,55	4,6	5,1	6,5								3,68
2			0,4	0,9	5,1	6,2	7,5								4,03
$\overline{Y_j}$			0,45	1,22	4,85	5,65	7								3,85 3,86

Applying the statistical equation described above the statistical indicators of the growth are:
1. The timeline global mean:

$\overline{X_C} = 3,76$ cm for *Penicillium crysogenum*

$\overline{Y_C} = 3,85$ cm for *Fusarium graminearum*

2. The global average rate:

$D_P = 0,26$ cm for *Penicillium crysogenum*

$D_F = 1,63$ cm for *Fusarium graminearum*

3. The mean overall poll:

$\overline{X} = 3,76$ cm for *Penicillium crysogenum*

$\overline{Y} = 3,86$ cm for *Fusarium graminearum*

4. The global standard deviation:

$S_P = 0,107$ cm for *Penicillium crysogenum,*

$S_F = 0,123$ cm for *Fusarium graminearum*

For the same experimental data are determined the confidence intervals for the average global, standard deviation, and to different environments growth recorded at different temperatures.

For the values obtained at temperature T = 26 °, there have been obtained the following results:

a) If it is applied the formula (9), the likelihood of trust by 95% and the table value $t_{\alpha/2;n-1} = t_{2,5\%;13} = 0,694$, it obtains the confidence intervals for the average growth of strains of *Penicillium crysogenum*:

$$\mu_P \in \left(3,76 - \frac{0,107}{\sqrt{14}}0,694; 3,76 + \frac{0,107}{\sqrt{14}}0,694\right) = (3,74; 3,78) \quad ,$$

b) If it is applied the formula (10), the likelihood of trust by 95% and table values $\chi^2_{\alpha/2;n-1} = \chi^2_{2,5\%;13} = 24,74$ and $\chi^2_{1-\alpha/2;n-1} = \chi^2_{0,975\%;13} = 5,01$, it obtains the confidence intervals for the dispersion of growth strains of *Penicillium crysogenum*:

$$\sigma^2 \in \left[\frac{13 \cdot 0,107}{24,74}; \frac{13 \cdot 0,107}{5,01}\right] = [0,0562; 0,2776] \ ,$$

c) If it is used the formula (11), the likelihood of trust by 95% and the following table value, $t_{\alpha/2;n_1+n_2-1} = t_{2,5\%;26} = 0,684$, it results confidence intervals for the difference of growth means by strains of *Penicillium crysogenum* for two different temperatures. We consider the case, for instance temperatures T = 26 ° C and T = 30 ° C. Then, the confidence interval of the difference means for the first temperatures is:

$\mu_2 - \mu_1 \in (3,76 - 1,65 - s \cdot 0,378 \cdot 0,684; 3,76 - 1,65 + s \cdot 0,378 \cdot 0,684) = (2,085; 2,135)$ cm

where $s = 0,098$ cm.

Similar we can determine the confidence interval to the general mean, standard deviation, and to differences of growth means by strains of *Fusarium graminearum* , recorded at different temperatures.

2. Validation of the primary model with mathematical methods

In order to establish some conclusions regarding the growth model to determine which estimates best the studied situation, are made appropriate graphics corresponding to the development strains of *Penicillium crysogenum* and *Fusarium graminearum* during the 14 days that measurements were made, at certain temperatures. It is originally indicated, in accordance with graphics obtained, mathematical curves that estimates best studied phenomenon, namely primary model.

It made such a development for *Penicillium crysogenum*, at temperature T = 30 °, as indicated rate of growth within 24 hours. In the next step is verified the growth model's plausible for the species *Pencillium crysogenum*.

Because the analysis period, the evolution phenomenon presents a continuous growth, the empirical points curve presents a form that can be estimated depending logarithmical function, the model that can be used for the evolution of the phenomenon is an approximation of the form:

$$y_t = f(t) + u_t$$

where:

$y_t =$ the recorded values during the period examined phenomenon

$f(t) =$ the trend component that can be described with a logarithmical functions:

$Y_t = f(t) = a + b * \ln t$

$u_t =$ the residual variable.

In making the calculations easier, it notes $x_t = \ln t$. The model turns in one straightforward:

$y_t = a + b * x_t + u_t$

After conducting calculations it was resulted the following system of equations:

$$\begin{cases} 14 \cdot \hat{a} + 25{,}19122 \cdot \hat{b} = 689 \\ 25{,}19122 \cdot \hat{a} + 53{,}1185 \cdot \hat{b} = 1373{,}177 \end{cases} \Rightarrow \begin{cases} \hat{a} = 18{,}39919 \\ \hat{b} = 17{,}12546 \end{cases}$$

The estimate of the residual variable will result in the following relationship:

$$\hat{u}_t = y_t - \hat{Y}_t$$

In order to test the parameters and significance of the model will calculate:

The residual variation of dispersion:

$$s^2_{\hat{u}_t} = \frac{\sum \hat{u}_t^2}{T - k - 1} = \frac{41{,}64805}{12} = 3{,}47067 \Rightarrow s_{\hat{u}_t} = 1{,}8629$$

The average square deviations of the two estimators: $\hat{a}$ and $\hat{b}$

$$s_{\hat{a}} = \sqrt{s^2_{\hat{u}_t} * \left[\frac{1}{T} + \frac{\bar{t}^2}{\sum (t - \bar{t})^2} \right]} = \sqrt{3{,}47067 * \left[\frac{1}{14} + \frac{1{,}799373^2}{7{,}790094} \right]} = 1{,}3001$$

$$s_{\hat{b}} = \sqrt{\frac{s^2_{\hat{u}_t}}{\sum (t - \bar{t})^2}} = \sqrt{\frac{3{,}47067}{7{,}790094}} = 0{,}6674$$

Because the number of terms of the series is less than 30, the estimators testing will be done using the test "t" - Student. The Student distribution table for a threshold of significance $\alpha = 0{,}05$ and the number of degrees of freedom $\nu = n - k - 1 = 12$, to take value $t_{0{,}05;12} = 2{,}179$.

$$t_c = \frac{|\hat{a}|}{s_{\hat{a}}} = \frac{18{,}39919}{1{,}3001} = 14{,}152 > t_{0{,}05;12} = 2{,}179$$

$$t_c = \frac{|\hat{b}|}{s_{\hat{b}}} = \frac{17{,}12546}{0{,}6674} = 25{,}659 > t_{0{,}05;12} = 2{,}179$$

So, for significance threshold of 5% the both estimators are significantly different from zero.

The correlation report correlation value:

$$R = \sqrt{1 - \frac{\sum \hat{u}_t^{\,2}}{\sum (y_t - \bar{y})^2}} = \sqrt{1 - \frac{41{,}64805}{2326{,}357}} = 0{,}991008$$

The testing correlation report is made by Fisher- Snedecor test:

$$F_c = \frac{T-k-1}{k} * \frac{R^2}{1-R^2} = \frac{12}{1} * \frac{0{,}98209}{0{,}0179} = 658{,}38435$$

The table distribution Fisher-Snedecor, for a threshold of significance $\alpha = 0{,}05$ and the number of degrees of freedom $\nu_1 = k = 1$ and $\nu_2 = T - k - 1 = 12$, it takes the value $F_{0{,}05;1;12} = 4{,}76$

If $F_c = 658{,}38435 > F_{0{,}05;1;12} = 4{,}76$, the correlation report is significantly different from zero, for a threshold of significance $\alpha = 0{,}05$.

With a view to verifying the independence of residual variable values will be used Durbin - Watson test, which consists of calculating the amount of:

$$d = \frac{\sum_{t=2}^{n} (\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{n} \hat{u}_t^{\,2}} = \frac{72{,}45473}{41{,}64805} = 1{,}7396$$

From the distribution table Durbin-Watson, a threshold of significance $\alpha = 0{,}05$, depending on the number of observations $T = 14$ and on the number of variables exogenous $k = 1$, it takes the values (over the case $n = 15$): $d_1 = 1{,}08$;

Because $d_2 = 1{,}36 < d = 1{,}73 < 4 - d_2 = 2{,}64$ it can accept the hypothesis of independence residual variables.

3. Preliminary data regarding the mycotoxin production

Regarding the production potential of the two types of micotoxins, depending on the temperature and incubation time, were analyzed 72 samples obtained from *Fusarium graminearum MI 113,* producing micotoxina DON and 72 samples obtained from *Penicillium chrysogenum MI 210*, producing micotoxin OTA. The analysis results were noted the following points: the strain of *Fusarium graminearum 37*, the highest concentration of DON micotoxin was obtained from incubation temperature of 26º C, day 17 of sampling, otherwise this value temperature , 26° C, were found to increase the concentration of DON micotoxin during all 17 days of , starting initially be in the first day of a concentration of DON of 89.44 ppb, the strain of *Penicillium chrysogenum*, concentration the largest of micotoxina OTA has been recorded in 17 day-of incubation, temperature of 36° C. Regarding the OTA determination, the chromatographic methods led to the following conclusions: the ability of the most high biosynthesis by OTA has been recorded in the cultivation of fungal stalk at 23º C, with the maximum value from 8 days of cultivation, at low temperatures, respectively 12º C , a extension of time cultivation has caused a significant increase synthesis of micotoxins covered in this study, the accumulation of OTA cultural extension of time, if cultivation is less evident at 16 and 26º C .

Conclusions

The application of described statistical tools to the existing experimental data, has conducted to the following results:

- the growth of the *Fusarium graminearum* strains under eight different temperatures levels involves a correlation coefficient of $r = 0,41575$, an experimental test value $t_{stud} = t_{\exp} = 0,3432$, while the table value is $t_{tab} = 2,22814$. Comparing these values, it can be stated that there is a linear correlation of strains growth versus time; to the same finding one can arrive and applying some models of growth (logistics function, Gompertz model, etc.).

- for the *Penicillium crysogenum* strains, it has been measured a correlation coefficient of $r = 0,18096$, the experimental test value $t_{stud} = t_{\exp} = -0,58186$, while the table is $t_{tab} = 2,22814$.

Comparing these values, we can draw a similar conclusion for *Fusarium graminearum*, respectovely that there is a linear relationship between an increase resulting from different temperatures and time.

The analysis of the results and the determination the type of curve after which the fungi growth in the initial experience, it has been made both for *Penicilium crysogenu*m as well as for *Fusarium graminearum* with package programs Eviews, which is a dedicated software essentially economic and statistical analysis of experimental data .

In order to test the significance and model parameters used it is recommened to be calculated:

- the residual variation of dispersion, to checking independence variable residual values used to test Durbin-Watson;
- the square average deviation;
- the correlation report and test its relationship with Fisher-Snedecor test;
- the checking plausible model using the method of variance analysis.

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