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MICROBIAL GROWTH FLUCTUATING IN RESPONSE TO SOLAR-TERRESTRIAL ACTIVITY VARIATIONS

Populations of microorganisms display fluctuations in the variable physiological and biochemical properties during cultivation under constant laboratory conditions. A series of explanations were proposed for this phenomenon, and different factors were studied as possible regulators. It was found that such fluctuations possess cosmic rhythms, but no factor(s) were proposed that could sufficiently explain and predict the magnitude of changes that happened on a daily basis in the long-term experiments. In this study we investigated specific growth rate fluctuations of Saccharomyces cerevisiae yeasts that were marked daily during cultivation under constant conditions. The effects of different solar and terrestrial factors were then analysed. The significant correlation indices were found for growth rate fluctuations against solar wind speed and the number of flares M on the Sun. These two factors determined the cyclic nature of the growth rate fluctuations, and thus its general course of increase or decrease. The effects of several other factors (Flares C number, planetary A index variation, and changes in the atmospheric factors such as temperature and humidity) and their two-way interactions were significant in producing an equation to describe the magnitude of changes of the yeast's growth parameters. The R^2 of the equation achieved 91 % and adjusted R^2 was 78 %. It is obvious that temperature and humidity are the factors that cannot directly influence the yeast populations under laboratory conditions and thus we suppose that they only reflect modifications of the really important factor(s) that take place in the Earth's atmosphere. We have concluded that different solar and terrestrial factors are responsible for the fluctuations in the daily kinetic parameters of the yeast growth.

Key words: growth rate fluctuations, yeast, Saccharomyces cerevisiae, solar activity, atmospheric factors.

Living organisms are open systems and their development depends on both the direct contact with external physical, chemical and biological factors and a possibility of forming appropriate responses to the action of these factors. As a consequence, flows of processes in the nonliving and living nature have general rules and therefore biological objects possess cosmophysical rhythms [3]. Current knowledge in the field of biological rhythms is extremely poor. It is well known, that animals, plants, fungi and cyanobacteria display seasonal and daily or circadian rhythms in their biochemistry, physiology and/or behaviour [7, 8, 10]. However, much remains undecided at present, for example, whether seasonal reproduction is mainly a direct response to environmental conditions or whether it involves the photoperiodic machinery with memory capacities and relationship to the circadian system [7]. Woelfle and Johnson [10] asserted that «a variety of biological processes in various organisms are controlled by biological clocks. These processes include gene expression, photosynthesis, sleeping/waking and development and this regulation is thought to help organisms adapt to the daily changes in light, temperature and other factors in their environment. Circadian regulation of gene expression (i.e., the levels of specific proteins in cells) can be accomplished by clock control of transcription, mRNA stability, translation and protein degradation». Nevertheless, the reasons why the same biological process runs different ways from one day to the next are still unclear as are the factor(s) that influence the work of biological clocks [4, 6]. Undoubtedly the cosmo-physical factors have a significant influence on different processes of the Earth, whilst the analysis of the literature shows that most research is aimed at discovering the mechanisms of seasonal and circadian rhythms rather than the solar and geophysical activities and thus, the cosmic rhythms remain almost completely unconsidered [1, 5].

Thus the main task of our study was to explore fluctuations in the specific growth rate parameters of the yeast *Saccharomyces cerevisiae*, which occur under constant laboratory conditions, and to analyse findings by comparing them with the parameters of activity of the solar and atmospheric factors during the same period.

MATERIALS AND METHODS

Yeast strain and cultivation parameters. The yeast *Saccharomyces cerevisiae* strain Y-517 from the Ukrainian Collection of Microorganisms at the Zabolotny Institute of Microbiology and Virology of NAS of Ukraine were used in this study. The culture of yeast was initially grown on agar

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medium at 28 °C during 24 h and then washed off with sterile distilled water, filtered and diluted to 10^9 cells/ml (OD_{540} = 0.75). Aliquots of received cell suspension were added to 10 ml of Ryder medium in 50 ml glass flasks and the concentration was adjusted to 10^6 cells/ml. The Ryder medium consisted of 3 g/l $(NH_4)_2SO_4$, 0.5 g/l NaCl, 0.7 g/l $MgSO_4 \times 7H_2O$, 1 g/l KH_2PO_4, 0.1 g/l K_2HPO_4, 0.2 % yeast-extract, 1 % glucose. The pH of the media was adjusted at 5.4±0.05. Incubation was carried out on a shaker at 240 rpm at 28±0.5 °C in darkness.

Growth rate experiments. Cultivation of the yeast cells was started at the same time every day. The specific growth rate (μ, h^{-1}) was found as the increase in cell mass per unit cell mass per unit time (SGR = Ln $(N_2 / N_1) / (t_2 - t_1)$). Biomass increase was controlled every 0.5 h by optical density measurements at a wavelength 540±10 nm in a cuvette with optical way of 3 mm. The log-phase was common in the range of 6 h and 8 h of cultivation. Each daily average of the specific growth rate index was based on a minimum of three independent repeats.

Solar and terrestrial factors. Data about solar and geomagnetic activity for the period of experiment (from January 21 to June 10, 2003) were taken from the website: http://www.dxlc.com/solar/indices.html. Geomagnetic activity was assessed using planetary *A* (A_P) index. Parameters of the atmospheric factors (temperature (Celsius), pressure (mm-Hg) and relative humidity (%)) were received daily from the website: http://www.gismeteo.ua.

Statistical analyses. Statistical data processing was carried out with STATISTICA (data analysis software system), version 6 (StatSoft, Inc. 2001, www.statsoft.com). The Shapiro-Wilk *W*-test was used in testing for non-normality. The fluctuations of the averages of specific growth rate of the yeast obtained in the daily experiments over a two and a half month period were compared with fluctuations of the solar and terrestrial factors activity for the same period by Spearman rank order correlation analyses.

An analysis of variance (ANOVA) for high-order linear (L) and quadratic (Q) main effects as well as two-way interactions models of influences of solar, geomagnetic and atmospheric factors on the yeast growth rate were carried out by the central composite design. This design was used to fit to the data of the general model of the type:

$$y = b_0 + b_1{*}x_1 + ... + b_k{*}x_k + b_{12}{*}x_1{*}x_2 + b_{13}{*}x_1{*}x_3 + ... + b_{k-1}{*}x_k{*}x_{k-1} + b_{11}{*}x_1^2 + ... + b_{kk}{*}x_k^2$$

x_i stands for the factor values for factor *i*, and *y* stands for the dependent variable values. The effects of solar and terrestrial factors were studied using three models, where Model 1 included the solar and geomagnetic factors, Model 2 examined atmospheric factors and Model 3 considered all available factors.

Results

Cosmo-physical variations and those in the atmospheric factor in SGR fluctuations. Populations consist of the great number of individual living organisms possessing their own internal features, which put them out of an association. Investigation of kinetic indices of population growth is the averaging of properties of all organisms belonging to it [9]. This implies that the general courses of events inherent in a population are described by the mean values of kinetic indices, which are obtained by researchers through experimentation. In this case, the dispersion can be the measure of heterogeneity and indicate the undoubted existence of intrapopulation differences between individuals. The specific growth rate of a microbial population reflects great amount of interactions between living organisms and their environment and is one of the most important kinetic indices that describe the developmental processes of the population [6, 9]. Therefore we used the daily averages of specific growth rate index to estimate its fluctuations marked in the daily experiments over more than two months. Values of specific growth rate as well as mean, maximum and minimum values of the factors of solar-terrestrial activity and atmospheric activity for the days on which experiments were carried out, are presented in Table 1.

The mean value of specific growth rate (*SGR*) during this period was 0.293 ± 0.055 h^{-1}, and its minimum and maximum values were 0.134 h^{-1} and 0.439 h^{-1}, respectively. During the period of the experiments several geomagnetic storms occurred and the A_p index reached 54 nT. Maximum and minimum values of the *Sunspot number* were 190 and 41. The number of *Flares C* was, as expected, more prevalent than *Flares M*, while *Flares X* were absent during this period. The atmospheric *Pressure* changed slightly (74.9 ± 0.9), while the *Temperature* and *Humidity* both varied significantly.

Table 1

Parameters of specific growth rate of *Saccharomyces cerevisiae* Y-517 and factors of solar-terrestrial and atmospheric activity for the days on which experiments were carried out.

Item	Mean ± SD	Min. value	Max. value	Shapiro-Wilk *W* test of normality	
				W	p
Specific Growth Rate of *S. cerevisiae*					
Growth rate, daily means	0.293 ± 0.055	0.134	0.439	0.90	0.004
Solar-Terrestrial Activity					
Solar flux, units (10^{-22} W/m^2/Hz)	126.8 ± 12.9	96.1	155.7	0.99	0.939
Sunspot number	108.3 ± 40.4	41.0	190.0	0.96	0.240
Flares: *C*	35.7 ± 32.4	10	140	0.79	0.000
M	13.3 ± 5.2	10	20	0.47	0.000
X	0	0	0	-	-
A_p index (daily low-high), nT	18.1 ± 11.8	3.0	54.0	0.89	0.000
A_p index (daily means), nT	15.5 ± 4.9	5.0	28.0	0.94	0.064
Solar wind speed (daily low-high), km/sec	544.1 ± 127.2	338.0	971.0	0.95	0.001
Solar wind (daily means), km/sec	544.2 ± 98.5	382.0	755.0	0.96	0.192
Atmospheric Activity					
Temperature, °C	-1.8 ± 6.0	-15.0	25.0	0.73	0.000
Pressure, mm-Hg	74.9 ± 0.9	73.1	77.3	0.97	0.364
Humidity, %	77.2 ± 12.5	49.0	93.0	0.89	0.002

The Shapiro-Wilk test of normality (*W* statistics) showed that we were dealing with a population of observations that composed some samples which are unlikely to be from a normal distribution. *W* statistics was significant for the *Flares C* and *M*, for the A_p index, the *Solar wind speed* daily low-high values and for the atmospheric *Temperature* and *Humidity*. Therefore, the hypothesis that the respective distributions are normal should be rejected. Among solar-terrestrial factors the daily means for the *Solar flux*, the *Sunspot number*, the A_p index and the *Solar wind speed* were likely to have normal distribution. The *Pressure* was the only variable with a normal distribution among atmospheric factors. Therefore, in further analysis we used the Spearman rank order correlation coefficient measurements to investigate relationships between our variables.

Correlation analysis showed high correspondence between values of the *SGR* and the *Solar wind speed* (*SWS*) as well as between the *SGR* and the *Flares C* and *M* (Table 2). The *SGR* correlated much better with the averaged *SWS* data (-60 %, $p \le 0.001$) than with its objective minimum and maximum values. This seems logically relevant since the values of the specific growth rate are measured in the logarithmic phase, the parameters of which depend significantly on the environment generally and during the lag-phase specifically. Hence, the magnitude of the *SGR* depends on the growth strategy that cells have chosen over the previous hours of the preceding stages of growth. An equation for such a correlation appears as shown below:

*SGR = 154.9 - 0.1*SWS*, (R^2=0.31).

A significant negative relationship was noted between the *SGR* and *Flares C* and *M* (-35 % and -47 %, respectively). The correlation of the *SGR* with *Flares M* looked at first artificial since during only six days of the entire period of investigation this type of flare was present. Nevertheless, detailed analyses showed that in the days when *Flares M* were multiple, an increase of the *SGR* values occurred, whilst in the days of only one such flare the *SGR* decreased although the day before and after this event the *SGR* indexes were much higher.

Interestingly, there was a 44 % correlation between the *SWS* and A_p index but this was not reflected in the relationship of the latter with the *SGR*.

Besides those correlation indices presented in Table 2, additional statistically significant correlations were found when we examined percentages of the original values of our variables. The *Temperature* variable correlated with that of *Pressure* (R=-0.37, $p \le 0.032$) and with the *Humidity* fluctuations (R=0.45, $p \le 0.007$) during the period of experiments. Furthermore the *Pressure* showed correlation with the *Solar Flux* (R=-0.41, $p \le 0.016$) and the *Sunspot number* (R=0.38, $p \le 0.027$) but relationships of variables with *SGR* did not alter substantially.

Table 2.

Correlations of values of *Saccharomyces cerevisiae* specific growth rate (h^{-1}) with solar, geomagnetic and atmospheric factors.

Factors	Yeast specific growth rate, h^{-1}
	Spearman rank order correlations
Solar flux	0.04
Sunspot number	0.19
Flares *C*	**-0.35** ($p \le 0.038$)*
Flares *M*	**-0.47** ($p \le 0.004$)
A_p index	-0.16
A_p index, daily low-high	-0.14
Solar wind speed, km/sec	**-0.53** ($p \le 0.0001$)
Solar wind speed, km/sec (daily means)	**-0.60** ($p \le 0.0001$)
Temperature, °C	-0.15
Pressure	-0.16
Humidity, %	-0.14

*The *p* values are presented for significant correlations only.

Smoothing of the data usually provides a clearer picture of the overall shape of the relationship between the *x* and *y* variables. For this reason we used the lowest smoothing method and the negative relationship of the *SGR* with the *SWS* and the *Flares C* became more obvious (Fig. 1). *SGR* exhibited a pronounced tendency to increase in the periods when both the number of the *Flares C* and speed of the Solar wind decreased and vice versa. However, whereas correlation indices of the *SGR* with the *SWS* parameters as well as with the *Flares C* and *M* numbers were significant, no relation was found between the *SWS* and the numbers of *Flares C* and *M* for this period. This last finding corresponds well with the data of [2], which showed a progressive decrease in the relationship between the number of flares on the Sun and parameters of the solar wind over several previous decades.

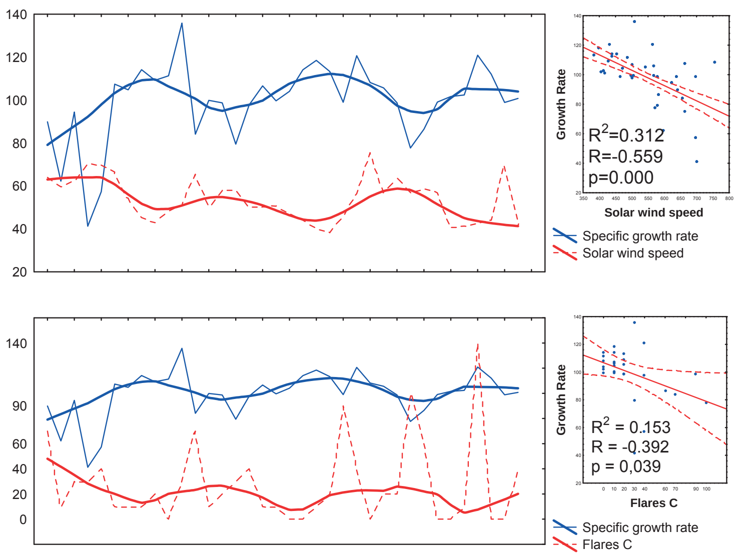

Fig. 1. Correspondence between the specific growth rate (h^{-1}) of *Saccharomyces cerevisiae*, the *Solar wind speed* (km/sec) and the number of *Flares C*. Real values are presented by broken lines whereas smoothed values were obtained using the lowest smoothing method. For better visualisation the *Solar wind speed* data was decreased ten times and the *Flares C* number magnified ten times.

Undoubtedly, the common tendencies found between these variables cannot explain all the perturbations that occurred on a daily basis in the yeast growth rate values. Firstly, significant decreases or increases in the yeast growth rate were not proportional in magnitude to changes in the *SWS* on certain days during the experiment (especially the first ones). Secondly, it appears more likely that the interaction between *SGR* and these two variables had a positive correlation in the first and last days. Excluding these days from the analysis revealed a 39 % ($p \leq 0.039$) negative correlation between the *SGR* values and the number of *Flares C*. Thirdly, microbes did not achieve maximal growth rate values in the *SWS* minimums but one or two days before the *SWS* achieved its maximum. Thus it seems obvious that the *SGR* fluctuations are not the result of changes in the number of *Flares C* and the *SWS* parameters alone and consequently other active factor(s) and, correspondingly, more complex relationships should be found.

Analysis of variances and model design. We used central composite design to investigate the most complicated model, which included linear and quadratic main effects and two-way interaction effects of the solar-terrestrial factors on the *SGR* values. Rearrangement of all available variables showed that three factors are enough to explain at least 60 % of oscillations of the *SGR* noted during the period of the negative correlation. These factors are the number of *Flares M*, the *Solar wind speed* and the A_P index. The *SWS* linear effects were found to be the greatest contributor with partial R^2 equal to 0.99 whilst the quadratic effects of A_P index and the number of *Flares M* were second and third order contributors with partial R^2 equal to 0.97 and 0.93, respectively. These three factors are enough to explain 94 % of the marked *SGR* fluctuations during the days of positive correlation. However, such an approach left it unclear which factor(s) are able to change a positive correlation between the values of *SGR*, the *SWS* and the solar *Flares C*, to a negative one.

To reveal the factor(s) responsible for the changes in the correlation indices between variables measured above, we analysed changes of the *SGR* against the fluctuations in activity of the solar and geomagnetic factors (Model 1), the atmospheric factors (Model 2) and all variables combined (Model 3). ANOVA effects used to predict the *SGR* and efficacy of solar-geomagnetic and atmospheric factors in the formation of the *SGR* are shown in Table 3. In the first approach (Model 1), factors involved in the computation of linear and quadratic main effects were the *Solar flux*, the *Sunspot number*, the *Flares C* and *M*, the *SWS* and the A_P index. In this model the solar wind speed parameters and the number of flares *M* on the days of this experiment were the largest contributors to the investigated effect. The R^2 of this model was 62 % and adjusted R^2 was 41 %. In Model 2 only the *Humidity* showed an effect on the *SGR*. The R^2 and adjusted R^2 values for this model were to lower than in the previous one and round 42 % and 29 %, respectively. Finally, in Model 3 where all factors were combined, the *SGR* values were found to be dependent on and correlated with the number of flares *M*, the A_P index and the *Humidity* values. The R^2 and adjusted R^2 values for this model were 78 % and 54 %, respectively. The atmospheric *Humidity* and the *Flares M* were the two factors contributing the most to the overall effect.

The above calculations show that the effects of solar and geomagnetic factors without taking into account the influence of atmospheric factors (Model 1) were only able to explain 62 % of the *SGR* fluctuations. Similarly, the atmospheric factors effects alone (Model 2) were not sufficient to provide a good prediction of the *SGR* values. Combination of the model with two-way interaction effects contributed to an increase in R^2 value from 78 % to 91 % with adjusted R^2 = 78 %. The equation for this model is as follows:

$$SGR = 61.0 + 14.0*Ap - 0.09*SWS + 74.5*FlC - 1.0*FlC^2 + 1048.5*FlM + 130.1*FlM^2 - 2.0*T + 0.1*T^2 - 2.5*M - 0.03*Ap*SWS + 1.6*Ap*FlC - 37.6*Ap*FlM + 0.4*Ap*T - 0.1*SWS*FlC - 0.8*SWS*FlM - 0.01*SWS*T + 0.01*SWS*M - 62.5*FlC*FlM - 0.9*FlC*T - 0.5*FlC*M - 71.6*FlM*T$$

Combination of the model with the two-way interactions produced the equation with a better predicting potential. Although we finally developed an overly complex model, it explained the incidences where we found positive and negative correlation indices between fluctuations of the *SGR* values with the *SWS* and the solar *Flares C*. For example, factors such as the A_P index, the *SWS*, the *Flares M* number, the atmospheric *Pressure* and *Humidity* had slightly varied activities at the beginning of our investigations. During that period the *SGR* fluctuations substantially depended on the abrupt changes in the number of the solar *Flares C* (Fig. 1) and the simultaneous rise in temperature from minus 6 °C to minus 1 °C. In the final days, of all investigated factors, only the *SWS* was as low as in the beginning (425±15 km/sec) and we noted the same positive correlation between the *SGR* fluctuations and the *Flares C* number. A drastic increase of the *Flares C* number from 0 through 10 to 140 resulted in 20 % increment of the *SGR* on these days. The next days a decrease of the *Flares C* number to zero and an increase of the *SWS* to 700 km/sec retarded the speed of yeast growth. The marked negative correlations between the activities of solar factors and the *SGR* of the yeast population on other days cannot be explained by simple changes in the *SWS* and the *Flares C* number, thus, a more sophisticated equation should be applied to explain such effects. The equation found with the help of the central composite design explained the observed fluctuations of the *SGR* without dividing them into any periods of positive or negative correlations. The high correspondence between the values observed in the experiment and those predicted by the above equation is shown in Fig. 2.

Table 3.

ANOVA effects coefficients ± SE for models* assessing environmental factors influencing the fluctuations of specific growth rate of *Saccharomyces cerevisiae* Y-517.

Variable	Model 1 (R^2= 0.62; Adjusted R^2= 0.41)	Model 2 (R^2= 0.42; Adjusted R^2= 0.29)	Model 3 (R^2= 0.78; Adjusted R^2= 0.54)
Intercept	77.46 ± 8.29 [a]	104.21 ± 7.14 [a]	79.26 ± 11.52 [a]
Solar flux (L)	-31.69 ± 19.02	–	-60.52 ± 26.26 [c]
Solar flux (Q)	27.23 ± 28.18	–	47.27 ± 39.60
Sunspot number (L)	10.85 ± 13.79	–	20.11 ± 17.08
Sunspot number (Q)	-36.00 ± 22.82	–	-44.32 ± 23.29
A_p index (L)	13.80 ± 12.58	–	11.38 ± 14.39
A_p index (Q)	-55.48 ± 22.02 [c]	–	-63.82 ± 20.66 [b]
Solar wind speed (L)	-34.58 ± 11.37 [b]	–	-29.09 ± 11.88 [c]
Solar wind speed (Q)	-0.18 ± 17.96	–	3.33 ± 16.93
Flares *C* (L)	-0.87 ± 16.36	–	-2.48 ± 18.26
Flares *C* (Q)	18.09 ± 25.43	–	-11.10 ± 29.03
Flares *M* (L)	-8.11 ± 13.05	–	-6.91 ± 12.61
Flares *M* (Q)	46.66 ± 19.97 [c]	–	53.36 ± 19.84 [c]
Temperature (L)	–	-8.47 ± 15.84	-31.90 ± 22.26
Temperature (Q)	–	46.78 ± 30.04	44.02 ± 38.58
Pressure (L)	–	-27.02 ± 13.96	-28.44 ± 15.23
Pressure (Q)	–	-1.14 ± 19.82	-21.09 ± 22.19
Humidity (L)	–	3.05 ± 11.47	13.27 ± 13.75
Humidity (Q)	–	-69.20 ± 17.71 [a]	-37.68 ± 19.02

*Model 1 includes solar-terrestrial factor only; Model 2 includes atmospheric factors only, Model 3 includes all environmental factors.

L and Q – are the linear and quadratic main effects.

[a]*P* values for these variables <0.001; [b]*P* value for these variables <0.01; [c]*P* value for these variables <0.05.

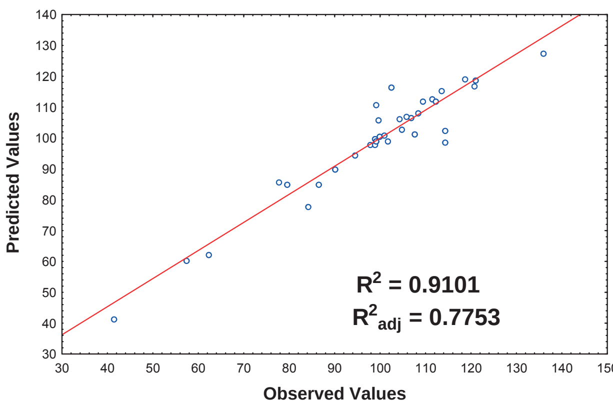

Fig. 2. Observed and predicted values of the specific growth rate fluctuations of the yeast *Saccharomyces cerevisiae* under different solar-terrestrial factors activity.

According to the found regression equation any increase of the A_P index and/or the number of *Flares C* and *M* should result in the microorganisms' growth intensification. While the increase of the *SWS* values and/or atmospheric humidity should lead to a reduction of the *SGR*. The atmospheric *Temperature* is characterized by the "transition point", under which any rise of the temperature leads to decrease of the *SGR* and above which the growth rate increases with increasing temperature.

Hence, the increase in the solar flare activity and strong geomagnetic disturbances should lead to the intensification of the *SGR*. However, this will not take place as both those factors are accompanied by increased *SWS*, which is the most important determinant of resultant *SGR* (Fig. 3). Consequently it is most probable that the growth rate of microbes will decrease during the geomagnetic storms.

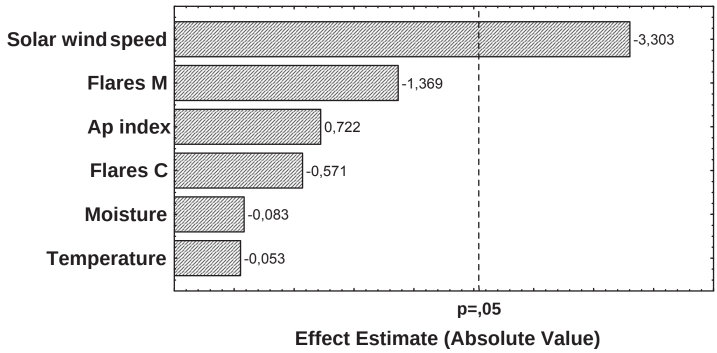

Fig. 3. Pareto chart of the linear main effects of the variables on the *Saccharomyces cerevisiae* **specific growth rate fluctuations.**

Discussion

It appears evident that daily variations in specific growth rate of yeasts marked by us during investigation of growth processes in a periodic culture, correlate well with cosmophysical factors such as the *Solar wind speed*, the A_P *index*, and the number of *Flares C*. In all cases the marked dependences of correlations were considerably higher than 95 %. It is important that higher correlation indices correspond exactly to mean values of those variables because the experiments on determination of specific growth rate took about 10 hours daily, and during such time the cosmophysical and atmospheric factors usually change their values several times. Therefore the specific growth rate is an averaged result of the prolonged influence of different factors on heterogeneous population [6, 9]. In other words, the environmental factors exert influence on the general course of a biological process increasing or weakening it. Deviations from a mean some days (described with dispersion) are more credibly explained by individual physiological and biochemical responses of cells in response to the global action of external regulators of development, and that is why they correlate poorly with cosmophysical factors.

The effects of cosmic factors alone, ignoring the action of the atmospheric ones (Model 1), did not allow the production of a model (even complex) with high descriptive character. In the same way the effects of atmospheric factors alone (Model 2) were found insufficient and explained no more than 42 % of *SGR* fluctuations. The simultaneous use of all accessible factors (Model 3) led to substantial increasing of the predictor possibilities of the regression equation (R^2=0.91).

It is obvious that such factors as the *Temperature* and *Humidity* are unable to exert direct action on the changes of the *SGR* of microbes kept in the laboratory conditions. However, at least two assumptions may be made about the role of these factors and consequently the mechanism(s) of their action. (i) Activity of these factors depends on some other factor(s) that was not examined in our research, and using them in this analysis allowed us indirectly to take into account the influence of that factor of unknown nature, which affected the *SGR* fluctuations along with cosmophysical factors. (ii) Air temperature, humidity and pressure undoubtedly influence the potency of cosmic-factors to disturb the biosphere processes. For example, they characterize the ability of cosmic rays, electromagnetic radiation and charged particles to penetrate into the depths of the atmosphere, the surface and depths of the earth and hydrosphere and affect biocenosis, all these in turn lead to the inevitable local or global changes of the same atmospheric indices. Activity of these factors can both result in and be a reflection of the activity of solar and geocosmic factors and can play a role of a circumterrestrial amendment or clarification of the actions of the studied cosmophysical factors.

Therefore, the fluctuations that one can note in the biological processes under constant laboratory conditions are the result of the multifactor action and some of these factors may be of the cosmic origin.

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КОЛЕБАНИЯ СКОРОСТИ РОСТА МИКРООРГАНИЗМОВ В ОТВЕТ НА ИЗМЕНЕНИЯ АКТИВНОСТИ СОЛНЕЧНО-ЗЕМНЫХ ФАКТОРОВ

Р е з ю м е

Нестабильность различных физиологических и биохимических свойств микроорганизмов, отмечаемая в процессе культивирования даже при постоянных лабораторных условиях - вероятно неотъемлемый атрибут живого. Ряд объяснений был предложен для этого явления, а также различные факторы изучались как возможные регуляторы и триггеры отмечаемых колебаний. Было установлено, что такие колебания обладают космической ритмикой, но фактор(ы), которые могли бы в достаточной степени объяснить и предсказать масштабы колебаний, происходящих на ежедневной основе в долгосрочных экспериментах, предложены не были. В данной работе мы исследовали показатель удельной скорости роста дрожжей *Saccharomyces cerevisiae*, которые отмечали ежедневно во время культивирования при постоянных условиях. Влияние различных солнечно-земных факторов было проанализировано. Значимые показатели корреляции были отмечены между удельной скоростью роста и скоростью солнечного ветра, а также числом вспышек *M* на Солнце. Эти два фактора определяли цикличность колебаний удельной скорости роста и, следовательно, общий ход его увеличения или уменьшения. Эффекты некоторых других факторов (число вспышек *C*, планетарный *A*-индекс, а также атмосферные факторы, такие как температура и влажность) были необходимы для построении уравнения, описывающего изменения удельной скорости роста дрожжей, с высокими значениями коэффициента детерминации (R^2 = 91%) и скорректированным R^2 (78%). Очевидно, что температура и влажность – факторы, которые не могут непосредственно влиять на популяцию дрожжей в лабораторных условиях и, таким образом, мы предполагаем, что их изменения, которые имеют место в атмосфере Земли, служат отражением некоторого действительно важного фактора . Мы пришли к выводу, что различные факторы, описывающие активность солнечно-земных факторов, хорошо подходят для описания и прогнозирования колебаний кинетических параметров роста дрожжей и могут оказаться триггером наблюдаемых колебаний.

К л ю ч е в ы е   с л о в а: колебания скорости роста, дрожжи, *Saccharomyces cerevisiae*, солнечная активность, атмосферные факторы.

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КОЛИВАННЯ ШВИДКОСТІ РОСТУ МІКРООРГАНІЗМІВ У ВІДПОВІДЬ НА ЗМІНИ АКТИВНОСТІ СОНЯЧНО-ЗЕМНИХ ФАКТОРІВ

Р е з ю м е

Нестабільність різних фізіологічних і біохімічних властивостей мікроорганізмів, що відзначається в процесі культивування навіть при постійних лабораторних умовах - ймовірно невід'ємний атрибут живого. Ряд пояснень був запропонований для цього явища, а також різні чинники вивчалися як можливі регулятори і тригери таких коливань. Було встановлено, що такі коливання мають космічну ритміку, але фактор(и), які могли б в достатній мірі пояснити і передбачити масштаби коливань, що відбуваються на щоденній основі в довгострокових експериментах, запропоновані не були. У даній роботі ми досліджували показник питомої швидкості росту дріжджів *Saccharomyces cerevisiae*, який визначали щодня під час культивування при постійних умовах. Вплив різних сонячно-земних факторів було проаналізовано. Достовірні показники кореляції були визначені між питомою швидкістю росту і швидкістю сонячного вітру, а також числом спалахів *M* на Сонці. Ці два фактори визначали циклічність коливань питомої швидкості росту і, отже, загальний хід його збільшення або зменшення. Ефекти деяких інших

чинників (число спалахів *C*, планетарний *A*-індекс, а також атмосферні коливання температури і вологості) були необхідні для побудови математичного рівняння, що описує зміни питомої швидкості росту дріжджів, з високим значенням коефіцієнту детермінації (R^2 = 91%) і скоригованим R^2 (78%). Очевидно, що температура і вологість - фактори, які не можуть безпосередньо впливати на популяцію дріжджів в лабораторних умовах і, таким чином, ми припускаємо, що їх зміни, які мають місце в атмосфері Землі, слугують відображенням деякого дійсно важливого чинника. Ми прийшли до висновку, що різні фактори, що описують активність сонячно-земних факторів, добре підходять для опису і прогнозування коливань кінетичних параметрів росту дріжджів і можуть виявитися тригером відмічених коливань.

К л ю ч о в і   с л о в а: коливання швидкості росту, дріжджі, *Saccharomyces cerevisiae*, сонячна активність, атмосферні фактори.

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