REVIEW

USE OF FOOD RESOURCES AND DEVELOPMENT OF FOOD PRODUCTION TECHNOLOGY

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Abstract: Various changes in demographic models of world population and evolution of food production technologies have been considered. Numerical constant values in the hyperbolic model of Heinz's cybernetics are defined as per the CurveExpert program and based on statistical data of the global population increased for the certain period at the mean square deviation of S = 74.8 of one million people a year and the correlation ratio of r = 0.994. Note at the same time that the calculated Heinz`s "Doomsday" falls on the 115th year of the life and the date of birth of this model developer. The relation of the world population growth to stages to develop food production technologies has been analyzed. The marginal population is evaluated in terms of the direct energy considerations. A variety of development hypotheses is proposed throughout the human development history based on the Darwin's model, astrophysics of the solar system and the policy.

Keywords: The von Foerster's model, the world population, the food technology

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INTRODUCTION

This article is aimed to clarify historical, economic and philosophical experience in production and consumption of food and to evaluate prospects for further development in this field of human activity. Currently we face some desperate predictions which make the subject and purpose of our research urgent upon the analysis. For instance, Professor John Beddington [1], UK Government's scientific adviser, predicted that by 2030 we would face disastrous scarcity of vital resources. By this time, the population will reach 8.3 billion people; the need in energy will jeopardize by 50% where the demand for fresh water will grow by 30%. V.I. Arnold [2], one of the Soviet mathematicians, developed the theory of catastrophes. The mathematical aspect of this poses certain doubts even where such intricate phenomenon as the cataclysm is fully covered addressing the bifurcation theory of differential equations and the theory of smooth reflection peculiarities, though it accentuates the urgency of mathematical analysis of problems, in addition. Ilya Prigogine, the Nobel laureate, in collaboration with Isabelle Stengers [3] looked for methods to restore the union between humans and nature based on new principles to be the solidarity of science, culture and so in addition to the union of humankind and nature.

OBJECTS AND METHODS OF RESEARCH

The research is focused on critical periods in history of technology for food production industry. In 1960, Heinz von Foerster, the scholar [4], published an article in the "Science" Magazine titled "Doomsday. Friday 13, November 2026". Based on the data on global population growth in 1958 he built a hyperbolic model as per which the world population by 2026 would be unlimited

$$N(t) = \frac{C}{t_0 - t}, \quad (1)$$

where *N(t)* is the dependence of the global population *N* on time *t*; t_0 is the time constant by Heinz; C = 199686.86 is the constant of the global population by demographic data prior to 1950 that we calculated using a mathematic software product. Then the formula (1) takes on the form:

$$N(t) = \frac{199686.86}{2026 - t}. \quad (2)$$

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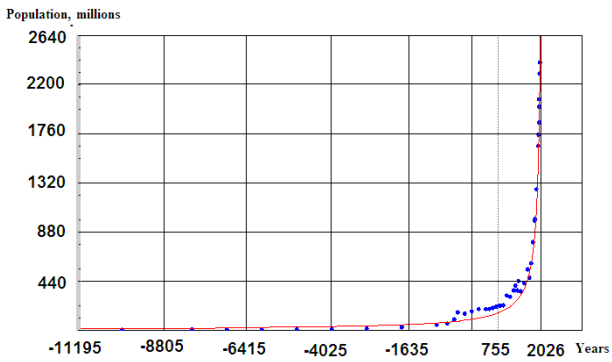

Fig. 1. Graph plotted on the global population based on statistic data up to 1950 using the CurveExpert software for the empirical formula (2). The standard deviation of the plotted data makes S = 74.8 and the correlation coefficient r is equal to 0.994.

RESULTS AND DISCUSSION

Kremer M. (1993) [5] proposed the similar global population-associated graph in 1993. Up to 1970s, the global population actually grows as per the hyperbolic law.

However, since 1989 the absolute growth rate of the global population tends to decline (US Census Bureau (USCB), 2008) [6]. By 2100, the growth rate could decline to less than 5 million people a decade. As some demographers limit the growth rate, the modeling will reach 10–12 billion people and some predict on the lower level of the global population stabilization. In this case, for example, the logistic law (Kapitza, 1996 [7]; Verhulst, 1845 [8]; Lotka, 1925 [9]; Volterra, 1926 [10]; Haub, 1995[11]) seems to be more appropriate.

The final scenario of population development is still vague. But it is clear that the Doomsday by Heinz would not occur in 2026 due to the global drive to perpetuity and it may occur for quite different reasons.

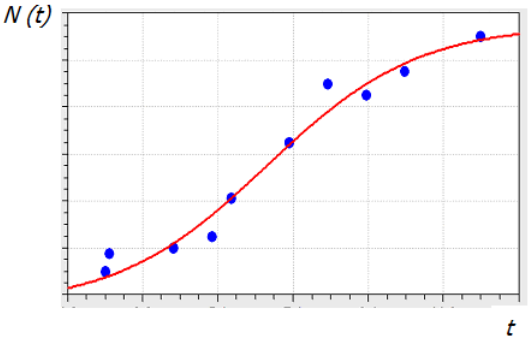

Fig. 2 . Standard graph of the logistic law.
(Today: 09-02-2017 13:08:49 Word population amounts to 7 496 359 712, http://countrymeters.info/ru/World [12]).

The astrophysical concept of the solar system and the Darwinian evolution model basis compile the following arguments on the development of food production technologies.

Photosynthesis is the main source of biological energy, the photosynthetic autotrophs (mainly, the green plants) use solar energy to synthesize organic compounds of inorganic, the heterotrophs (including humans) exist due to energy stored as autotrophic chemical relations. The Sun's energy resources are not endless. As it radiates, the mass of the Sun is reduced by 4.3 million tons per second (K.–P. Schröder and R. Connon Smith, 2008) [13]. The Sun can generate the energy for photosynthesis on the Earth for about 100 billion years, but the energy required will be "cut off" someday.

Let us consider the process of photosynthesis in detail. There are three stages of photosynthesis: photophysical, photochemical and chemical. At the photophysical stage, the light quanta pigments are absorbed, they transform to the excited state and the energy is transferred to other molecules of the photosystem. At the photochemical stage, the charges separate in the reactive center of the photosynthetic electron transport. The first two stages are jointly called the light-dependent stage of photosynthesis. The third stage takes place with no commitment of the outer world and includes biochemical reactions of organic compound synthesis using the energy stored at the light-dependent stage. Most such reactions as observed in Calvin cycle (J. Bassham, A. Benson, and M. Calvin, 1950) [14] are the processes of gluconeogenesis formation of sugars and starches from carbon dioxide in the air.

In 1941, Melvin Calvin, the American biochemist, proved that the water molecule photolysis is the primary photosynthetic process resulting in oxygen formation released in the atmosphere, and hydrogen used to reduce the carbon dioxide to organic substances. Using the radioactive carbon isotope, 14C, paper chromatography, and conventional methods of the organic chemistry, Calvin and his team managed to trace biosynthetic paths of photochemical processes. By 1956, the pathway of full carbon conversion in the photosynthesis was clarified. In 1961, Calvin was awarded the Nobel Prize in chemistry for researches on carbon dioxide assimilation at plants. The chemical photosynthesis formula may be submitted as follows:

$$6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2 . \qquad (3)$$

Based on such reaction over 1017 kcal of free energy has been stored in the world each year that matches with assimilation over 1010 tons of carbon as carbohydrates and other organic substances (Stayer L., 1985) [15]. If such considerations are deemed correct, the maximum theoretical number of people to be supported by photosynthesis may be calculated at ease. Considering that there are 365 days a year and 1 person needs about 3,000 calories of energy per day, we obtain

$$\frac{10^{17}}{365 \cdot 3000} = 9132420913 \approx 10^{10} . \qquad (4)$$

Apparently, humans and other Earth creatures cannot, for various reasons, use all the stored energy (E.J. Kormondy 1996) [16]. Each link of the trophic chain lost about 90% of useful energy where the mankind still uses reserves of energy as the coal, oil, gas and other energy sources. However, the most

global population fails to receive the adequate quantity and quality of food recently. The food security is the urgent economic challenge for many countries and the global population approaches to photosynthesis energy capacity limits on the planet.

Let us consider the evolutionary classification of food production technologies that justifies the attempts of some forecasts in this area. This technology may be named the first generation technology. The technology of food production was used to be limited to hunting and gathering and differed little from the food production in the animal kingdom. Before humans managed to acquire tools to hunt or farm, insects might have been the important portion of their diet. Cave paintings in the Northern Spain dated back about 30000 to 9000 BC depict the collection of edible insects and wild bee nests suggesting for potential entomophagous society [17].

The Old Stone Age (Lower Paleolithic), that is up to 10–8 thousand BC was the period for the fossil man who used stone, wood and bone tools processed with living employment of thereof to differ significantly from other animals (E. Callaway, 2013 [18]; A.C. Guyton, J.E. Hall, 2006 [19]). The first-generation technology provides the energy to approximately 3 million people. Standing on two legs, the human enjoys more rational way to travel as compared to animals running on four legs. Coupled with the with the human body cooling mechanism by sweating, the human being acquired the ability to catch up any hunting animal at long distances (G.A. Harrison, J.M. Tanner, D.R. Pilbeam, P.T. Baker, 1988) [20]. First-generation technologies represent rudiments of second-generation technology that included the food extraction and transportation, more considerable approaches to power supplies saving, in elements of communal pattern in the hunting and gathering area.

Second-generation technologies may be named as reproduction technologies.

Historically, this technology has evolved around 8–3 thousand BC in the New Stone Age (Neolithic Period). Later on, the human being opened up the skills of grinding and drilling of stone tools, spinning and weaving, pottery art. People hunted together with wolves. They kept domesticated animals – cows, sheep, horses. The hunting transferred to its more intense and adjustable phase. At the same time, the gathering activity was developed to cropping and cultivation of useful plants. This technology provides power to approximately 50 million people by the end of the Neolithic Period and for about 3 billion by the year 1960 (J. Armelagos, 2014) [21]. The increasingly growing needs of human beings are mainly met extensively by increasing the area of existence and the number of livestock. The significance of grain culture should be specifically emphasized where people acquired the skills of massive local cultivation and natural conservation of dried grain.

The importance of the grain crop is evidenced by the well-known expression from the 10th satire of the Roman satirical poet Decimus Junius Juvenal (Decimus Junius Juvenalis in Latin, ab. 60-127) "Bread and circuses"! Juvenal used it to describe the policy of statesmen bribing people with money and food and circus performances. Such acts helped them to seize and hold their power in ancient Rome. (http://antique-lit.niv.ru/antique-lit/gilenson-drevnij-rim/yuvenal.htm) [22].

Ordinary Romans ate mostly cereal products – the bread and porridge. As per the Romans, the hunger meant that the grain, the main food reserves, ended manifested in public disaffection and revolts due to the scarcity of grain or cereal crop failures. The bread was used as the manipulating tool to manage political processes not only in ancient Rome [23].

Currently, there is a wide range of grain and pseudo-seeds food on markets, including the wheat, barley, oats, rye, millet, spelt wheat, green grain and corn. There are such grain crops as kamut, the ancient type of wheat used to be mainly cultivated in ancient Egypt. The American rice is largely marketed to be the pre-cooked, dried and purified wheat coarsely or finely grinded. Valuable pseudo-crops, such as amaranth, Quinoa do not refer to grain crops but to plants of genus wormseed. The buckwheat the grain of which resemble the grain crop refers to plants of the buckwheat family (http://ladychef.ru/ingredienty/hleba-i-zrelishh-istoriya-i-raznooobrazie-zlakovyh-kultur) [24].

The main cereal crop is the wheat. China is the main wheat producer in the world. In 2014, the share of China in the world grain crop production reached 17.3%, the volume of production made 126.2 million tons. For 10 years, as compared to 2004, the wheat production in China increased by 37.3% or 34.3 million tons. In the next 10 years the growth of wheat production in China is expected to decline in view of the limited land plot available. By 2024, according to the OECD forecast, it will reach 130.9 million tons that almost matches the level of current indexes. According to the USDA, the wheat crop in China by 2024/2025 will reach 133.1 million tons. Among the wheat-producing countries, Russia is ranked third in the world. In 2014, the wheat production in Russia amounted to 59.7 million tons (8.2% of global production). For the 10 consequent years, the figures increased by 31.4% or 16.6 million tons. In 2015, the wheat production in Russia was over 62 million tons as per the Ministry of Agriculture of the Russian Federation making 63.8 million tons (http://ab-centre.ru/page/proizvodstvo-pshenicy-v-mire-strany-proizvoditeli-pshenicy) [25].

The main factor determining the growth of wheat production in the world was an increase in productivity rather than in acreage. The measures aimed to improve the wheat crop technologies and contribute to higher productivity included the increase in the use of mineral fertilizers. In view to increase the yield results and to hold high level of wheat production in the world, we will need to constantly review the mineral fertilizer dosage used. The challenge is to increase the food yields in future by rational use of fertilizer [26].

As it is well-known, the theory of demographic cycles explores the processes of population change under conditions of limited natural resources.

Raymond Pearl [27] proposed this theory and proved that changes in the number of animal populations (and perhaps humans) are described by the so-called logistic curve.

The logistic curve in Fig. 2 shows that the population grows rapidly in the very beginning with the abundance of resources available and high-consumption rate. Then the growth slows down and the population stabilizes near the asymptote corresponding to the maximum possible volume of complete consumption of natural resources.

The achievement of the maximum possible number of population means that there is a minimum level of consumption at the survival margin where the natural increase is completely eliminated by the starvation death. In fact, this state of "hungry homeostasis" turns out to be unstable, the fluctuations in environmental factors result in "demographic catastrophes", catastrophic hunger or epidemic. The disaster causes a drastic reduction in population followed by the new curl in the new demographic cycle recovered [27, 28].

With regard to changes in the population growth rate in graphs 1 and 2, the availability of demographic cycles in history was proved by Wilhelm Abel in the ‘30s of XX century [29].

Upon the review of data on economic situation in the XII-XIV centuries, V. Abel showed that the population growth fir that period caused the exhaustion of arable land resources; in turn that resulted in food scarcity, increases in grain prices and starvation. Farmers who were unable to get food for their families were forced to cut weekly expenses and went to look for better jobs to larger cities. The urban growth was followed by the craft blooming though the craft itself was not adequate to allow food for the entire surplus population, and the cities were full of unemployed and the poor. Hunger and poverty resulted in riots both in large cities and in villages. In Flanders, such riots were manifested as the social revolution. The French social struggle ended in adoption of absolutism. In the end, the Black Death epidemic that broke under conditions where millions of people were broken by permanent malnutrition resulted in deaths of half the European population. That was the "demographic catastrophe" to end the demographic cycle. Thus, it describes the cycles by R. Pearl that really existed in the past [30].

The second-generation technologies employ elements of the third-generation technology, that is, the technology intensification. The reproduction rate of human beings is rising through breeding more productive animals and growing more efficient plants.

Third-generation technologies may be named as the intensification. The end of the dominance of the second-generation technology can be roughly specified as the middle of the 20th century, when the humankind exhausted all opportunities of extensive growth of food production: the crops suitable for cultivation, the number of animals limited due to the land plot restriction could no longer be increased. It is believed that population will not grow indefinitely and stabilized totaling, as mentioned above, some 10–15 billion people.

Main peculiarities of the third-generation technology, intensification technology, are as follow:

(1) Use of microbiological methods of food production – the efficiency of micro-organisms, algae, fungi is somewhat greater than that of traditional agricultural animals and plants. This is the rule of biology that works to mean that the smaller the body, the less it is effective (Timoshenko L.V., 1999) [31]. It is easy to trace the following patterns: the time to double the cattle biomass is 30–60 days, 20–40 days for pigs, 2–24 days – for chickens, 6–12 days for grass, 2–6 hours for chlorella, 0.3–2 hours for bacteria and yeast. In other words, the pattern may be depicted as 1440:960:576:288:6:2 in hours.

As it already mentioned, a steady increase in population up to 9 billion people was predicted by 2050 that requires an increase in food sources or forage for the existing agro-ecosystems resulting in even greater impact on the environment. The deficiency in agricultural land, water, forest, fisheries and biological resources is already predicted. High quality edible insects contain protein, vitamins and amino acids wholesome for humans. Insects are known for high food conversion ratio, for example, crickets need six times less than cattle, four times less than sheep, or less than half as compared to pigs and broiler chickens to produce the same amount of protein. In addition, they emit fewer greenhouse gases and ammonia than conventional livestock. Insects can be grown on organic waste.

(2) Artificial reduction in trophic food chains (plant – animal – people), food production directly from autotrophic organisms, namely soy milk, cottage cheese, artificial meat, eggs and so forth (J.D. Mauseth, 2008)[32]. In process of feeding, the potential food energy goes to its consumers. When the potential energy is transferred from unit to unit of the food chain, up to 80–90% is lost as the heat. The longer is the trophic chain, the lower is the production of its last link in relation to that of the initial one.

(3) Mass production of genetically modified foods with specific nutritional and medicinal properties.

One of signs of the next food technology generation is the creation of artificial foods. A. N. Nesmeyanov, the Academician of the USSR, the outstanding chemist laid the basis (1962) of the new research trend, namely the synthetic food creation. He specified the pathway (1960–1970) for the synthesis of simple and available compounds (carbohydrates, nitro compounds, aldehydes), amino acids and natural proteins of products to imitate the smell and taste of food [33]. The caviar product named “Iskra” (abbreviated “black artificial granular caviar”, in Russian “ISKRA”) became the first known industrial design of the protein caviar in the USSR. First in the world, the USSR obtained the caviar at the “Chibis” plant constructed in 1960 at the Institute of Elementorganic Compounds (Moscow). The plant capacity – 1.5–2 kg/h of caviar ready for use. The granular caviar produced at the “Chibis” Plant contains the casein with addition of gelatin, dextrin, starch, glycerin and sodium hydroxide. The taste is added with the fish oil and chemical “flavor of glutominate, etc.” [34, 35]).

G. L. Slonimsky, the Doctor of Chemical Sciences who cooperated with A. N. Nesmeyanov in the works of that time stated that: "I flashed with the idea of the caviar molding, so I said I would try to do it. By 1964 we tested our first laboratory samples of the artificial caviar from the skimmed milk. And then, the technology was developed by the Institute by its own resources. Since then, this cheap and delicious product called "Protein Granular Caviar" (based on the casein protein of eggs and other food waste) is manufactured in Moscow and other cities..." [36].

For the first time in the world, the production of the protein caviar was started in the Moscow dock refrigerator. The dairy plant in Myski town in Kuzbass was ranked second in the world in early seventies of the last century (where this industrial technology by Nesmeyanov-Slonimsky was implemented). It was initiated by young leaders of the Kemerovo Institute of Food Science and Technology (KemIFST founded in 1972) supported by the Kemerovo Regional Committee of the CPSU with members who first tasted the caviar. The historical tasting procedure at the meeting of the Regional Party Committee Office was attended by Prof. B. Azarov, the Rector of KemIFST and V. Aret, Ph.D, Vice-Rector of the Research Department. The regional administration authorized to continue the manufacture of this innovative product that required the certain political courage since the production of artificial foodstuff was not acknowledged as the main line of the food programme of the CPSU. Still, sometimes low-expert people spread rumors on production of black caviar from the oil.

Main researches are followed by long-term flow of inventions. For example, ideologically close events are still under development at the institute of the Academician Nesmeyanov.

The range of similar inventions followed first developments at the Nesmeyanov Institute. For example, in 1986, a team of inventors headed by the Academician I. A. Rogov [37] developed the method to manufacture the nutritional protein caviar at the Tbilisi State University. The invention was the use of animal-milk proteins, known as the albumin milk.

Til now, inventors improve various technology aspects using the caviar as the invention by V. A. Gromov in 2003 (V. Gromov, 2003) [38]. The invention will help to create the universal food dye that gives the caviar the color and shade desired.

The next three technology generations can be considered as irrelevant fantasy for evolution. The reason for them lies in reasons other than the increase in human number.

The fourth-generation technology may be called as the nuclear. Signs thereof are as follow:

(1) The development of artificial photosynthesis in similar ways of assimilation of nuclear and other energy.

(2) Integration of food technology and pharmaceutical products aimed at optimizing and providing individualized human body substances vital for activity.

Fifth-generation technology can be called as the biotechnology that will be followed by genetic, chemical, mechanical and information restructuring of plants, animals and humans. Education and social family functions will be fundamentally restructured.

The sixth-generation technology is quite radical and fantastic. It is as follows: Signs thereof are as follow:

(1) Rejection of the protein body as a life carrier, transition to informative electro-magnetic or any other physical field (as per terminology by Vernadsky (2013) [39], that is, the anthroposphere, the final solution to diseases, the beginning and the end of life.

(2) Output of life from the Earth planet to the infinite space and its migration to the speed of light, the problem of the fading sun.

CONCLUSION

The history of mankind is the history of "existence of biopolymer bodies capable of self-replication under the constant exchange of matter and energy with the environment" (as defined by the Academician V. Goldansky (1986) [40]. It will be completed and will go to the history of other intelligent system existence capable of self-replication and non-random impact on the environment.

This optimistic path of evolution may be changed in many possible events, including astrophysical and political ways. For example, a huge meteorite will fall on the Earth destroying the entire life. Or, resulting from the military science development and political conflicts a nuclear war will be broken or humans will be contaminated with incurable diseases.

"We face great environmental challenges: climate change, food production, overpopulation, decimation of other species, epidemic disease, and acidification of oceans. In total, they remind that we live the most dangerous live of the humanity evolution. Nowadays, we dispose of the technology to destroy the planet we live on, but we have not developed the ability to escape it, yet. In a few hundred years, we will possibly establish human colonies amid stars, but right now we live on the one planet and we need to work together to protect it. To do that, we need to break, not build up, barriers within and between nations. If we are to stand a chance of doing that, the global leaders need to acknowledge that they failed and keep on failing. When certain people are authorized to use resources at their hands, we will have to learn to share far more than currently we do" (Stephen Hawking, 2016) [41]. Deep analysis of the problem was given in the work Prosekov A. and Ivanova S. [42].

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