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тел.: +38(0512) 70-93-54
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Industrial enterprises intellectual resources management in a knowledge-based economy

Halyna Ostrovska*

PhD in Economics, Associate Professor
Ternopil Ivan Puluj National Technical University
46001, 56 Ruska Str., Ternopil, Ukraine
https://orcid.org/0000-0002-9318-2258

Abstract. The article substantiates the theoretical provisions, scientific and practical recommendations for the industrial enterprises management in the formation of knowledge-based economy intellectual resources have been developed. The content and the main elements of the infrastructure-reproductive approach to the management of industrial enterprises intellectual resources are revealed. The classification of industrial enterprises intellectual resources management organizational levels is offered. The types of personnel policy that correspond to a certain level of the enterprise intellectual resources management organization are identified. The results of the study can be used to develop tools, methods, systems and mechanisms for managing the intellectual resources of industrial enterprises, aimed at maximizing the innovation effect, needed to ensure sustainable innovation at the current level

Keywords: knowledge-based economy, industrial enterprise, innovative development, intellectual potential, intellectual resources management, the effect of innovation, intellectual and innovative activity of personnel

INTRODUCTION

The imperative of advancing intelligence development has become an imperative not just for existence but for the survival of civilization in the socio-economic transformation conditions. The origins of this problem are that the economic basis of modern society is characterized by the existing sector of high-tech, knowledge-intensive industries.

An industrial enterprise in a knowledge-based economy is an innovative enterprise, which is the most complex research and production system that ensures the implementation of "research- production" consistently ascending cycles. An integral part of production and economic activity of such an enterprise is the integration of intellectual activity, which is enhanced by the intellectual abilities of staff aimed at producing new knowledge (intellectual product) and innovation activity in the transformation field of various intellectual products into innovative products and its further commercialization directly or in warehouse of finished goods (services). Management of intellectual resources is becoming an urgent need for modern industrial enterprises, determining their innovative activity and competitiveness on the basis of providing the intellectual staff capabilities necessary reproductive level, the development of its innovative competencies. Therefore, an innovative industrial enterprise should consider the management of intellectual resources as a constant strategic priority.

Industrial enterprises inevitably become dependent on the intellectual capabilities of staff. Thus, in the world of hi-tech technologies, the attention of leading companies managers is focused on the use of employees creativity and knowledge in an innovative project team. Under these conditions, in the field of economics and human resources management, an increasingly common problem is the lack of innovative and competent workers in many areas of industry [1, 2]. In such conditions, the desired result of industrial enterprises human resource management is, first of all, high-quality staff development aimed at innovative result in the

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*Corresponding author

format of knowledge-based economy, that is improvement of professional knowledge, skills, experience, raising the professional qualification level on this basis and its integration into professional competencies in the modern innovation sphere. Therefore, it is necessary to review and rethink the conceptual guidelines for the management of industrial personnel on a new principled basis in terms of priorities for innovative economic development. In this context, attention is focused on the need to increase the scientific focus on industrial enterprises intellectual resources management (IEIRM) and the development of the employee innovative competencies on this platform.

It should be noted that international and domestic theory and methodology of human resource management are represented by various concepts focused on personnel management aspects. These concepts are due to technological and structural changes in economy on an innovative basis, but do not give a clear vision of the management specifics in the development of personnel innovative competence and intellectualization aimed at industrial enterprises solving diversification and technological modernization in a knowledge-based economy, that is current scientific problem. Thus, the lack of ability to ensure industrial personnel effective management in the new economic environment on the basis of traditional approaches has identified the main idea of the study aimed at developing the theory and intellectual resource management methodology based on the infrastructure-reproductive approach.

The purpose of the article is to deepen the methodological principles and develop recommendations for the industrial enterprises intellectual resources management on the basis of infrastructure-reproductive approach in a knowledge- based economy formation. The choice of research methods is based on the consideration objectivity and comprehensiveness, consistency (in terms of formal and mathematical logic) principles, as well as sufficient justification. In accordance with these principles, a wide range of general scientific research methods (general logic, theoretical, empirical) was used, which made it possible to systematize the idea of the employees intellectual resources managing specifics.

LITERATURE REVIEW

Scientific ideas of such domestic scientists as V. Heyets and A. Gritsenko, H. Pylypenko and N. Fedorova, O. Butnik-Siversky, N. Bryukhovetskaya and I. Buleyev, B. Andrushkiv, O. Kuzmin and L. Lipych, V. Petrenko, I. Moyseenko, Y. Sytnyk, A. Nalyvayko and O. Grebeshkova, L. Maliuta and R. Sherstiuk are aimed at thorough research of business entities ntellectual resources management methodological and applied aspects.

In particular, V. Heyets, A. Gritsenko, H. Pylypenko and N. Fedorova actively study the problems of social and class transformations and the formation of a new education, science and innovation quality as components of the reconstructive development of Ukrainian economy [3, 4]. O. Butnik-Siversky substantiates intellectual resources as one of the main factors in the processes of the economy socio-economic development intensification [5]. N. Bryukhovetskaya and I. Buleyev develop mechanisms for innovative development of domestic industrial enterprises [6]. O. Kuzmin and L. Lipich consider methodological aspects of the intellectual potential management concept as a tool to increase the competitiveness of the enterprise [7]. B. Andrushkiv summarizes the directions of the enterprise intellectual potential effective use as an entering the European economic space ways [8]. The creation of effective mechanisms for attracting intellectual resources and the peculiarities of their development are studied by V. Petrenko. With, the researcher confirms that the effective use of intellectual resources in today's information economy contributes to a higher level of social welfare [9]. I. Moyseenko in his works strengthens the role of intellectual resources in the context of industrial enterprises innovative activity in Ukraine [10]. S. Ilyashenko, Y. Sytnyk, A. Nalyvayko and O. Grebeshkova cover the intellectual resources activation in the context of the knowledge management modern paradigm [11, 12, 13]. L. Maliuta and R. Sherstiuk outline the realities and prospects of the industrial enterprises intellectual potential effective use in a knowledge-based economy [14, 15]. S. Kis outlines the problems of management activity intellectualization and enterprise personnel intellectual activity intensification [16].

Nevertheless, issues related to the industrial enterprises intellectual resources management remain insufficiently researched, or debatable up to this day, which necessitates their further study to ensure their effective use.

RESULTS

In the current socio-economic transformation, determined by the technological factor, the advanced development of intelligence has become the dominant factor of the knowledge-based economy. Today's economy is, first of all, an effective sector of high-tech industries, which relies more on the resources of the intellectual component [17]. Thus, the strategic importance of modern industrial enterprises intellectual resources increases.

The study of the industrial enterprises intellectual resources management (IEIRM) specifics allowed us to conclude that there is a sufficient variety of approaches to management in this area. The reason for turning to the personnel management methodological experience, on the one hand, and the experience of managing the intellectual resource component (intellectual capital and intellectual potential), on the other, is the specific intellectual resources economic nature as an object of management. This necessitates the need to take into account in this kind of studies, firstly, the staff intellectualization genesis as a result of intellectual resources synthesis such as knowledge, skills, abilities, experience, competencies, abilities, and secondly, the inseparability of these resources from staff as a carrier – not in the form of passive nature "packaging", but the one that significantly affects the qualitative aspect of intellectual resources at the collective level.

The proposed infrastructure-reproductive approach in the context of enterprises intellectual resources management study allows to consider the personnel intellectualization as an object of management, focusing, firstly, on its reproducible nature of the managed process, and secondly, on its infrastructural place and role in the innovation cycle, focused on creating conditions for the formation and development of such necessary in today's innovative employees competencies. With, the personnel intellectualization reproductive cycle structure includes five stages: forecasting and planning of intellectual resources; formation of intellectual resources (personnel selection, selection, as well as the creation of a personnel reserve for the enterprise innovative plans implementation); development of intellectual resources, based on the enterprise innovative development program; use of intellectual resources in innovation processes, ensuring the innovative activity of employees; transformation of intellectual resources into the enterprise economic potential. The advantage of this approach is that it distinguishes the possibility of research and solution on its basis quite specific problems in the enterprises intellectual resources management, due to the need and feasibility of balanced reproduction and innovative competence of employees (Table 1).

Table 1. *The main elements of the infrastructure-reproductive approach to the enterprise intellectual resources management in a knowledge-based economy*

Element	Characteristic
Type	Program-targeted, focused on innovative results
Purpose	Development of intellectual resources management organization in the conditions of knowledge-based economy
Tools	Economic evaluation of the enterprises intellectual resources indicators management
Opportunities	– organizational management environment influence integration; – economic assessment of management efficiency and quality; – structuring the object of management and systematization of the management specifics characteristics; – methodical support of enterprises intellectual resources management; – modeling of systems and management mechanisms that allow to algorithmize the organization management
Advantages	– contributes to the reduction of fragmentation and segmentation in the theory and methodology of enterprises intellectual resources management; – focused on resource provision of the innovation process; – object of management, presented in the reproductive-infrastructural interpretation; – universal in relation to various categories of industrial enterprises workers; – due to the conditions of innovative economic development
Limitation	Internal level of industrial enterprises

The disclosed elements make it possible to specify the content of the infrastructure-reproductive approach as a specialized and focused on the study of industrial enterprises intellectual resources management and the formation of appropriate management systems.

The use of the proposed approach in the context of the enterprises intellectual resource management the sample study (Table 2), allowed to obtain results to supplement the theory of personnel management development elements, consisting in the classification of industrial enterprises intellectual resource management organizational levels, as well as identifying types of personnel policy, corresponding to a certain level of enterprises intellectual resources management organization.

Table 2. *The main characteristics of the sample industrial enterprises*

Classification criterion	Characteristics of the enterprise
The size of the enterprise	The number of staff is more than 1 thousand people
Appointment in the conditions of economy innovative development	– commercialization and serial production of new products; – industrial familiarization of new technologies
Type of innovation	– grocery; – process
Innovation strategy	Evolutionary change of products, technologies(violent (power) strategy)
The ability to ensure the creation, perception, consolidation and development of innovations	Technological (with marketing elements)

The classification of different industrial enterprises intellectual resources management organizational levels by coverage of the personnel intellectualization reproductive process elements is given in the Table 3.

Table 3. *Organizational levels of intellectual resources management by the personnel intellectualization reproductive process covering elements*

The level of IEIRM management organization	Criterion of the IEIRM management organization level	IEIRM control elements
Passive: the reproductive process of intellectualization cannot be organized	Representation in the enterprise personnel policy not less than one element of IEIRM	1. Development of the enterprise intellectual resources
Moderately active: the reproductive process of intellectualization is difficult to organize	Representation in the enterprise personnel policy not less than two elements of IEIRM	1. Formation of the enterprise intellectual resources. 2. Development of the enterprise intellectual resources.
Active: the reproductive process of intellectualization can be organized under the condition of enterprise intellectual resources Management functions development	Representation in the enterprise personnel policy not less than three elements of IEIRM	1. Formation of the enterprise intellectual resources. 2. Development of the enterprise intellectual resources. 3. Use of the enterprise intellectual resources.
Focused-active: the reproductive process of intellectualization is organized and effective as an infrastructure of the innovation process	Representation in the enterprise personnel policy complete elements set of IEIRM	Balanced rational presentation to the enterprise intellectual resources management at all stages of the personnel intellectualization reproductive cycle

The content of enterprises intellectual resources management different organization levels is specified in terms of effective management critical conditions, which include two types of conditions: necessary and sufficient. The necessary condition characterizes the quality level of intellectual resources and the completeness of their use in the innovation process. By this criterion

$$EIR=EIRa=EIRq, \tag{1}$$

where *EIR* – the enterprise intellectual resources; *EIRa* – intellectual resources that are actually used in the innovation process; *EIRq* – intellectual resources of the required quality, based on the need to achieve innovative goals of the enterprise.

Sufficient condition allows us to optimize the ratio of economic results from the use of intellectual resources in the innovation process and the cost of their formation and development.

Thus, the use of enterprise intellectual resources efficiency (K_{eire}) in the innovation process is greater than 1.

Characteristics of enterprises intellectual resources management organizational levels under critical conditions of effective management necessity and sufficiency, revealing a certain organizational optimum in management achievement degree are given in the Table 4.

Table 4. *Organizational levels of the enterprise intellectual resources management under effective management necessity and sufficiency critical conditions*

Organizational level	Characteristics according to the criteria of necessity and sufficiency conditions
Passive	1) irregular, unfocused formation and development of enterprise intellectual resources; 2) the enterprise intellectual resources are not fully used, but the level of their actual use meets the production needs (the enterprise is inactive in the context of innovation); 3) $K_{eire} < 1$
Moderately active	1) unreasonably high costs for the formation and development of the enterprise innovation sphere intellectual resources, which do not determine the investment return; 2) underutilization of the enterprise intellectual resources; 3) $K_{eire} < 1$
Active	1) total use of the enterprise intellectual resources, the quality level of which, however, does not meet the resource needs of the enterprise in the innovation sphere or the enterprise intellectual resources actual use level is lower than the intellectual capabilities of staff; 2) $K_{eire} \leqslant 1$
Focused active	1) optimal ratio between the quality level of the enterprise intellectual resources and the completeness of their use in the innovation sphere: EIR = EIRa = EIRq; 2) $K_{eire} > 1$

From the solving problems point of view on the innovative economic development trajectory formation, it becomes necessary the focused active level of the enterprises intellectual resources management, presented by a single set of interconnected elements formed on the principle of intellectual resources reproducible balance for industrial enterprises innovative development. In accordance to the intellectual resources management organization levels, we consider the industrial enterprises personnel policies types in terms of innovative economic development (Table 5).

Table 5. *Identification of industrial enterprises personnel policy types in a knowledge-based economy*

The level of *EIR* management organization	Type of personnel policy
Passive	Passive, non-innovation-oriented: passive innovation-oriented direction of all personnel policy elements
Moderately active	Moderately active innovation orientation: a) personnel policy is focused on providing the company with highly qualified personnel; b) personnel policy passive innovation orientation in many areas is preserved
Active	Active innovation orientation: personnel policy is aimed at the formation and development of professionals innovative team capable to ensure the innovative development of the enterprise
Focused active	Focused active innovation orientation: personnel policy, formed on the principle of the enterprise intellectual resources reproducible balance in the interests of ensuring its stable innovative development

The prospect of intellectual resources managing on the basis of infrastructure reproductive approach will avoid many typical problems in management practice, which lead to inefficient use of intellectual potential in terms of innovative economic development. As a result of the industrial enterprise intellectual resources management organizational integration into the management system, such administrative results become achievable.

1. Increasing the focus and systematization of the enterprise intellectual resources formation and development periodicity (up to continuity).
2. Optimization of costs for the enterprise intellectual resources formation and development.
3. Ensuring the complete use of intellectual resources, the quality level of which meets the enterprise needs in innovation field.
4. Creating working conditions that eliminate the underutilization of intellectual resources and, consequently, reduce the subsequent associated economic and moral-psychological losses for individual employees, the workforce and the enterprise as a whole.

Let's note, that the inefficient reproduction of intellectual resources in the innovation sphere, which is essentially a mismatch between the potential of employees and the needs of the enterprise in innovative development, is mainly due to multiple discrepancies: between the growing needs of the enterprise in innovative development and the existing professional level employees; in cases of irrational arrangement of executors on workplaces in the innovative project; in the absence of the necessary motivation or motivational fatigue of employees; in case of dissatisfaction with work, etc.

CONCLUSIONS

The transition to a knowledge-based economy involves profound institutional transformations, rethinking the conceptual approaches and industrial values of "technogenic" culture, and the new culture values emergence of informational and "homogeneous" nature, which emphasizes the role and importance of interdependent information and human resources.

An actual modern economy problem in connection with the highlighted trends is the formation of a new platform that provides stable positive dynamics in the vector of the economy innovative development and digitalization. One of the main factors in creating such an innovative platform is the labor-groups innovation, the mass and scale of which will allow it to form the appropriate effect, which is determined mainly by intellectual resources, namely their effective and purposeful formation, development and use in innovation processes. Moreover, this effect becomes a determining factor in the deep transformation of existing or the birth of new economy institutions.

The main target of modern industrial enterprises intellectual resources management should be the achievement and stabilization of their required reproduction level, due to the needs of the enterprise in innovative development in accordance with the knowledge-based economy stage. This guideline determines the sequence of problem solving, tools, the order of resource allocation in the internal management process, aimed at innovative results. In this regard, the need to find adequate management approaches that allow develop the necessary management systems and mechanisms, required in the implementation of domestic economy innovative development promising directions.

The long-term continuation of the study tendencies may be: further development of theoretical and systemic ideas about the specifics of intellectual potential development managing as a reproductive process, improving methodology, methods, organizational procedures and tools for evaluating the effectiveness of management.

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Управління інтелектуальними ресурсами промислових підприємств в умовах економіки, заснованої на знаннях

Галина Островська

Кандидат економічних наук, доцент
Тернопільський національний технічний університет імені Івана Пулюя
46001, вул. Руська, 56, м. Тернопіль, Україна
https://orcid.org/0000-0002-9318-2258

Анотація. У статті обґрунтовано теоретичні положення та розроблено науково-практичні рекомендації щодо питань управління інтелектуальними ресурсами промислових підприємств в умовах становлення економіки, заснованої на знаннях. Розкрито зміст та сформовано основні елементи інфраструктурно- відтворювального підходу до управління інтелектуальними ресурсами промислових підприємств. Запропоновано класифікацію організаційних рівнів управління інтелектуальними ресурсами промислових підприємств за охопленням елементів відтворювального процесу інтелектуалізації персоналу. Ідентифіковано типи кадрової політики, що відповідають певному рівню організації управління інтелектуальними ресурсами підприємства. Результати дослідження можуть бути використані для розробки інструментів, методів, систем, а також механізмів управління інтелектуальними ресурсами промислових підприємств, спрямованих на максимізацію ефекту новаторства, необхідного для забезпечення стабільного інноваційного розвитку на сучасному рівні

Ключові слова: економіка, заснована на знаннях, промислове підприємство, інноваційний розвиток, інтелектуальний потенціал, управління інтелектуальними ресурсами, ефект новаторства, інтелектуально-інноваційна активність персоналу

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CVP analysis in the conditions of multi-product production as a tool of operational controlling

Nataliia Babiak*

PhD in Economics
Kyiv National Economics University named after Vadym Hetman
03057, 54/1 Peremohy Ave., Kyiv, Ukraine
https://orcid.org/0000-0002-3210-4045

N. Krutous

Auditor
"Bakertilly Ukraine" LLC
03150, 28 Phizkultury Str., Kyiv, Ukraine

Abstract. Current conditions for the successful operation of enterprises are characterized by the globalization of the economic sphere, the accelerated pace of scientific and technical progress, and the strengthening of innovative trends. Therefore, any institution, when building its own strategy, first of all strives to provide conditions for long-term and promising activity, which can be achieved only by creating a strong competitive advantage. In particular, a recognized way to win the competition is cost leadership. Therefore, the search for a rational tool for the organization of the cost management system is currently an urgent issue. In addition, the competitiveness of modern enterprises depends on the model of financial flow management. Advantage and leadership in the market goes to organizations that minimize business risks by calculating losses with constant and variable components. CVP analysis is used to calculate the break-even turnover of each type of product. The purpose of the work was to study the application of CPV analysis to solve the problems of multi-product production and cost accounting in order to increase the efficiency of production activities. The article used the method of economic analysis, calculation of break-even points, comparison, modeling. The features of CVP analysis in the conditions of multi-product production are revealed, and the methods of its implementation are compared. The possibilities of applying the results of the analysis when making management decisions in the operational controlling system are determined. The problem of distribution of total fixed undistributed costs for certain types of products by various methods, as well as determination of the break-even level of production and sale of certain types of products on the basis of weighted average marginal profit, was investigated. The impact on profit of a change in the level of fixed costs and specific variable costs with the help of operating leverage as part of an operational analysis at a manufacturing enterprise was studied

Keywords: CVP analysis, variable costs, fixed costs, marginal profit, break-even point, operational analysis

INTRODUCTION

Modern operating conditions of enterprises are characterized by further globalization of economic activity, high rates of scientific and technical progress, innovative development, and increased aggressiveness of the competitive environment. Therefore, any organization, when building its own strategy, first of all, strives to create conditions for long-term and perspective activity, which is possible only by creating a strong competitive advantage. In particular, cost leadership is a recognized way of winning the competition, and

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*Corresponding author

in connection with this, the problem of creating an effective cost management system at the enterprise, capable of linking existing management information into a single whole within the framework of a single company, arises. Therefore, the search for a rational mechanism for the organization of the cost management system is currently quite relevant. One of these mechanisms is cost controlling, which is a component of the operational controlling system, the most famous and effective tool of which is CVP analysis.

Features of CVR analysis when used in the controlling system in the process of analysis, planning and control of costs and financial results of the enterprise are revealed in the works of foreign and domestic economists: A. Upchurch [1], S.H. Kim [2], O. Klementyeva, O. Zolotaryova [3], T. Odintsova, O. Nevmerzhitska [4], A. Paskalova [5], O. Tereshchenko [6], A.V. Kuprienko [7], I.V. Baryshevska [8], A.H. Osadcha [9] and others. However, the question of practical application of this toolkit at enterprises that produce many types of products remains understudied.

The purpose of the article is to test and determine the features of the use of CVR analysis in the practical activities of industrial enterprises, in particular in the conditions of multi-product production.

RESULTS

Analysis of the ratio "cost-volume-profit" (Cost-Volume-Profit) is one of the powerful tools in cost management and boils down to establishing the break-even point, i.e. determining the limit from which the company's revenues fully cover its costs. With the help of such an analysis, it is possible to better assess the possibilities of making a profit, and the guarantees of the company's break-even become obvious.

The break-even analysis can be performed mainly in the short term and is based on the following assumptions [2; 6; 10]:

- all costs can be 0divided into fixed and variable;
- there is a certain linear relationship between total costs, the volume of revenue and the volume of production;
- in the planning period, fixed costs do not change significantly along with changes in production volumes;
- variable costs per unit of production are stable, and total variable costs change in direct proportion to the volume of production and sales;
- prices for finished products and for resources forming the cost of production are fixed at a certain level;
- labor productivity and product range are unchanged;
- the level of costs and profit changes only under the influence of changes in the volume of production and sales of products;
- in the planned period, the number of manufactured products coincides with the volume of sold products.

CVP analysis is designed to reveal the optimal proportions between costs, sales price, sales volume and, as a result, minimize business risk. To carry out the above analysis, it is necessary to divide all costs of the enterprise into fixed and variable. In practice, this distribution creates many problems, being a rather time-consuming and complicated procedure, since many items of expenses are mixed and contain both constant and variable components.

Based on the analysis of previous studies [3; 9; 10], it can be concluded that in most cases, CVR analysis is carried out in the conditions of single-product production. Indeed, in this case, its analytical significance is great, and the obtained results are more accurate, since the calculation is not affected by such factors as the variety of assortment, the structure of production. And in the case of multi-product production, the analysis is reduced only to the identification of the impact on the overall profit and break-even of production, but at the same time, profit and profitability indicators by types of products are not additionally calculated.

Among Ukrainian scientists, there are many opinions regarding the distribution of fixed costs, with the calculation of break-even turnover, profitability and profitability by type of products. It is believed that the most appropriate basis for the allocation of fixed costs can be sales revenue, marginal profit or volume of production. It follows that, depending on the distribution base, we can calculate several indicators of cost, break-even points, and profit. And this, in principle, contradicts the main purpose of CVP analysis – to determine the volume of products for which the received income will be equal to the incurred costs, and such an indicator should be unambiguous.

So, for example, T. Odintsova and O. Nevmerzhitska, when applying CVP-analysis, propose to distribute fixed costs by types of products in proportion to sales volume [4]. Let's try to calculate such break-even points using the example of the company "Kromberg & Schubert", whose main activity is the production of onboard cable networks, special cables and completing electrical equipment for cars. The enterprise is characterized by a wide range of products. For the calculation, we will use the indicators related to one of the production shops of the enterprise with the corresponding list of the nomenclature. An example of the calculation is given in Table 1.

To calculate fixed costs, they were distributed according to the sales structure for each type of product. The obtained results of break-even points correspond to the main idea – the obtained gross profit covers fixed costs. But it is necessary to pay attention to the fact that one of the key conditions is violated - the unchanged structure of the assortment. The resulting distribution of fixed costs is also questionable. In general, a lot of attention is paid to the issue of distribution of fixed costs in the literature, but there is no universally correct algorithm for all enterprises, since they differ in the specifics of costs.

Table 1. Calculation of the break-even point based on the division of fixed costs by the structure of product sales

Indicator\Product type	NCV3 HLS	SLS MG	SLK Sportwagen Hauptleitung	SL Roadster Autarke	Motorrad Haupt-leitung	Motorrad Autarke	Total
Issue volume, units	166,799	Haupt-leitung	22,351	14,201	110,904	112,700	427,793
Production structure, %	39	838	5	3	26	26	100
Selling price, euros	197	0.2	368	107	86	12	
Sales volume, thousands of euros	32,859.4	392	8,225.2	1,519.5	9,537.7	1,352.4	53,822.7
Wage rate, EUR/hour	8.8	328.5	8.8	8.8	8.8	8.8	
Time for the manufacture of the part, min.	305.6	8.8	460	11	129	3	
Labor payment for one part, euros	44.8	442	67.5	1.6	18.9	0.4	
Total salary, thousands of euros	7,476.1	64.8	1,507.9	22.9	2,098.3	49.6	11,209.2
Raw materials and materials for 1 part, euro	120	54.3	235	60	43	9	
Total amount of raw materials, thousands of euros	20,015.9	205	5,252.5	852.1	4,768.9	1,014.3	32,075.4
Variable costs per unit of production, euros	165	171.8	302	62	62	9	
Total variable costs, thousands of euros	27,492.0	269.83	6,760.4	874.9	6,867.2	1,063.9	43,284.6
Marginal profit per unit, euro	32	226.1	66	45	24	3	
Gross profit, thousands of euros	5,367.4	122	1,464.7	644.5	2,670.6	288.5	10,538.1
Fixed costs, thousands of euros				8,607			
Product sales structure, %	61.05	0.61	15.28	2.82	17.72	2.51	100.00
Fixed costs (distribution by sales volume), thousands of euros	5,254.7	52.5	1,315.3	243.0	1,525.2	216.3	8,607.0
Break-even product turnover, units	163,297	430	20,071	5,354	63,340	84,480	336,971
Production structure, %	48	0,1	6	2	19	25	100
Sales volume (breakeven), thousands of euros	32,169.5	168.5	7,386.1	572.8	5,447.2	1,013.7	46,757.9
Total variable costs, thousands of euros	26,914.8	116.0	6,070.8	329.8	3,922.0	797.5	38,150.9
Gross profit, thousands of euros	5,254.7	52.5	1,315.3	243.0	1,525.2	216.3	8,607

Source: *built by the authors based on the internal reporting of the company "Kromberg & Schubert Ukraine"*

Foreign scientists [1;2], when using CVP analysis in conditions of multi-product production, avoid the distribution of fixed costs. Thus, the work of A. Upchurch gives an example of determining the break-even point using the weighted average marginal profit [1]. We will perform a similar calculation on the example of the same enterprise (Table 2).

The main feature of this calculation of the break-even point is that it is necessary to adhere to the assumption that the structure of production should remain unchanged. On its basis, the weighted average marginal profit is further calculated, which is still used to calculate the total break-even volume of production. Leaving the structure of production unchanged, the volume of break-even production is calculated for each type of product. Also, the same results can be obtained using the measure of total marginal profit. So, after calculating the ratio between fixed costs and total marginal profit, we get the same total amount of break-even as in the previous calculation.

Compared to the previous method of calculation, the data are more realistic and appropriate for use, because if the existing structure of production is preserved, as a result of the calculation, we get the break-even volume of each type of product, which in the end brings the marginal profit necessary to cover fixed costs.

Table 2. *Calculation of the break-even point based on the calculation of the weighted average marginal profit*

Indicator\Product type	NCV3 HLS	SLS AMG Haupt-leitung	SLK Sport-wagen Haupt-leitung	SL-Roadster Autarke	Motorrad Haupt-leitung	Motorrad Autarke	Total
Fixed costs, euros				8,607,000			
Production structure, %	39.0	0.2	5.2	3.3	25.9	26.3	100.0
Medium weighted	12.55	0.24	3.42	1.51	6.24	0.67	24.63
Marginal profit, euros				349,400			
Break-even point, units	136,233	684	18,255	11,599	90,581	92,048	349,400
Breakeven turnover	26,837.9	268.3	6,717.9	1,241.1	7,789.9	1,104.6	43,959.7
Products, units	22,454.1	184.7	5,521.6	714.6	5,608.8	868.9	35.4
Scope of implementation	4,383.8	83.6	1,196.3	526.5	2,181.1	235.7	8,607.0

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

However, it cannot be said that the results of the calculation of break-even points in the conditions of multi-product production have a high analytical value. For example, if there are products with a loss in the production structure, the decision to increase the price of the product is correct in principle, but when calculating for the enterprise as a whole, this product will not break even until similar calculations are carried out for the enterprise or shop as a whole. Therefore, for a more detailed analysis, it is advisable to calculate additional indicators. So, for example, from the break-even point formula, you can calculate the size of fixed costs for each type of product, from which it follows that fixed costs are equal to the product of the marginal profit per unit of production and the break-even volume (Table 3). On the basis of the obtained data, it is possible to calculate the indicators of total cost and profit for each type of product.

Table 3. *Calculation of profit by types of products based on the distribution of fixed costs, thousands of euros*

Indicator	NCV3 HLS	SLS AMG Haupt-leitung	SLK Sport-wagen Hauptleitung	SL Roadster Autarke	Motorrad Haupt-leitung	Motorrad Autarke	Total
Fixed costs	4,383.8	83.6	1,196.3	526.4	2,181.2	235.6	8,607.0
Total variable costs	27,492.0	226.1	6,760.4	875.0	6,867.2	1,063.9	43,284.6
Cost of manufactured products,	31,875.8	309.7	7,956.7	1,401.4	9,048.4	1,299.5	51,891.6
Volume of implementation,	32,859.4	328.5	8,225.2	1,519.5	9,537.7	1,352.4	53,822.7
Profit	983.6	18.8	268.5	118.1	489.3	52.8	1,931.1

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

Such a calculation allows you to examine each type of product from the point of view of the costs incurred for its production and the amount of profit it generates. However, it must be remembered that such data are not 100% reliable, because even with such a calculation, the distribution of fixed costs is quite conditional and may not correspond to reality. This is the complexity and peculiarity of using CVP analysis in the conditions of multi-product production. The obtained data can only serve as a guideline for making further management decisions.

Also quite often in the literature there is a division of fixed costs depending on the amount of marginal profit per product group. For comparison, we will perform the necessary calculations (Table 4).

It is worth noting that as a result of this distribution, we get a very close volume of fixed costs, as in the case of calculation using the weighted average marginal profit method. Accordingly, with this method, we will get approximately the same break-even points as in the previous case, because both methods are equivalent given the fact that they involve the use of the same indicators. Therefore, it can be argued that the only adequate method of distribution of fixed costs in conditions of multi-product production is the method of distribution by the volume of marginal profit in any variation. After all, such a distribution allows obtaining the most real and expedient results for making further management decisions related to the management of the cost of production, namely, variable and fixed costs.

Table 4. *Distribution of fixed costs depending on the marginality of products*

Indicators	NCV3 HLS	SLS MG Hauptleitung	SLK Sport-wagen Hauptleitung	SL Roadster Autarke	Motorrad Hauptleit ung	Motorrad Autarke	Total
Volume of issue, pcs	166,799	838	22,351	14,201	110,904	112,700	427,793
Profit per unit, euros	32	122	66	45	25	3	
Marginal profit, thousands of euros	5,261.1	101.9	1,478.2	646.1	2,732.4	285.1	10,504.7
Marginal profit structure, %	50	1	14	6	26	3	100
Fixed costs (distribution by marginal profit), thousands of euros	4,363.3	83.2	1,190.7	523.9	2,171.0	274.8	8,607.0

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

In order to make informed decisions about changes in the volume of production and sales of products, it is also necessary to take into account additional factors affecting the results of operations, such as changes in demand for products, changes in prices for raw materials, and other events that can cause significant deviations from the planned results of operations. One of the ways to take into account the factor of change in demand for products is the calculation of optimistic and pessimistic versions of CVP-analysis, presented in the work of A. Pascalova [5], which is used precisely in the conditions of multi-product production. The calculation methodology consists in the fact that various options for the sale of goods are considered depending on the size of the marginal profit. It is assumed that goods with a lower marginal profit are sold first, depending on demand, or the situation may be the opposite. Taking into account two multipolar options, the company receives a reliable range of development of possible events.

Having estimated values of the marginal profit of each type of product, it is obvious that some goods are more profitable than others, and some bring a minimum profit, which, most likely, with the correct distribution, does not even cover the amount of fixed costs aimed at its production. We rank the analyzed products by the size of the marginal profit (Table 5).

Table 5. *Product profitability ranking*

Indicator\Type of product	Selling price, EUR	Variable costs per unit of production, EUR	Marginal profit per unit, EUR	Rank
SLS AMG Hauptleitung	392	270	122	1
SLK Sportwagen Hauptleitung	368	302	66	2
SL Roadster Autarke	107	61	46	3
NCV3 HLS	197	165	32	4
Motorrad Hauptleitung	86	62	24	-5
Motorrad Autarke	12	9	3	6

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

First, let's use the optimistic scenario of CVP analysis. We assume that in line with the interests of the enterprise, first of all, given the possible demand, products with the highest marginal profit will be sold, or we assume that the market situation is such that the enterprise independently chooses which product to sell first (Table 6).

From the data presented in Table 6, we can see that under an optimistic scenario, the company will exceed the break-even point by selling only 5 types of products. The proceeds from sales will cover all variable and fixed manufacturing costs. The break-even point under such conditions will be equal (Table 7):

$$BP1=42\,932\,574+9\,537\,744\cdot(1\,027\,978/2\,670\,568)=46\,603\,923\ (euro). \qquad (1)$$

So, based on the volume of sales of 46,603.9 thousand euros and on the condition that the goods with a larger volume of marginal profit will be sold first, the company will reach the break-even point. At the same time, the volume of the first four products according to the level of marginality remains unchanged, and the Motorrad Hauptleitung product needs to be sold only in the amount of 3,671.3 thousand euros, compared to the input data in the amount of 9,537.7 thousand euros.

Table 6. *Optimistic version of CVP analysis*

Indicator\Type of product	Sales volume, euro	Sales volume by cumulative sum, euro	Variable costs, euro	Marginal profit, euro	Marginal profit coefficient	Profit (loss) by cumulative sum, euro (=8607000)
SLS AMG Hauptleitung	328,496	328,496	226,115	102,381	31%	-8,504,619
SLK Sportwagen Hauptleitung	8,225,168	8,553,664	6,760,432	1,464,736	18%	-7,039,883
SL Roadster Autarke	1,519,507	10,073,171	874,971	644,536	42%	-6,395,347
NCV3 HLS	32,859,403	42,932,574	27,492,034	5,367,369	16%	-1,027,978
Motorrad Hauptleitung	9,537,744	52,470,318	6,867,176	2,670,568	28%	1,642,591
Motorrad Autarke	1,352,400	53,822,718	1,063,888	288,512	21%	1,931,103
Total	53,822,718		43,284,615	10,538,103	20%	

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

Table 7. *Break-even point according to the optimistic version of the CVP analysis*

Indicators	Break-even point, euro		SLS AMG Hauptleitung	SLK Sportwagen Hauptleitung	SL Roadster Autarke	NCV3 HLS	Motorrad Hauptleitung
Sales volume, euros	46,603,923		328,496	8,225,168	1,519,507	32,859,403	3,671,349
Volume of realization, pcs.	246,879	*or*	838	22,351	14,201	166,799	42,690
Variable costs, euros	37,996,923		226,115	6,760,432	874,971	27,492,034	2,643,371
Marginal profit, euros	8,607,000		102,381	1,464,736	644,536	5,367,369	1,027,978

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

There is also a possible variant of the development of events, in which the company will primarily be able to sell goods with the smallest marginal profit per unit. Such a development can be called pessimistic. Let's calculate the break-even point under such conditions (Table 8).

Under the pessimistic version of the CVP-analysis under the given conditions, the company breaks even with the sale of only four types of products, which is one position less than under the conditions of the optimistic version. Let's calculate the break-even point:

Table 8. *Pessimistic version of the CVP analysis*

Indicator\Type of product	Sales volume, euros	Sales volume by cumulative total, euros	Variable costs, euros	Marginal profit, euros	Marginal profit coefficient	Profit (loss) by cumulative total, euros (8607000)
Motorrad Autarke	1,352,400	1,352,400	1,063,888	288,512	21%	-8,318,488
Motorrad Hauptleitung	9,537,744	10,890,144	6,867,176	2,670,568	29%	-5,647,920
NCV3 HLS	32,859,403	43,749,547	27,492,034	5,367,369	16%	-280,550
SL Roadster Autarke	1,519,507	45,269,054	874,971	644,536	43%	363,986
SLK Sportwagen Hauptleitung	8,225,168	53,494,222	6,760,432	1,464,736	18%	1,828,721
SLS AMG Hauptleitung	328,496	53,822,718	226,115	102,381	31%	1,931,103
Total	53,822,718		43,284,615	10,538,103	20%	

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

$$BP2=43\,749\,547+1\,519\,507\cdot(280\,550/644\,536)=44\,410\,950\ (euro). \quad (2)$$

Table 9. *Break-even point according to the pessimistic version of the CVP analysis, euros*

Indicator	Break-even point, euro		Motorrad Autarke	Motorrad Hauptleitung	NCV3 HLS	SL Roadster Autarke
Scope of implementation	44,410,950	or	1,352,400	9,537,744	32,859,403	661,403
Volume of realization, pcs.	396,584		112,700	110,904	166,799	6,181
Variable costs	35,803,950		1,063,888	6,867 176	27,492,034	380,853
Marginal profit	8,607,000		288,512	2,670,568	5,367,369	280,550

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

So, according to the pessimistic forecast, the break-even point is even smaller by 2,193.0 thousand euros than according to the optimistic one. At the same time, the number of types of products is also smaller. In the pessimistic scenario, it is enough for the company to sell only 3 types of products in full and SL Roadster Autorke products in the amount of 661,403 euros. This result is caused by the fact that the products with the highest marginal profit in the total, taking into account the number of units sold, are many times smaller than the total amount of marginal profit of products with a smaller amount of profit per unit. So, for example, such a product type as NCV3 HLS received a unit profitability rank of 4 out of 6, but at the same time, the volume of the total marginal profit for this group of products is more than 50% of the total marginal profit for the shop. Therefore, for practical use it is more appropriate to use the averaged methods of CVP analysis presented above.

Conducting a CVP analysis is not limited to the calculation of the break-even point. Its continuation is an operational analysis, in the process of which the change in profit is considered as a function of the following factors: variable and fixed costs, the price of products (works, services), the volume and range of products sold. The main goal of such an analysis in modern conditions is to find answers to the question: what will happen to financial results if the specified factors are changed. O. Klementieva and O. Zolotaryov [3] paid a lot of attention to this issue in their research. Based on the obtained break-even point with the help of operational analysis, we will try to determine the margin of financial strength and operating leverage for the enterprise under study (Table 10).

Table 10. *Operational analysis in enterprise profitability management*

Indicator	Base value	Change in sales volume (-10%)	Change in fixed costs (+10%)	Change in variable costs (+10%)
1. Sales volume, euros	53,822,718	48,440,446	53,822,718	53,822,718
2. Total wages, euros	11,209,228	10,088,306	11,209,228	12,330,151
3. Total cost of raw materials, euros	32,075,387	28,867,848	32,075,387	35,282,926
4. Total variable costs, euros	43,284,615	38,956,154	43,284,615	47,613,077
5. Marginal profit, euros (p. 1-4)	10,538,103	9,484,292	10,538,103	6,209,641
6. Fixed costs, euros	8,607,000	8,607,000	9,467,700	8,607,000
7. Break-even point, euro (p. 6/5*1)	43,959,729	43,959,729	48,355,702	74,602,079
8. Stock of financial strength, euros (p. 1-7)	9,862,989	4,480,717	5,467,016	
9. Margin of financial strength, % (p. 8/1)	18	9	10	
10. Profit, euros (p. 5-6)	1,931,103	877,292	1,070,403	-2,397,359
11. Profitability ratio, % (p. 10/1)	3.59	1.81	1.99	-4.45
12. Operating lever (p. 5/10)	5.46	10.81	9.84	

Source: *built on the basis of the authors' own calculations based on the data in Table 1*

The indicator of the reserve of financial strength reflects the size of a possible decrease in the volume of product sales, which will not lead to a loss. So, under basic conditions, the company can allow a decrease in sales volume by 18%, or by 9,863.0 thousand euros. In this case, it will be in the break-even zone.

To model changes in economic indicators, the enterprise needs to use the indicator of operating leverage, applying various scenarios of the development of events. The action of the mechanism of operating leverage is based on the fact that the presence of any amount of constant types of them in the composition of operating costs leads to the fact that when the volume of sales of products changes, the amount of profit always changes at an even higher rate. The higher the specific weight of fixed costs in the total amount of costs of the enterprise, the greater the amount of profit changes relative to the rate of change in the volume of sales.

The effect of operating leverage can be observed when the basic conditions change. In our example, indicators were listed when changing such components as the volume of sales, the volume of variable and fixed costs. As you can see, the most critical for the enterprise is the increase in variable costs - under such conditions, the enterprise receives a loss, and the break-even point increases almost twice compared to the basic conditions. This indicates the expediency of managing variable costs to a greater extent than fixed costs, because with a 10% increase in fixed costs, according to our calculations, the company usually loses part of the profit, but this is the most acceptable option of all those mentioned. When the sales volume decreases by 10%, the company suffers a loss of profit due to the fact that the volume of marginal profit has decreased compared to fixed costs – the operating leverage under such conditions doubles. With the help of operational analysis, it is also possible to monitor the combinations of variable and fixed costs, sales price and volume of products sold that are adequate for the enterprise. After all, in some cases it is better to reduce the price of the product to increase sales volumes, and in others to increase individual items of fixed costs, which will ensure high demand [3].

Once again, we have a situation where the operational analysis involves the calculation of indicators based on the total volume of sales, disregarding the conditions of multi-product production, and in particular, it does not take into account the existing structure of production and sales. This fact also makes the results of the analysis conditional, very generalized, so they can only serve as a guide for making further management decisions.

CONCLUSIONS

The practical application of CVP analysis is related to solving a number of operational controlling tasks, namely: operating profit management, demand forecasting, assessment of break-even guarantees. The most important applied value of building a CVP-analysis model is related to the possibility of quantitative assessment of purposeful management of the ratio of fixed and variable costs in order to increase the efficiency of production activities under various trends of the product market situation and stages of the life cycle of the enterprise.

The complexity and peculiarity of the application of CVP analysis in the conditions of multi-product production is that its results are only indicative for making management decisions. The problem lies in the distribution of fixed costs by types of products, which in most cases is quite conditional and may not correspond to reality. However, the implementation of detailed accounting and detailed analysis at the enterprise will ultimately allow to separate all fixed and variable costs, which will increase the level of reliability of the results obtained. At the same time, the practical application of CVP analysis is limited, given the unreality of meeting all its inherent conditions.

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CVP-аналіз в умовах багатопродуктового виробництва як інструмент операційного контролінгу

Наталія Бабяк

Кандидат економічних наук
Київський національний економічний університет імені Вадима Гетьмана
03057, просп. Перемоги, 54/1, м. Київ, Україна
https://orcid.org/0000-0002-3210-4045

Н. Ю. Крутоус

Аудитор
ТОВ «Бейкер Тіллі Україна»
03150, вул. Фізкультури, 28, м. Київ, Україна

Анотація. Актуальні умови успішної діяльності підприємств характеризуються глобалізацією господарської сфери, прискореними темпами науково-технічного прогресу, посиленням інноваційних тенденцій. Тому будь-яка установа при побудові власної стратегії, насамперед прагне до надання умов для тривалої і перспективної діяльності, що можливо досягти лише за рахунок створення сильної конкурентної переваги. Зокрема, визнаним способом перемоги в конкурентній боротьбі є лідерство за витратами. Тому в даний час актуальним питанням є пошук раціонального інструменту організації системи управління витратами. Крім того, конкурентоздатність сучасних підприємств залежить від моделі керування фінансовими потоками. Перевага і лідерство на ринку переходить до організацій, які розрахунком втрат із постійними та змінними складовими мінімізують підприємницькі ризики. Для розрахунку беззбиткового обороту кожного виду продукції використовують CVP-аналіз. Метою роботи було дослідження застосування CPV-аналізу для рішення задач багатопродуктового виробництва і обліку витрат з метою підвищення ефективності виробничої діяльності. У статті було використано метод економічного аналізу, розрахунку точок беззбитковості, порівняння, моделювання. Розкрито особливості CVP-аналізу в умовах багатопродуктового виробництва, проведено порівняння методик його здійснення. Визначено можливості застосування результатів аналізу при прийнятті управлінських рішень в системі операційного контролінгу. Досліджено проблематику розподілу загальних постійних нерозподілених витрат на окремі види продукції різними методами, а також визначення беззбиткового рівня виробництва і реалізації окремих видів продукції на основі середньозваженого маржинального прибутку. Досліджено вплив на прибуток зміни рівня постійних витрат та питомих змінних витрат за допомогою операційного важелю в рамках операційного аналізу на виробничому підприємстві

Ключові слова: CVP-аналіз, змінні витрати, постійні витрати, маржинальний прибуток, точка беззбитковості, операційний аналіз

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Productivity of the mother root and cutting garden of the Pumiselect clone rootstock in the Steppe of Ukraine

Volodymyr Zamorskyi*

Full Doctor in Agrisciences, Professor
Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine
https://orcid.org/0000-0002-7437-9071

T. Kamedzko

PhD in Agrisciences, Associate Professor
Belarusian State Agricultural Academy
213407, 5 Michurin Str., Gorky, Belarus

Tatyana Manushkina

PhD in Agrisciences, Associate Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0001-5843-271X

Mykola Samoilenko

Full Doctor in Agrisciences, Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0002-3292-9717

V. Bushilov

Graduate Student
Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine

Abstract. The dynamics of productivity of the mother root & cutting garden of the Pumiselect clone rootstock was studied, taking into account the soil and climatic conditions of the Steppe zone of Ukraine, as well as technological aspects of crop management. In the first three years of vegetation of mother plants, there was an intensive build-up of the aboveground part of the bushes, which gave rise to transfer them to the state of operational plantings. Taking into account the annual complete alienation of growth in the next 4-9 years, significant aging of plants occurred, which was manifested in a decrease in habitus indicators, the number of shoots and their length. As a result, the productivity of mother root plantings decreased (the number of cuttings from 570.2 thousand units/ha up to 133.6 thousand units/ha), which limited the feasibility of long-term cultivation in order to obtain lignified cuttings

Keywords: Pumiselect, clone rootstock, mother root plantings, shoots, biometric characteristics, lignified cuttings

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*Corresponding author

INTRODUCTION

The natural conditions of Ukraine are favorable for growing a wide variety of fruit and berry crops. In recent years, the domestic fruit and berry industry has been developing rapidly, and fruit production has stabilized at almost 2 million tons. Despite a significant reduction in the area of plantings at fruit-bearing age, gross yield was largely compensated by an increase in the level of average yield [1, 2]. A noticeable growth potential for the collection of vitamin products was observed in the farms of the Steppe zone, as the most suitable for growing heat – loving stone-fruit crops, where their production increased 1.34 times over the past 15 years, and the yield – 1.97 times [3].

The use of clone rootstocks is one of the reserves for the intensification of fruit growing. Rationally selected rootstocks depend not only on the strength of growth and the period of entry of the garden into fruiting, but also on the yield, winter hardiness, drought resistance and durability of plantings. They make it possible to change the production technology, reduce the variation in the growth and fruiting of grafted trees in homogeneous plantings, accelerate the beginning of fruiting, and improve the quality of fruits [4]. Taking into account the peculiarities of the technological process and market relations, the best rootstock-graft combinations can make fruit production profitable.

Dwarf rootstock Pumiselect isolated in Germany (Geisenheim Research Institute) [5], proposed for apricot, cherry plum, peach and plum. It forms a powerful root system. It is drought-resistant, cold- resistant, resistant to Plum shark virus. Trees on the rootstock of Pumiselect grow small-the growth Force is half that on seedlings of cherry plums, wild apricot and almonds. They are characterized by high bud awakening and fruitfulness, low shoot-forming ability, high quantitative and qualitative indicators of the crop during the early entry of plantings into fruiting. Plants are demanding of the soil, do not withstand flooding well. It is recommended for intensive plantings of stone-fruit crops.

In this regard, studies on promising methods of rootstock reproduction are relevant, taking into account the biological characteristics of plants and a complex of abiotic factors.

Due to analysis of recent research and publications. Pumiselect rootstock is considered as promising for laying intensive orchards of stone fruit crops in various soil and climatic conditions, in particular, in the USA [6], Poland [7-9], the Czech Republic [10], Serbia [11], Tajikistan [12] and Ukraine [13, 14]. The expediency of using Pumiselect rootstock for Peach [4, 6, 8], apricot [9, 11], plum [10] is shown. The classic technology of reproduction of plants of the Pumiselect clone rootstock involves the use of a culture of vertical and horizontal layering. At the same time, in practice, propagation by lignified cuttings is also quite common. In [12], it was shown that when propagated by lignified cuttings, the highest percentage of rooting of Pumiselect rootstock cuttings was 86% in the variant treated with Kornevin at a concentration of 0.1%. Based on research [13], it was revealed that the Pumiselect clone rootstock was characterized by a high degree of rooting for a long time, which gave reason to consider its reproduction by lignified cuttings in the conditions of southern Ukraine as quite technological and promising. The rooting rate of cuttings was 68.3-82.0%, the yield of standard planting material was 67.9-81.3%.

In [14], it was found that the quality of rootstock plants obtained using the technology of reproduction by lignified cuttings is significantly higher compared to growing by Vertical cuttings. The yield of standard rootstock plants when rooting cuttings was 91.78%, while when propagating by vertical jigging it was only 60.19%. Final calculations showed that the profit from production when growing rootstocks with lignified cuttings was 2.16 times higher compared to propagation by vertical cuttings, and the level of profitability was 114.14 and 94.95%, respectively.

Analysis of scientific data obtained both in foreign countries and in Ukraine indicated the prospects of using Pumiselect rootstock and conducting research on its intensive reproduction. The issues of productivity of the mother root & cuttings garden and the duration of operation of Pumiselect rootstock plantings for harvesting lignified cuttings, depending on the biometric indicators of mother root plants in the Steppe of Ukraine, were not comprehensively considered.

The purpose of the research is to study the elements of productivity of the mother root & cutting garden of the Pumiselect clone rootstock and justify the period of its effective operation in the Steppe of Ukraine.

MATERIALS AND METHODS

The research was carried out on the basis of the nursery of LLC "Pidguryevskoe" of the Pervomaisky District of the Mykolaiv region, a branch of the Department of viticulture and fruit and vegetable growing of the Mykolaiv National Agrarian University. The experimental farm was located in the northern Steppe zone, the northern Steppe subzone was insufficiently moistened with ordinary chernozems. The terrain of the territory was slightly sloping, the slope of the south-eastern exposure was up to 1°.

The material for conducting the research was the Clone rootstock of Pumiselect. The experiment was laid in 2007 with improved planting material. The area where the queen cells were located was separated from the field crop rotation. Its predecessor was black fallow. The soil of the experimental site was ordinary chernozem, formed under mixed grass-feather grass-tipchak vegetation on loess rocks. The humus content in the arable layer was 3.3-3.8%, the humus layer was powerful and reached 150 cm. At a depth of 50-60 cm, the humus content decreased to 2.8-3.0%. The content of mobile phosphorus (by Machigin) was 21 mg/kg (average), the content of exchange potassium was 303 mg/kg of soil (increased). The average hydrolyzed nitrogen content was 90 mg/kg of soil (high). The calcium and magnesium content was very high as 24.2 mg/100 g of soil and 3.9 mg/100 g of soil, respectively. The amount of absorbed base alkali was 28.8 mg/100 g of soil (increased). Moreover, in the sum of the absorbed bases, the main share was occupied by calcium (84.0%), the smallest one was sodium (2.4%). The content of total carbonates in the surface layer didn't not exceed 1.1%, the content of "active lime" didn't not exceed 0.5%, which was safe for fruit crops. The reaction of the soil solution was slightly alkaline (pH=7.1). According to the mechanical composition, the soil of the experimental field was light clay, the content of physical clay ranged from 55-60%. According to the complex of general characteristics and indicators, the soil met all the conditions for maintaining perennial fruit plantations with additional application of mineral fertilizers.

The scheme of placement of mother plants in a mother root-cuttings garden of 3.0×1.0 m. preparation of the site, planting, care of plantings, harvesting of rootstocks and cuttings was carried out in accordance with generally accepted technologies and recommendations for the care of mother root plantings.

The structure of queen cells according to biometric indicators (height, diameter of plants, number of shoots and their length) was determined at the end of the growing season by measuring 100 plants (25 plants in four-fold repetition). The number of shoots of zero branching order per plant was taken as the main indicator of variation. Subsequently, the entire array of observations and records was ranked at intervals of 30 shoots. Harvesting of shoots for cuttings was carried out on mother root plantings (mother root & cutting garden) in the autumn (and decade of November) and spring (and decade of March) terms.

Mathematical processing of the results was performed in Microsoft Office Excel 2007.

RESULTS

During the first year of growing season of mother root plantings, a complex of agrotechnical measures was aimed primarily at the survival rate of planted plants. In general, weather conditions contributed to a balanced passage of growth processes, including the growth of the root system and the aboveground part. At the end of the growing season, the average height of plants was 0.85 m. A small number of shoots that grew at sharp angles, and their length, contributed to the formation of a compact habit. The area of the crown projection in relation to the area of nutrition that was allocated to mother plants was developed slowly and amounted to only 0.3%.

During the first three years of cultivation, young mother plants were fully formed and met the parameters that make it possible to transfer them to the category of operational plantings. During this period (1-3 years), the height of plants gradually decreased from 1.89 m to 1.80 m, while the crown diameter did not change and amounted to 1.69-1.70 m, relatively stable biometric indicators of the crown did not lead to a change in its habit. Calculations showed that the crown index was 1.09 up to 1.12, the crown projection area was 2.11 up to 2.24 m^2, and the ratio of the crown projection area to the feeding area was 0.71 up to 0.76. The working row spacing remained wide enough, which did not interfere with mechanized tillage, protecting plantings from pests and diseases.

At the end of the 4th year of vegetation (2010), the appearance of mother plants was rounded, the crown habit index was 1.12 (Table 1). In plants of the 4th year of cultivation, many shoots had large angles of departure, and the height of the plants exceeded their diameter. Taking into account the fact that the plant placement scheme was somewhat sparse (3.0×1.0 m), this did not lead to the fact that the projection area of the plant crown exceeded the allotted feeding area. A similar relationship between the studied indicators was observed at the end of the growing season in plantings of the 5th and 6th years of cultivation. In the future, some features in the condition of mother root plantings were revealed, taking into account their age and operating technology.

Table 1. *Biometric characteristics of mother root & cutting plantings of the Pumiselect clone rootstock*

Age of plantings	Plant height (H), m	Plant diameter (D), m	I=H/D	S projections, m^2	S projections/S nutrition
4	1.89	1.69	1.12	2.24	0.75
5	1.86	1.70	1.09	2.27	0.76
6	1.80	1.64	1.10	2.11	0.71
7	1.65	1.55	1.06	1.89	0.63
8	1.11	1.20	1.05	1.13	0.38
9	0.89	0.84	1.06	0.55	0.18
Average	1.53	1.44	1.06	1.70	0.57
LSD_{05}	0.09	0.09	-	-	-

The annual mass harvesting of cuttings depleted the mother root plants. Building up new shoots during the year, and then removing them in the autumn period, it did not leave the possibility of accumulating plastic substances to undergo balanced growth processes in the spring of the following year. This was manifested in changes in the main indicators of habit, primarily the height and diameter of mother root plants in the next three years of their operation. Moreover, every year there was a clear tendency to reduce the biometric indicators of mother root plants.

So, already in the plantings of the 7th year of cultivation, the average height of plants was only 1.65 m, in the 8th year it was 1.11 m, in the 9th year it was 0.89 m. That is, during the next 3-year cycle of operation of plantings, there was a clear decrease in the average height of plants, which was 89.2%, 60.0% and 48.1%, respectively, compared to the average indicators of 2010-2012 yrs.

From the 4th to the 9th growing season, the crown diameter also gradually decreased-from 1.69 m to 0.84 m and the crown projection area decreased from 2.24 m^2 to 0.55 m^2. In the end, this led to the fact that the ratio of crown indicators projection area/feeding area significantly decreased from 0.75 to 0.18. It should be noted that the shoots developed equally evenly in the radial direction. This contributed to the fact that the working row spacing of plantings even increased from 1.32 m to 1.80 m.

As records showed in the initial period of operation of mother root plants, the crown diameter significantly exceeded the distance between them in a row. In a row, the shoots of one plant were placed in the adjacent area of the projection of the crown of the neighboring plant by an average of 22 cm. As the plantings aged, as already noted, the crown diameter decreased and, as a result, the penetration of shoots of one plant into the crown of a neighboring plant decreased, too. So, in the first years of operation of plantings (4-6 years of cultivation), the penetration of shoots into the neighboring zone of plants at the end of the growing season was 32-35 cm. As the plantings aged, the penetration of shoots significantly decreased and by the 8th year the cultivation of plantings was only 10 cm.

The lowest biometric indicators were characterized by mother root plants at the end of the growing season of the 9th year of cultivation. The crown index was 1.06. Moreover, the crown diameter was significantly smaller than the distance between neighboring plants and decreased to 0.84 m. The projection area was equal to 18.0% of the feeding area that was allocated for mother root plants when laying plantings. Reducing the habit of the crown, primarily its diameter, led to an increase in technological passage in row spacing, but it did not affect the use of equipment in any way.

The overall aging of plants and the decrease in basic biometric indicators significantly affected the productivity of mother root plantings. Thus, during the 5th-9th years of cultivation, there was not only a change in the habit of mother root plants, but also its structural components, first of all, the number and length of shoots. There was an obvious tendency to reduce these indicators during the entire cycle of operation of mother root plantings (Table 2).

Table 2. *Dynamics of shoot-forming ability of mother root plantings of the Pumiselect clone rootstock*

Age of plantings	Shoot		Increment		
	length, cm	number, PCs.	plant, m	ha, 1,000 m	%
5	79.9	53.5	42.7	142.3	158.6
6	74.7	47.7	35.6	117.7	131.2
7	72.8	40.8	29.7	99.0	110.4
8	63.0	26.6	16.8	56.0	62.4
9	53.0	18.9	10.0	33.3	37.1
Average	71.1	37.9	26.9	89.7	100.0
LSD_{05}	4.86	2.61	-	-	-

In the 5th-7th years of operation, the largest number of shoots and their growth were observed both per plant and per unit area. With increasing age of plantings, the number of shoots per plant and their length decreased, and these indicators were lowest in plants of the 9th year of cultivation. The average growth of shoots of one mother root plant decreased from 42.7 m to 10.0 m, or 4.3 times, and the total growth decreased from 142.3 thousand m/ha to 33.3 thousand m/ha. In the 8th-9th year of operation of mother root plants, their significant depression was detected. The average growth length decreased by 26.8-50.8%, the number of shoots decreased by 20.1-28.3%. This could not but negatively manifest itself in the overall growth of plantings. If in the initial period (6-7 years) the decrease in the length of shoot growth, which fell on one plant, was insignificant (7.0%), then in subsequent years the tendency to reduce the length of growth increased.

It is known that the placement of leaves on the shoot, their self-shading negatively affects the process of photosynthesis. One of the indicators that determine the feasibility of the plant placement scheme and their feeding area is the area of the assimilation surface, which falls on the feeding area or the projection area of mother root plants. The dynamics of reducing the diameter of mother root plants was slower than the dynamics of the area of the leaf apparatus, which led to a significant decrease in the assimilation surface per unit projection of the plant (Table 3).

Table 3. *Dynamics of the leaf area of mother root plantings of the Pumiselect clone rootstock*

Age of plantings	Leaf area, m^2			Ratio	
	plant	Ha	%	Sl/Sn	Sl/Sp
5	4.72	15,733.2	186.9	1.57	2.08
6	3.25	10,833.2	128.7	1.08	1.54
7	2.59	8,633.2	102.5	0.86	1.37
8	1.43	4,766.6	56.6	0.48	1.26
9	0.64	2,133.3	25.3	0.21	1.16
Average	2.53	8,419.8	100.0	0.84	1.64
LSD_{05}	0.18	-	-	-	-

Note: *Sl – Leaf area, m^2; Sn – plant nutrition area, m^2; Sp – area of plant projections, m^2*

In young plants (5^{th} year of cultivation), the area of the Leaf apparatus was slightly larger than the area of nutrition, their ratio was 1.57. As the plantings aged, this indicator changed significantly, it was the lowest in the 9^{th} year of cultivation and it was only 0.21. That is, if 1.0 m^2 of the area of nutrition of a 5-year-old plant accounted for 1.57 m^2 of leaf surface, then in the 9^{th} year – 0.21 m^2, or 5.73 times less. Intensive operation of the mother root & cutting garden for 4-5 years, in which a significant share of the growth was alienated annually, caused its intensive aging, which was manifested in a decrease in the biomorphological indicators of plantings.

In the mother root & cutting garden of the Pumiselect clone rootstock, where the main indicator of the feasibility of using plantings was the growth of the current year, the number of shoots could be the basis for gradation of plants into groups. Surveys showed that more than 100 shoots could form on well-developed plants during the year. Plants that had limited development contributed to the regrowth of only 10-20 shoots. In our work, the variation on this feature was in the range of 10 up to 100 shoots.

At the beginning of the operation of mother root plantings (the 5^{th} year of cultivation), the plants were of somewhat different quality, but at the same time they were almost evenly represented in the established groups (Table 4). Thus, the number of plants of Group I, where 0-30 shoots were formed, was 30.5%, Group II (31-60 shoots) was 27.0%, and Group III (61-90) shoots was 26.3%. The lowest number was found for plants of Group IV (90-120 shoots) as 16.2%.

Table 4. *Structure of the mother root & cutting garden of the Pumiselect clone rootstock, %*

Age of plantings	Plant groups by number of shoots				Number ofplants per 1.0 ha, PCs
	I 0-30	II 31-60	III 61-90	IV 91-120	
5	30.5	27.0	26.3	16.2	100.0
6	35.2	31.5	22.3	11.0	100.0
7	43.7	33.0	16.8	6.5	100.0
8	68.0	25.2	6.8	0.0	100.0
9	87.0	13.0	0.0	0.0	100.0
Average	52.9	25.9	14.5	6.7	100.0

With an increase in the age of plantings, there was a decrease in their productivity not only in general, but also the very structure of individual groups in the mother root-cuttings garden changed. It was found that the number of plants on which the maximum number of shoots (Group IV) grew out of 540 PCs/ha up to 216.7 PCs/ha significantly decreased. In the 8^{th}-9^{th} year of cultivation, plants of Group IV were completely absent. The same trend was observed for plants of Group III. The number of such plants in the plantings of the 5^{th} year of cultivation was 26.3%, the 7^{th} year of cultivation it was 16.8%. There were absolutely no such plants in the most summer plantings of the 9^{th} year of cultivation.

It is obvious that a decrease in the number of the most productive mother root plants in plantings with age leads to an increase in the proportion of plants with lower productivity indicators in plantings (Table 5). So, if in the plantings of the 5^{th} year of cultivation the share of the least productive plants (Group I) was 30.5%, then in a year it was 43.7%, in three years it was 43.7%, in five years it was 87.0%. A slight increase in the proportion of plants belonging to Group II in plantings of the 6^{th}-7^{th} years of cultivation can be explained by the fact that over time the proportion of plants of groups III-IV decreased, and the proportion of unproductive plants increased significantly.

Table 5. *Structure of the mother root & cutting garden of the Pumiselect clone rootstock, PCs/ha*

Age of plantings	Plant groups by number of shoots				Number of plants per 1.0 ha, PCs
	I 0-30	II 31-60	III 61-90	IV 91-120	
5	1,016.7	900.0	876.6	540.0	3,333.3
6	1,173.3	1,050.0	743.0	366.0	3,333.3
7	1,456.6	1,100.0	560.0	216.7	3,333.3
8	2,266.6	840.0	226.7	0.0	3,333.3
9	2,900.0	433.3	0.0	0.0	3,333.3
Average	1,762.6	864.7	481.3	224.7	3,333.3
LSD_{05}	128.1	60.9	33.5	15.2	-

Along with the number of shoots that grow on mother root plants, a qualitative indicator is important as the length of shoots. Less developed plants were characterized by the fact that the average length of shoots was shorter than that of the most developed plants. Moreover, this trend continued with age, although the absolute values changed slightly. Thus, the average growth for plants for the entire period of research ranged from 61.6-82.0 cm (Table 6).

Table 6. *The length of shoots depending on the condition of the mother root plants of the Pumiselect clone rootstock, cm*

Age of plantings	Plant groups by number of shoots				%
	I 0-30	II 31-60	III 61-90	IV 91-120	
5	69.0	75.3	81.5	84.6	112.4
6	64.5	70.1	77.3	81.1	105.1
7	62.3	67.6	72.3	80.3	97.9
8	60.2	63.1	68.1	0.0	88.6
9	51.9	55.5	20.0	0.0	74.5
Average	61.6	66.3	74.8	82.0	100.0
LSD_{05}	4.38	4.51	5.42	5.69	-

The greatest length of shoots was observed in mother root plantings in the first years of their operation. As the plantings aged, the growth length decreased, and a decrease in the average shoot length was noted regardless of the degree of development of the mother root plants. Thus, in plants of Group IV, this indicator decreased by 5.4% over three years. For plants of Group III, the average shoot length decreased by 12.0% over four years, for plants of Group II and Group I over five years the length decreased by 13.4%. It should be noted that as the plantings aged, the growth rate decreased, which was determined separately for each group of plants (Table 7). So, if in the least developed plants in the initial period of operation of plantings it was 10.4 m, then over the years it decreased to 7.8 m. The same trend was observed for mother root plants, in which the number of shoots was 31-60 as the total increase decreased from 33.9 m to 24.9 m. The decrease in the length of growth over five years of operation of mother root plants in relation to the average productivity ranged from 159.8% to 37.4%.

Table 7. *Growth length depending on the condition of the mother root plants of the Pumiselect clone rootstock, m/plant*

Age of plantings	Plant groups by number of shoots				%
	I 0-30	II 31-60	III 61-90	IV 91-120	
5	10.35	33.88	61.12	88.83	159.8
6	9.68	31.54	57.98	85.16	133.1
7	9.34	30.42	54.22	84.32	107.2
8	9.03	28.40	51.08	00.00	62.6
9	7.78	24.98	00.00	00.00	37.4
Average	9.24	29.84	44.88	51.66	100.0
LSD_{05}	0.67	2.17	3.26	3.81	-

As the mother root plantings aged, as already noted, the number of shoots on one plant decreased. These circumstances led to the fact that in the 8^{th} year of vegetation, no mother root plants of Group IV were found, which had the maximum growth length, and in the 9th year as Group III. A significant share in the plantings was represented by plants of Group II, in which an average increase of 29.8 m was noted.

Taking into account the structure of the mother root & cutting garden and age-related changes in plantings, the dynamics of its productivity was established. As could be seen from the above calculations, the qualitative composition of plantings decreased with aging, which led to a decrease in the total length of growth. So, if in the first years it was 133.1 up to 159.8% of the average productivity, then in the 8th-9th years of operation it was much less as 37.4-62.7%. Basically, the decrease in the productivity of plantings was noted due to the fact that subsequently the most productive plants belonging to groups III-IV were absent. Although, it should be noted that more developed plants that moved from a larger group to a smaller one slightly increased their indicators (Table 8). The total growth of plants of Group I, taking into account their number, increased from 10.5 thousand m/ha (5th year of cultivation) to 22.6 thousand m/ha (9th year of cultivation). But a significant increase in the structure of plantings of plants of the first group did not allow to compensate for the losses of the most productive plants.

Table 8. *Total growth depending on the condition of mother root plants of the Pumiselect clone rootstock, thousand m/ha*

Age of plantings	Plant groups by number of shoots				%
	I 0-30	II 31-60	III 61-90	IV 91-120	
5	10.522	30.492	53.578	47.968	159.8
6	11.358	33.117	43.079	31.168	133.1
7	13.605	33.462	30.363	18.272	107.3
8	20.467	23.856	11.580	0.000	62.7
9	22.562	10.824	0.000	0.000	37.4
Average	15.703	26.350	27.720	19.482	100.0
LSD_{05}	1.02	1.85	1.98	1.44	-

If we consider the productivity of mother root plantings of the Pumiselect clone rootstock in order to obtain lignified cuttings, then the negative dynamics with increasing age of plantings is obvious. As the plants aged, their productivity significantly decreased. In particular, for the 5th-6th year of cultivation, the total increase allowed to harvest 474.9 up to 570.2 thousand units/ha of cuttings, and for 7-8 years it was 223.6 up to 382.8 thousand units/ha (Table 9).

Table 9. *Productivity structure of mother root plants of the Pumiselect clone rootstock, thousand m/ha*

Age of plantings	Total length of shoots		Number of cuttings by size 0.25 m	
	Per mother rootplant, m	Per 1.0 ha motherroot & cutting-cuttings garden, thousand m	ThousandPCs/ha	%
5	42.77	142.56	570.2	100.0
6	35.62	118.72	474.9	83.3
7	28.71	95.70	382.8	67.1
8	16.77	55.90	223.6	39.2
9	10.02	33.39	133.6	23.4
Average	26.77	89.19	356.8	62.5
In total	133.89	446.27	1,785.1	-

The lowest productivity of mother root plantings was characterized by the 9th year of cultivation as 133.6 thousand units/ha of cuttings, that is, there was a decrease in the productivity of mother root plantings during the five years of their operation by 4.3 times. It should be noted that the total length of shoots that grew per 1.0 hectares of the mother root & cutting garden from the 5th to the 9th years of vegetation was 446.3 thousand m, which made it possible to prepare 1.78 million cuttings with a size of 0.25 m.

As a result of the research, a general trend towards a decrease in the productivity of the mother root & cutting garden in the dynamics from the 5th to the 9th year of vegetation of mother root plants of the Pumiselect clone rootstock was noted. The length of shoots, the length of growth, and the qualitative composition of plants decreased, which further affected the rooting of cuttings and the quality of the resulting rootstocks. It is obvious that cyclic operation of such plantings is needed, which will help extend the duration of their productive use.

CONCLUSIONS

Based on the conducted scientific studies on the productivity of the mother root & cutting garden of the Pumiselect clone rootstock in the conditions of the Steppe of Ukraine, the following conclusions were formulated:

1. During the first three years of cultivation, young mother root plants formed morphostructural elements that gave rise to transfer them to the state of operational plantings. The dynamics of the formation of the height and diameter of mother root plants during this period made it possible to sufficiently justify the optimal plant placement schemes and feeding area.

2. Taking into account the almost complete alienation of annual growth after the end of the growing season, with an increase in the age of mother root plants, a decrease in their habit was revealed, which led to a decrease in the productivity of plantings. The height of mother root plants for five years of intensive operation decreased by 2.1 times, the width decreased by 2.0 times, the crown projection area decreased by 4.1 times, the leaf apparatus area decreased by 7.4 times.

3. A direct relationship was found between an increase in the age of mother root plants and changes in habit indicators and the main morphological elements which determined their productivity. There was an annual decrease in the number of growing shoots and their length, which, in turn, led to a decrease in the total length of growth from 142.3 thousand m/ha to .3 thousand m/ha, or 4.3 times.

4. In the most productive period of operation of mother root plantings, it was possible to prepare 35.6 up to 42.8 m of growth per plant and 474.9 up to 570.2 thousand units/ha of cuttings, while from aging plantings it was only 10.0 up to 16.8 m of growth per plant and 133.6 up to 223.6 thousand units/ha of cuttings.

Thus, the mother root plants of the Pumiselect clone rootstock, when used intensively, significantly reduced their biometric indicators with increasing age of plantings. Moreover, already in the 7th-9th years of cultivation, there was a sharp decrease in the productivity of plantings and the quality of cuttings, which led to a reduction in the duration of active plant life.

Prospects for further research are to develop elements of cyclic operation of the mother root & cutting garden, which will help to extend the duration of productive use of mother root plants for harvesting lignified cuttings.

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Продуктивність матково-живцевого саду клонового підщепи пуміселект в умовах Степу України

Володимир Заморський

Доктор сільськогосподарських наук, професор
Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна
https://orcid.org/0000-0002-7437-9071

Т. Камедько

Кандидат сільськогосподарських наук, доцент
Білоруська сільськогосподарська академія
213407, вул. Мічуріна, 5, м. Горки, Білорусь

Тетяна Манушкіна

Кандидат сільськогосподарських наук, доцент
Миколаївський національний аграрний університет
54008, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0001-5843-271X

Микола Самойленко

Доктор сільськогосподарських наук, професор
Миколаївський національний аграрний університет
54008, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0002-3292-9717

В. Бушілов

Випускник
Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна

Анотація. Досліджено динаміку продуктивності матково-живцевого саду клонових підщеп пуміселект з урахуванням грунтових і кліматичних умов зони Степу України, а також технологічних аспектів ведення культури. У перші три роки вегетації маточних рослин відбувалося інтенсивне нарощування надземної частини кущів, що дало підставу перевести їх в стан експлуатаційних насаджень. З урахуванням щорічного повного відчуження приросту в наступні 4-9 років відбувалося значне старіння рослин, що проявлялося у зменшенні показників габітусу, кількості пагонів і їх довжини. В кінцевому підсумку знижувалася продуктивність маточних насаджень (кількість живців від 570,2 тис. шт./га до 133,6 тис. шт./га), що обмежувало доцільність тривалого ведення культури з метою отримання здерев'янілих живців

Ключові слова: пуміселект, клонова підщепа, маточні насадження, пагони, біометрична характеристика, здерев'янілі живці

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The influence of climatic changes on the formation of corn productivity in the Western Forest-Steppe of Ukraine

Anatolii Polovyi*

Full Doctor in Geographical Sciences, Professor
Odesa State Ecological University
65016, 15 Lvivska Str., Odesa, Ukraine
https://orcid.org/0000-0001-8395-0068

Tatyana Kostiukievych

PhD in Geographical Sciences
Odesa State Ecological University
65016, 15 Lvivska Str., Odesa, Ukraine
https://orcid.org/0000-0002-1952-8839

Alla Tolmachova

PhD in Geographical Sciences
Odesa State Ecological University
65016, 15 Lvivska Str., Odesa, Ukraine
https://orcid.org/0000-0002-9340-5028

Olena Jigaylo

PhD in Geographical Sciences, Associate Professor
Odesa State Ecological University
65016, 15 Lvivska Str., Odesa, Ukraine
https://orcid.org/0000-0002-3552-327X

Abstract. Currently, the trend of actively accelerating the pace of global warming has a negative impact on the current situation in the field of agriculture in many parts of the globe. According to current forecasts, the consequences caused by it will continue to intensify in the coming years. Many facts testify to the predominance of the negative consequences of these influences, including: an increase in temperature regimes, an increase in their variability, an increase in the amount and frequency of precipitation, an increase in periods of drought, and the presence of extreme weather phenomena. In addition, climate changes, increased humidity and CO_2 in the air are making adjustments to crop yields. The main fodder crop in the world is corn, therefore adaptation of agricultural conditions to climatic fluctuations becomes an urgent stage for farmers. Today, corn meets demand not only in the food industry, but also in medicine and energy supply. The purpose of the work is to determine changes in the number of growing seasons and interphase periods of corn, to assess the photosynthetic productivity of crops and to forecast yield indicators. During the research, the method of comparison, monitoring, as well as observation and empirical research was used. The scenario of possible climate changes RCP 6.0 for the period until 2050 was used. The dynamic model of crop productivity, developed by A.M. Polovyi, was used as a research tool. The article presents the results of assessing the impact of climate change on the formation of corn productivity in the Western Forest Steppe of Ukraine. The value of the obtained results lies in their application in the development and improvement of the corn cultivation model in view of the widest list of climatic deviations

Keywords: maize, climate change, crop productivity, RCP 6.0 scenario

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*Corresponding author

INTRODUCTION

Today, the rapid pace of global warming is already affecting the agricultural sector in many parts of the globe, and its effects will only intensify in the coming years and decades. The predominance of negative results of this impact is indicated by numerous facts: increase in temperature and increase in its variability, change in the amount and frequency of precipitation, increased frequency of dry periods and droughts, increase in the intensity of extreme weather events, salinization of arable land and fresh water.

Reliable supply of the country's population with food is of strategic importance in the conditions of the global world, financial and economic crisis. In connection with the expected increase in air temperature in the Northern Hemisphere, Ukraine's food security will largely depend on how effectively agriculture adapts to future climate changes.

In solving the problem of food security, a special role belongs to corn grain as the most important and socially significant product. Maize is the main fodder crop in the world, as it is considered one of the best types of grain for the production of concentrated fodder for animal feed. The need for corn and its fields of application are not limited only to food purposes, the products of its processing are actively used in industry, animal husbandry and medicine. Today, corn is also the main source of raw material for biogas plants in Europe. This is due to its high yield and the absence of significant problems in cultivation [1; 2]. In the world, in recent decades, corn has been characterized by the highest rates of yield growth among grain crops. In recent years, there has been a tendency to increase the areas devoted to corn cultivation. Adaptation of agriculture to current and future climate changes is of crucial importance today – effective planning and implementation of adaptation measures at various levels of state institutions can help in the implementation of this issue. Therefore, the assessment of future climate changes is very important today, and not only for agriculture.

Today, there is no doubt that the change in climatic conditions leads to significant variability in the yield of many agricultural crops, including corn [3-5]. Up to a certain level, an increase in temperature can contribute to the growth of the yield of some crops in the "cooler" parts of the globe, but if it exceeds the optimal level for this crop or there is a shortage of moisture and nutrients, then the yield can decrease. An increase in the frequency of extreme events, especially floods and droughts, also damages agricultural crops and reduces their yield [6; 7].

An increase in temperature, humidity and the level of carbon dioxide (CO_2) in the atmosphere contributes to the spread of many weeds, pests and diseases. Extreme temperatures combined with reduced precipitation inhibit crop development, but most studies indicate that these effects will change over time and vary depending on where they occu [8; 9].

A special report of the Intergovernmental Panel on Climate Change [10] on emissions scenario issues predicts the possibility of regional differences in global production that could put more than 5 million people at risk of hunger by 2100 [7]. According to [10], the projected increase in global warming to 1.5°C is likely to reduce the yield of major cereal crops, including maize, in sub-Saharan Africa, Southeast Asia, and Central and South America. To ensure today's level of food security and in the coming decades, efforts have been made to create simulation models for corn aimed at predicting the growth, development and yield potential of agricultural crops under certain environmental conditions. According to [3; 11-13], the main problem affecting the growth and development of corn is the change in weather conditions, which lead to intraseasonal yield variability.

The impact of climate change on corn growing conditions in Northeast China was considered by scientists from the Institute of Geographical Sciences and Natural Resources Research of the Chinese Academy of Sciences [13]. The crop-environment synthesis model CERES-Maize v4.5 was used to simulate future maize yields in combination with data for the representative concentration trajectory scenarios (RCP)-RCP 4.5 and RCP 8.5. The results of the study indicate a trend towards a continued decline in maize yields for both climate change scenarios. Thus, when the RCP 4.5 climate scenario is implemented, the average corn yield will decrease by 2.1% by 2020, by 12.9% by 2050, and by 22.7% by 2080. Moreover, reductions of 6.3, 18.4 and 47.5% are expected in the corresponding periods under the RCP 8.5 scenario excluding CO_2. In turn, the impact of CO_2, according to scientists' calculations, will be too small to compensate for the negative effects of climate change.

Parks *et al.* [14] used the GLAM model to assess the impact of climate change on maize cultivation in West Africa. According to the results of the study, a decrease in corn yield by 5.95% is expected when the temperature increases by 2°C, and under the conditions of an increase in temperature by 4°C, a decrease in yield by 37% is expected. It is noted that significant crop failures, which previously occurred only once every 19.7 years, will be observed every 2.5 years.

The study of the influence of the current climate of Ethiopia on the yield of maize was carried out using the APSIM-maize and DSSAT CSM-CERES-maize models [15]. The climatic periods of the near future (2010-2039), the middle (2040-2069) and the end of the 21st century (2070-2099) were considered. Climate simulations were performed using 20 general circulation models (GCMs) and two representative concentration trajectories (RCP 4.5 and RCP 8.5). The results of the study showed that, according to the scenarios, a slight increase in corn yield is expected (by 1.7-4.2%).

For the territory of Ukraine, the influence of climatic changes on the conditions for the formation of corn productivity was studied by T.K. Kostyukevich and T.I. Adamenko [16]. The conducted comparative characteristics based on average long-term data (1986-2005) and climate change scenarios A2 and A1B showed that the best conditions for the formation of corn productivity will be observed in the territory of Polissia, the worst – in the territory of the Southern Steppe. For the Western Forest-Steppe, under the implementation of the A2 climate change scenario, a yield decrease of 4-8% is expected, under the climatic conditions of the A1B scenario, a more significant decrease in yield is expected – up to 20%.

Most of the reviewed works are focused on forecasting the impact of climate change on corn production in comparison with the adaptation and suitability of the territory for corn cultivation. The process-based models used to simulate maize vary in complexity but share common comparable input parameters that include crop phenology, plant cover characteristics, and biomass development. The comparability of the input parameters in the models is relevant for climate change studies, the results of which can be used to make decisions and determine the direction of the policy for the further development of agriculture.

The purpose of the study is to assess the possible impact of climate change on the productivity of corn crops (medium-ripening varieties and hybrids) in the conditions of the Western Forest Steppe of Ukraine.

MATERIALS AND METHODS

One of the simplest methods of displaying possible changes in the climatic regime of any meteorological quantity is a comparison with past data, in particular, average multi-year values for the base period. In this study, the period from 1991 to 2010 is taken as the base. To assess possible climate changes, we used the RCP 6.0 scenario (representative concentration trajectories), which is a stabilization scenario and is currently considered the most realistic possibility [17] and the RCP 6.0+CO_2 scenario, which takes into account a 30% increase in CO_2.

The impact of climate change on corn productivity was assessed based on the dynamic model of crop productivity by A.M. Field [18]. The basis of the model is the system of equations of radiation, heat, water balances and the balance of biomass (carbohydrates and nitrogen) in the plant cover in the "environment – plant" system. The "environment – plant" system is considered as a complex dynamic system that develops under the influence of internal and external factors. In this system, the process of growth, development and formation of plant productivity in their complex interaction are highlighted. Modeling the process of plant growth and development contains a quantitative description of the processes of photosynthesis, respiration, growth and development of plants. The identification of model parameters was carried out on the basis of observation data at the network of hydrometeorological stations of the Hydrometeorological Service of Ukraine of the State Emergency Service of Ukraine [19].

To characterize the indicators of photosynthetic productivity of corn and agroclimatic growing conditions under different climatic conditions, the following were calculated: the dates of the onset of the phases of corn development, the sum of positive air temperatures and the sum of precipitation for interphase periods, the relative area of corn leaves, net photosynthetic productivity, photosynthetic potential, and the increase in total dry biomass in the period of maximum development. It should be emphasized that the impact of climate change on the formation of the productivity of corn crops was considered under the conditions of modern agricultural technology and modern varieties and hybrids of the culture, assuming that they will not change significantly.

RESULTS AND DISCUSSION

The possibility of using corn as the most important object of agricultural culture in different soil and climatic conditions indicates its high lability, the ability to successfully adapt to significant fluctuations and various combinations of vital factors. However, the conditions necessary for the growth and development of corn cannot be infinitely variable. The parameters of these conditions are determined primarily by the ecological features of plants, which have developed during the long evolution of the species under the influence of natural factors and the conscious activities of many generations of farmers. These features are determined by the reaction of the plant to the influence of such factors as moisture, soil and air temperature, soil acidity and its provision of the necessary reserves of mineral nutrition elements available to the plant, light, interaction between corn plants and other plants in the crop. Corn can develop normally and accumulate a significant amount of organic matter with an optimal combination of all the above factors.

Corn is a monocarpic annual plant of the spring type of development. The duration of the life cycle of corn, depending on the conditions of its growth and varietal characteristics, varies greatly. In corn, the following are the most significant phases of plant formation: seedlings, fifth leaf, seventh-eighth leaf (period of intensive growth), shedding of the panicle, flowering of the panicle and cob, milky, waxy and full ripeness. The occurrence and duration of each of them depends on the complex of agrometeorological conditions.

In the western part of the Forest Steppe, corn is sown at the end of the second decade of April (April 17). Under the influence of climatic changes, the sowing dates are expected five days earlier – on April 12. According to scenario calculations, the emergence of seedlings is expected on May 8, which is three days earlier than according to long-term data (May 11) (Table 1).

Table 1. *Maize development phases based on average multi-year data compared to those expected under the RCP 6.0 climate scenario*

Period, years	Sowing	Seedlings	Ejection of panicles	Milk ripeness	Wax maturity	Duration of the period, days
1991-2010	17.04	11.05	26.06	20.07	16.08	121
2021-2050, RCP 6.0	12.04	8.05	20.06	17.07	2.08	112
Difference	-5	-3	-6	-3	-12	-9

The assessment of agrometeorological conditions for growing corn during the growing season based on average multi-year data in comparison with those expected under the RCP 6.0 climate scenario was carried out in interphase periods. For each period, the average air temperature, the sum of active temperatures, the sum of precipitation and the duration of the period were determined (Table 2).

Table 2. *Evaluation of agro-meteorological conditions for growing corn during the growing season based on average multi-year data compared to those expected under the RCP 6.0 climate scenario*

Period, years	Average air temperature for the period, °C	Sum of active temperatures for the period, °C	Sum of precipitation for the period, %	Duration of the period, days
		Sowing – seedlings		
1991-2010	12.5	300	100	24
2021-2050 – RCP 6.0	12.6	328	141	26
Difference	+0.1	+28	+41	+2
		Seedlings – throwing out panicles		
1991-2010	17.8	820	100	46
2021-2050 – RCP 6.0	19.1	804	98	42
Difference	+1.3	-16	-2	-4
		Ejection of the panicle – milk ripeness		
1991-2010	21.0	505	100	24
2021-2050 – RCP 6.0	22.6	498	88	22
Difference	+1.6	-7	-12	-2
		Milk ripeness – waxy ripeness		
1991-2010	20.9	564	100	27
2021-2050 – RCP 6.0	23.0	483	76	21
Difference	+2.1	-81	-24	-6
		Seedlings – waxy maturity		
1991-2010	18.1	2,189	100	121
2021-2050 – RCP 6.0	19.0	2,113	96	112
Difference	+0.9	-76	-4	-9

The sum of active temperatures accumulated during the sowing-seedling period according to the average long-term data is 300°C, according to the scenario data, it is expected to be a little more – 328°C, but the duration of the period according to the scenario data is also expected to be two days longer. According to scenario data, the average air temperature is expected to be at the multi-year level. Significant changes will be observed in the amount of precipitation – 41% higher than in multi-year conditions (Table 1; Table 2).

The panicle shedding phase under perennial conditions occurs on average at the end of June (June 26) with the accumulation of the sum of active temperatures around 820°C, under the conditions of climate change, this phase is expected six days earlier, the duration of the period as a whole will decrease by four days, and the sum of active temperatures will be close to 804°C. Under the conditions of climate change, the average air temperature during the interphase period of emergence-ejection of the panicle is expected at the level of 19.1°C, which is 1.3°C higher than under basic conditions. No significant changes are expected in the amounts of precipitation.

After the phase of throwing out the panicle in corn, the phase of milk maturity comes. According to long-term data, it occurs when the sum of active temperatures is around 505°C at the end of July (July 20), under the conditions of climate change, the onset of this phase is expected three days earlier (in general, the duration of the period will decrease by two days) when the sum of active temperatures is around 498°C.

Under the scenario conditions, the average air temperature during the interphase period of panicle ejection – milk ripeness is expected to be 22.6°C, which is 1.6°C higher than under baseline conditions. The amount of precipitation is also expected to differ - according to the scenario, the amount of precipitation decreases by 12% (Table 2). The milk ripeness phase is followed by the wax phase. Under long-term conditions, it occurs with the accumulation of the sum of active temperatures of about 564°C in mid-August (August 16), under the conditions of climate change, it is expected on August 2 with the accumulation of the sum of active temperatures of about 483°C. In general, under the conditions of the scenario, the duration of the period is expected to be reduced by six days. Under the conditions of climatic changes, the average air temperature during the period of milk-wax maturity is expected to be at the level of 23.0°C, which is 2.1°C higher than under basic conditions. A significant difference is also expected in the amount of precipitation – due to climate change, the amount of precipitation during the period will decrease by 24%.

No significant changes are expected during the growing season, but there is redistribution, sometimes very significant. So, for all periods according to the scenario data, except for the period of sowing and planting, a decrease in the amount of precipitation is expected. A similar situation is observed with other indicators. Also, under the conditions of climatic changes, a reduction in the duration of interphase periods is expected, this is due to an increase in the average air temperature, which in turn causes an acceleration of the onset of the phases of culture development.

The study of the influence of certain technological techniques on the growth and development of agricultural crops is usually accompanied by observations of the features of photosynthetic activity in crops. This question is extremely important, because the change in the conditions of plant growth inevitably, directly or indirectly, affects the production process, and accordingly - the formation of the crop. Numerous studies [20; 21] show that plant productivity is closely related to growth and photosynthesis – two cardinal physiological processes. The creation of a photosynthetic apparatus of high activity is the first condition for obtaining significant sowing productivity. The second, no less important condition is the creation of a photosynthetic apparatus of sufficient size, i.e. obtaining the optimal leaf area.

The main indicators characterizing the production process in crops are: relative leaf area, leaf surface index, photosynthetic potential, net productivity of photosynthesis, dry biomass.

The high productivity of corn is also due to the fact that assimilation of carbon dioxide occurs, as in other tropical plants belonging to the C4 plant group. The photosynthetic productivity per unit of leaf surface and per unit of time in corn is 2-3 times higher than in agricultural crops from the temperate climate zone, in which the assimilation of carbon dioxide passes through the C3 cycle.

Let's consider the differences in the intensity of the increase in leaf area in corn according to all options. Thus, the leaf area during the period of maximum development is 3.8 m^2/m^2 on average over a long-term period (Table 3), under the conditions of climate change RCP 6.0, the leaf area is expected to increase to 4.3 m^2/m^2, under the conditions of RCP 6.0+CO_2 , the area of corn leaves is also expected to increase compared to both previous options - up to 4.9 m^2/m^2.

Table 3. *Indicators of photosynthetic productivity of corn crops during the growing season according to average multi-year data compared to those expected under the RCP 6.0 climate scenario*

Period, years	Option, scenario	The period of maximum growth					
		leaf surface area, m^2/m^2	Increase in total dry biomass, g/m^2 per decade	Net productivity of photosynthesis, g/m^2 per day	Dry biomass of the whole plant, g/m^2	Crop capacity, %
1991-2010	Basic	3.7	264.6	8.5	954.8	100
2021-2050	RCP6.0	4.3	249.7	6.8	943.9	89
	RCP 6.0+CO_2	4.9	292.8	7.9	1,099.2	98

In Figure 1 presents the dynamics of accumulation of the relative area of leaves of corn crops under the conditions of climate change RCP 6.0 and RCP 6.0+CO_2 in comparison with the base period. As you can see, during the growing season, the dynamics of the growth of the leaf area both according to climatic changes and according to perennial conditions was almost the same, but its quantitative indicators differ significantly. But in all cases, these values correspond to the interphase period of vegetation of panicle ejection – milk ripeness. Photosynthesis forms the basis of the primary biological productivity of natural ecosystems and determines the formation of crops in agricultural crops. The intensity of the photosynthesis process is affected by illumination, temperature and other environmental factors. Let's consider the graph of the dynamics of the average intensity of photosynthesis of corn crops over a decade under the conditions of climate change

RCP 6.0 and RCP 6.0+CO² in comparison with the base period (Fig. 2). According to the climate scenario RCP 6.0, a slight decrease in the maximum value of the intensity of photosynthesis per decade is expected to 30.1 $mgCO_2/(dm^2 \cdot hour)$ in comparison with the basic conditions (31.8 $mgCO_2/(dm^2 \cdot hour)$). And in the case of the RCP 6.0+CO_2 scenario, on the contrary, the value is expected to increase to 36.2 $mgCO_2/(dm^2 \cdot hour)$. But in all cases, these values correspond to the interphase period of vegetation of panicle ejection - milk ripeness.

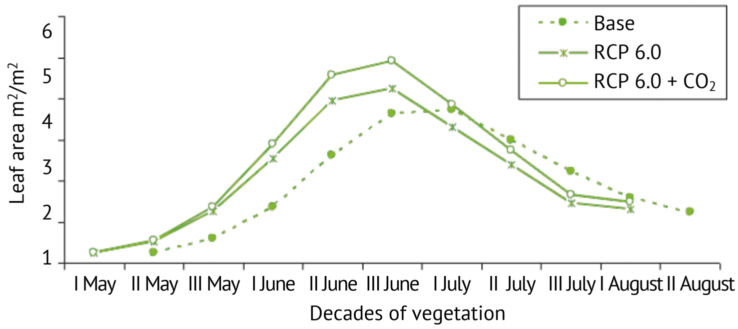

***Figure 1**. Dynamics of the relative area of leaves of corn crops during the growing season according to average multi-year data compared to those expected under the RCP 6.0 climate scenario*

The interrelationship of plants in agrocenoses is unstable, depending on many factors. The main task for obtaining high yields is the creation of such a crop, in which the potential possibilities of photosynthetic activity of plants in agrocenoses would be revealed as much as possible. This can be achieved by creating favorable conditions for the growth and development of plants. The growth of a plant and its biological productivity are primarily the result of photosynthetic activity, during which up to 95% of organic compounds are formed.

One of the indicators characterizing the production process of plants is the net productivity of photosynthesis. The maximum value of the net photosynthetic productivity of corn crops is 8.5 g/m^2 on average over many years (Table 3). Under the conditions of climate change RCP 6.0, the value of net productivity is expected to be significantly reduced – 6.8 g/m^2 per day, under the conditions of climate change RCP 6.0+CO_2 the value of net productivity is expected at the level of 7.9 g/m^2 per day. This is due to the reaction of plants to an increase in CO_2 in the air.

Such a reaction of plants determined the corresponding level of dynamics of the total dry biomass of corn and its growths. The maximum values of the increase in the total dry biomass of corn crops will be 264.6 g/m^2 per decade on average under long-term conditions (Table 3). According to the climate scenario RCP 6.0+CO_2, the growth values are expected at the level of 292.8 g/m^2 per decade, and under the conditions of climate change RCP 6.0 – at the level of 249.7 g/m^2 per decade.

The maximum value of the total dry biomass of corn crops on average according to long-term data is 954.8 g/m^2 (Table 3). An increase in dry biomass is expected under the implementation of the RCP 6.0+CO_2 climate scenario – up to 1,099.2 g/m^2, and under the climate change conditions of the RCP 6.0 scenario, it is expected to decrease to the level of 943.9 g/m^2.

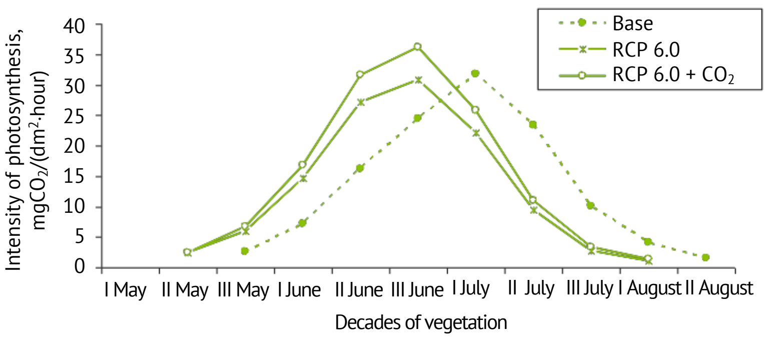

***Figure 2**. Dynamics of the average decade-long photosynthetic intensity of corn crops during the growing season according to average multi-year data in comparison with those expected under the RCP 6.0 scenario*

Thus, under the conditions of implementation of the climate scenarios, a decrease in corn yield is expected: under the RCP 6.0 option – by 11%, and under the RCP 6.0+CO_2 option – by 2%.

CONCLUSIONS

On the basis of the climate change scenario and the dynamic model of the formation of the corn crop, the variability of the expected moisture-temperature regime during the vegetation period of the crop towards an increase in air temperature and a decrease in the amount of precipitation compared to the current climatic period was assessed. A regular reduction of interphase periods and the vegetation period of the crop as a whole has been established. The assessment of the photosynthetic productivity of corn crops under climate change was carried out through its main indicators: the dynamics of the leaf area, the net productivity of photosynthesis, the dry biomass of the plant and the grain yield. Compared to the current climatic conditions, a decrease in corn grain yield by 2-8% is expected, depending on the implementation of one (RCP 6.0) or the other (RCP 6.0+CO_2) version of the scenario.

The perspective of further research is a more detailed consideration of the spatial and temporal variability of possible climate changes, conducting research on the response to climate changes in relation to other groups of varieties and hybrids of corn, as well as developing recommendations regarding the adaptation of agricultural techniques for growing corn in conditions of climate change.

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Вплив кліматичних змін на формування продуктивності кукурудзи в західному Лісостепу України

Анатолій Польовий

Доктор географічних наук, професор
Одеський державний екологічний університет
65016, вул. Львівська, 15, м. Одеса, Україна
https://orcid.org/0000-0001-8395-0068

Тетаня Костюкєвич

Кандидат географічних наук
Одеський державний екологічний університет
65016, вул. Львівська, 15, м. Одеса, Україна
https://orcid.org/0000-0002-1952-8839

Алла Толмачова

Кандидат географічних наук
Одеський державний екологічний університет
65016, вул. Львівська, 15, м. Одеса, Україна
https://orcid.org/0000-0002-9340-5028

Олена Жигайло

Кандидат географічних наук, доцент
Одеський державний екологічний університет
65016, вул. Львівська, 15, м. Одеса, Україна
https://orcid.org/0000-0002-3552-327X

Анотація. Наразі тенденція активного пришвидшення темпів глобального потепління негативно позначається на поточній ситуації у сфері сільського господарства у багатьох частинах земної кулі. За актуальними прогнозами, у найближчі роки наслідки, спричинені ним, будуть й надалі посилюватись. Щодо переважання негативних наслідків цих впливів свідчать багато фактів, серед яких: зростання температурних режимів, посилення їх мінливості, зростання кількості та частоти опадів, почастішання періодів засухи, наявність екстремальних погодних феноменів. Крім того, кліматичні зміни, підвищення вологості та CO_2 у повітрі вносять корективи в обсяги врожайності сільськогосподарських культур. Основною фуражною культурою у світі є кукурудза, тому адаптація сільськогосподарських умов до кліматичних коливань стає нагальним етапом для аграріїв. На сьогодні кукурудза задовольняє попит не лише у сфері харчової промисловості, але й медицини та енергетичного забезпечення. Метою роботи є визначення зміни кількості періодів вегетації та міжфазних періодів кукурудзи, оцінка фотосинтетичної продуктивності посівів та прогнозування показників врожайності. В ході дослідження було використано метод порівняння, моніторингу, а також спостереження та емпіричного дослідження. Використано сценарій можливих змін клімату RCP 6.0 на період до 2050 року. Як апарат досліджень використовувалася динамічна модель продуктивності посівів сільськогосподарських культур, розроблена А.М. Польовим. У статті представлено результати оцінки впливу кліматичних змін на формування продуктивності кукурудзи в Західному Лісостепу України. Цінність отриманих результатів полягає у їх застосуванні в розробці і вдосконаленні моделі культивування кукурудзи з огляду на найширший перелік кліматичних відхилень

Ключові слова: кукурудза, зміна клімату, продуктивність посівів, сценарій RCP 6.0

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The effect of treatment of vegetable pea seeds with boron and molybdenum on the growth and development of plants depending on the timing of sowing

Victoria Almashova*

PhD in Agrisciences, Associate Professor
Kherson State Agrarian and Economic University
73006, 23 Stretenska Str., Kherson, Ukraine
https://orcid.org/0000-0001-6180-1096

Sergiy Onischenko

PhD in Agrisciences, Associate Professor
Kherson State Agrarian and Economic University
73006, 23 Stretenska Str., Kherson, Ukraine
https://orcid.org/0000-0001-6983-6090

Olha Yevtushenko

PhD in Agrisciences
Kherson State Agrarian and Economic University
73006, 23 Stretenska Str., Kherson, Ukraine
https://orcid.org/0000-0002-0895-2407

Abstract. Currently, the issue of preserving organic matter, which is increasingly being replaced by synthetic alternatives, is relevant and expedient. But these substitutes are alarming because of their possible threat of dangerous after-effects, because the human body generally consists of what it consumes in everyday food. All chemical elements undesirable for the body that can cause the appearance of diseases and health complications fall under the category of dangerous food. In view of this, in order to preserve the volume of production of natural food products, there is a need to increase the share of leguminous crops. In addition to the positive effect on soil fertility, legumes are naturally filled with biologically pure nitrogen. Also, this crop has a higher content of valuable plant protein compared to cereal grain crops. In order to increase the production of pea grain, it is necessary to use high-yielding varieties of the moustached morphological type. The purpose of the article is to identify the influence of sowing dates and treatment of vegetable pea seeds with molybdenum and boron fertilizers on plant development indicators in the conditions of Southern Ukraine. The research used the laboratory method, as well as the methods of field experiment and phenological observation. It was established that the effect of boron and molybdenum delays the onset of the phenological phases of crop development, and the use of two different sowing times allows to delay the onset of the technological maturity phase by 6 days. This is important during harvesting for minimal losses of the vegetable pea crop. The practical value of the results lies in the application of combinations of molybdenum and boron fertilizers to increase the yield and nutritional value of leguminous crops

Keywords: vegetable peas, nutrients, boron and molybdenum fertilizers, indicators of plant growth and development

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*Corresponding author

INTRODUCTION

Currently, the issue of preserving organic matter, which is increasingly being replaced by synthetic substitutes, is relevant. But these substitutes are confusing because of the threat of dangerous after-effects, because the human body generally consists of what it uses in everyday food. At first glance, dangerous food includes all chemical elements that are undesirable for health, which can cause the further development of diseases and health complications. The reserve is the cultivation of leguminous crops, which are able to fix nitrogen from the atmosphere or apply organic fertilizers [1].

Increasing the share of leguminous crops in the structure of planted areas is the cheapest and most effective way of increasing soil fertility, increasing humus and nitrogen content, and protecting land from degradation. In addition to increasing the yield, such agricultural methods contribute to the accumulation of a greater amount of biologically pure nitrogen in it after harvesting vegetable peas, compared to existing technologies, they allow to extend the time of technical maturity of the seed and the period of its processing, which in the conditions of the south of Ukraine is a very important and urgent problem. The technology of growing green peas as one of the important leguminous crops is energy-saving, since the energy accumulated with the crop significantly exceeds its production costs.

Peas, compared to cereal grain crops, have a number of important advantages, especially in terms of yielding valuable vegetable protein. In addition, the cultivation of peas in crop rotations significantly reduces the total cost of crop production, improves the phytosanitary condition of crops and increases the productivity of arable land. Peas differ from other legumes in that the stem of the plant is not prone to branching and grows mainly in height.

In favorable years, due to overgrowth of plants, pea crops are severely damaged, so 2-phase harvesting should be carried out, which often leads to crop losses. The priority direction of effective restoration of cultivated areas and increase of pea grain production should be the cultivation of high-yielding varieties of the moustached morphological type with high potential productivity, resistance to environmental stress factors, lodging and suitable for harvesting by direct harvesting [2]. That is why there is a need to improve the technology of growing peas that are not prone to lodging, in order to increase the yield of this crop. Therefore, in the system of measures aimed at increasing the productivity of peas, great importance is attached to the rational use of fertilizers and the norms of sowing seeds.

The high yield potential of modern pea varieties can be maximally realized when growing them using technologies that involve the complex application of intensification factors [3]. The priority direction of increasing the sown areas of peas in the south of Ukraine should be the cultivation of high-yielding varieties of the moustached morphological type with high potential productivity, resistance to diseases and lodging, suitable for harvesting by direct harvesting.

In the system of measures aimed at increasing the production of peas, an important place belongs to new high-protein varieties, which must be high-yielding, resistant to diseases, lodging, suitable for direct harvesting [1]. Thus, plants of low-growing varieties with a strong stem begin to lay down only during flowering, while tall varieties with a long stem – even before the beginning of budding (in the 10-leaf phase). Short-stemmed pea varieties are characterized by a well-developed mechanical tissue, and have a developed transport system of the stem.

For the successful cultivation of vegetable peas for seeds, it is important to carry out a set of measures to increase soil fertility. Many years of research conducted by many scientists with various crops, including vegetable peas, testify that mineral fertilizers, along with improving the nutrient regime of the soil and plants, also affect the water regime, contribute to a more complete and economical use of moisture for crop formation [3].

Peas are considered a relatively cold-resistant plant. At the same time, it is demanding on soil moisture, reacts negatively to high temperatures and lack of moisture. Especially, the combination of heat and drought, which is a common natural phenomenon in the southern part of Ukraine, suppresses its growth and development. Unfortunately, peas have to experience drought and heat more and more often. Therefore, the producers of our region have to sow earlier so that half of the growing season falls on a period with moderate heat and sufficient humidity [3]. However, it is possible to sow even ordinary varieties of grain (shelled) peas very early. For example, in the Kherson region, peas can be sown during the winter or in early spring. However, there is a great risk of freezing of pea plants.

At low temperatures, pea shoots appear later (after 15-20 days) and unfriendly. Weakened seedlings are prone to diseases, suppressed by weeds and damaged by pests. This situation is especially negative for the growth and development of plants of sugar and brain pea varieties, for which the minimum germination temperature is 4°C.

It is also known that the optimal temperature for the development of seedlings is from 15 to 16°C. At low temperatures (less than 10°C), plants develop slowly and are strongly affected by fungal and bacterial diseases. The growth rate of peas at low positive temperatures is affected by the amount of reserve nutrients in the seeds, so plants that were treated with nutrients before sowing will germinate faster [4].

Seedlings of most pea varieties can tolerate short-term temperature drops to minus 6°C. However, the yield of "frozen" plants decreases by 10-30%, and the ripening of beans is delayed by 7 days. If the surface of the soil is covered with snow, then the seedlings can withstand a drop in temperature to minus 10-12°C. Seedlings can withstand a short-term drop in temperature to minus 1-2°C without a decrease in productivity.

There are several opinions among scientists who study this problem regarding the methods of sowing and the density of standing pea plants when grown for seeds and green peas. Most of them recommend, for the most part, the usual row method of sowing with a row spacing of 15 cm, which is carried out with seed drills, for example SZ-3.6, SZP-3.6. With this method of early sowing, coulters are less clogged with moist soil and seeds are sown more evenly than with narrow-row sowing [6].

Many experiments [4-6] of scientific research institutions and the practice of advanced product manufacturers have established the effectiveness of adding not only phosphorus, potassium and nitrogen fertilizers, but also organic fertilizers to peas or its predecessor. It was noted that when they are used correctly, they do not suppress, but, on the contrary, stimulate nitrogen fixation by nodule bacteria [4]. The regularity in the increase of the pea yield from the use of phosphoric fertilizers was observed in experiments by some authors, while the equivalence of terms and methods of application of these fertilizers was established for both field plowing and cultivation.

In the modern period of the development of agro-industrial production, one of the main conditions for the increase of gross harvests and peas is the constant improvement of the technological elements of cultivation in accordance with the morphological and biological characteristics of the variety. Issues of improving the grain quality of this important crop are also gaining priority. Modern cultivation technologies of grain legumes should be based on the management of all processes of ensuring high grain productivity and grain quality, as well as be directed to the maximum use of the culture's biological productivity potential. For the normal growth and development of plants, a suitable feeding area is required, in which they will have enough nutrients, water and solar energy to create the necessary vegetative mass and grain formation. By increasing or decreasing the feeding area, the effectiveness of mineral fertilizers can be increased. The productivity of peas is the highest when the optimal sowing rate is used. Its value depends on soil fertility, climatic conditions, predecessor, fertilizer, variety, terms and methods of sowing, seed quality.

Of the microelements, the role of molybdenum and boron should be especially noted. With a lack of molybdenum, nodules of nitrogen-fixing bacteria are weakly formed, the synthesis of free amino acids is disrupted in them, and the synthesis of leghemoglobin is inhibited [7]. With boron deficiency, vascular bundles are not formed in nodules, as a result of which the development of bacterial tissue is disturbed [8]. Also, the lack of boron leads to a deterioration in the quality of the harvested crop of products in the phase of technical ripeness.

In order to increase the yield of pea, its seeds are treated with boron – 2.7 kg/t, nitrogen and molybdenum-acidic ammonium (25 g per hectare seed rate). Inoculation of seeds with rhizorthorphin increases yield by 2.0-4.2 c/ha and improves its quality. The protein content increases by 2-5% [3].

British scientists [9; 10] believe that fertilizers should not be applied to peas, even on poor soils, because nodule bacteria will not develop, and the use of fertilizers will be ineffective. In their opinion, the use of nitrogen fertilizers is justified in small doses (N_{30}) and only on late sowing of peas. High efficiency on pea crops is ensured by the application of ammophos or superphosphate enriched with boron and molybdenum. The rate of P_2O_5 is 10-20 kg/ha. On the chernozem soils of the Steppe, molybdenum combines with alkalis and alkaline cations, turning into compounds that are soluble in water and inaccessible to plants [6].

It is known that boron plays an important role in the processes of plant fertilization: it enhances the germination of pollen, the growth of pollen tubes and is necessary for the formation of the vital activity of pollen. Boron is a necessary element of mineral nutrition of plants. In addition, depending on the type of plants and soil and climatic conditions, its amount in plants varies within fairly wide limits. If the dry mass of grain crops contains only 1-3 mg of boron per 1 kg of completely dry mass of plants, then in sunflower leaves – 50-60 mg, and in leguminous crops – 30-60 mg per 1 kg of completely dry mass [11; 12]. The development of ovaries and seeds due to a lack of boron lags behind normal, and the processes of seed maturation are disturbed, therefore boron has a positive effect on the seed productivity of many agricultural crops and the formation of fruits and berries in fruit and berry plants [13]. It also plays an important role in the synthesis of carbohydrates, which is necessary for establishing a normal symbiosis between nodule bacteria and the plant.The best results are provided by boron in combination with molybdenum, since the latter is necessary for the biochemical processes of fixing molecular nitrogen.

Being in the tissues of plants, boron can create complex compounds with organic oxyacids, carbohydrates and polyatomic alcohols. Vitamins - riboflavin and ascorbic acid also combine with boron. A number of experiments established the effect of boron on the activity of enzymes: catalase, dehydrase, invertase, etc.

Boron also affects osmotic processes and hydration of colloids. A positive effect of boron on drought resistance and salt resistance of plants was established. And with a lack of boron, the content of vitamins in the leaves decreases: ascorbic acid, thiamine, and riboflavin. Lack of boron in plant nutrition delays the synthesis of proteins and nucleic acids.

The effect of boron fertilizer on leguminous crops was studied in Latvian collective farms in 1961-1962. For dusting, 1-2 kg of fertilizer was used per 1 t of seeds, and when applied to the soil, 60 kg/ha. Boron increased the yield of peas by 2.5-3.0 t/ha. Favorable results were obtained when pre-sowing treatment of seeds with boron was combined with poisons [4].

Molybdenum fertilizers are also increasingly used in the cultivation of legumes, vegetables and some other crops. This is explained by the fact that molybdenum significantly affects the nitrogen metabolism of plants, nitrogen-fixing bacteria, as well as some algae and fungi. Molybdenum is involved in the fixation of molecular nitrogen by nodule bacteria in symbiosis with leguminous plants. It is also an active component of enzymes involved in the reduction of nitrates in tissues to ammonia, which is subsequently used in the processes of formation of amino acids and proteins. Molybdenum, changing its valency, participates in oxidation-reduction reactions and is an important link in the chain of element transfer from the oxidizing substrate (electron or hydrogen donor) to the substance being reduced.

The main role of molybdenum is that it enhances the activity of proteid enzymes associated with nitrogen metabolism and participates in the enzymatic activation of molecular hydrogen. Thus, according to some authors [5; 9], the green mass of leguminous plants contains from 1.9 to 9.1 mg, and in nodules on the roots of clover and lupine plants up to 17 mg per 1 kg of raw mass [7].

The purpose of the study is to establish the influence of early and late sowing and treatment of pea seeds with boron and molybdenum fertilizers on the onset of the main phases of plant development, based on a field experiment accompanied by phenological observations and analysis of plant samples.

MATERIALS AND METHODS

Experiments on the study of the influence of sowing dates and the use of boron-molybdenum fertilizer were conducted in the field crop rotation of the Kherson State Agricultural and Economic University in 2017-2018 according to the following scheme:

Factor A. Pre-sowing treatment of pea seeds:

1. $N_{30}P_{40}$ – background
2. Background + treatment of seeds with boron
3. Background + seed treatment with molybdenum
4. Background + treatment of seeds with boron and molybdenum

Factor B. Sowing dates:

1. The early term – the third decade of March
2. Late period – the first decade of April

The high-yielding variety "Alfa" was chosen as the object of research, which is characterized by a high response to the use of trace elements, and therefore has a large area of cultivation. This variety is zoned in the Steppe and Forest Steppe.

Experiments were carried out using the method of split plots in accordance with the methodology of field research. The experiment was repeated four times. The total area of the plot was 72 m^2, and the accounting area was 50 m^2. All observations were carried out on the basis of the above options in two non-adjacent repetitions. The field experiment was accompanied by phenological observations. Plant height was determined on fixed plants in two non-adjacent replicates. The results of the obtained experimental data were subjected to variance analysis [14].

RESULTS

Various external factors (environmental factors or the influence of human activity) can within certain limits change the timing of the transition from vegetative to generative phases [7]. Studying the possibility of influence of various current factors on the above process is important, first of all, for producers of agricultural products.

It is known that the phase of technical ripeness of green peas is very short and lasts an average of 3-5 days in the south of Ukraine, and producers of canned goods must have time to collect the harvest from the field in such a short time. This leads to the limitation of the production of high-quality products and the irrational use of expensive equipment of canneries during the season. There are other ways to extend the terms of receipt of raw materials for processing: the use of different sowing times, the use of varieties of different maturity groups, the introduction of increased doses of nitrogen fertilizers.

The research was carried out with the nitrogen and phosphorus indicator in the soil at the level of N30P40. It has been previously established that with the onset of the bean formation phase, a sharp change in the direction of physiological and biochemical processes in all plant organs occurs. Leaves, stems and roots work only on beans until the end of the growing season. The mass of above-ground vegetative organs and roots increases to a small extent. The roots, and therefore the tubers, receive less and less carbohydrates. Potatoes, experiencing energy hunger (deficiency of carbohydrates), reduce the activity of nitrogen fixation, the outflow of nitrogen and other elements from vegetative to reproductive organs increases, plants grow old, begin the process of self-destruction. The plant mobilizes all resources to produce the maximum possible number of high-quality seeds. About 70-80% of the nitrogen accumulated before flowering in the vegetative organs of legumes is redistributed to the seeds. Therefore, the variant of the experiment chosen by us - background $N_{30}P_{40}$ is scientifically justified.

The studies studied the effect of trace elements boron and molybdenum on the timing of the onset of phenological phases of development and the length of interphase periods of vegetable peas. It was established that the studied factors had a certain influence on these indicators. Data on the influence of boron and molybdenum on the timing of the onset of the main phenophases of pea for both sowing periods are given in Table 1. The analysis of the data in the table shows that the time of sowing had a significant effect on the time of onset of the phase of technical ripeness of green peas, which was also observed by other researchers.

It was established that the treatment of pea seeds with boron in the first period of sowing did not affect the length of its growing season, and in the second, when the temperatures were high, it accelerated its development by an average of 2 days.

The pattern described above was also observed during the second term of sowing vegetable peas, but in this case, the most noticeable effect on delaying the onset of the technical maturity phase was obtained by treating the seeds with molybdenum alone. The duration of the interphase period of vegetable peas, depending on the studied factors, is given in Table 2. It should be noted that the passing of the interphase period "blooming – seed pouring" and "seed pouring – technical maturity of seeds" in all variants of the experiment practically did not depend on the studied factors and differed little from the control for both methods of sowing.

Table 1. *Calendar date of the onset of phenophases depending on the elements of agricultural technology (2017–2018)*

Research options	The term of onset of phenophases according to the terms of research							
	The first sowing period (the third decade of March)				The second sowing period (the first decade of April)			
	Sowing	Seedlings	Flowering	Technical maturity	Sowing	Seedlings	Flowering	Technical maturity
$N_{30}P_{40}$ – background	19.03	02.04	28.05	18.06	02.04	12.04	03.06	24.06
Background + treatment of seeds with boron	19.03	02.04	28.05	18.06	02.04	12.04	01.06	23.06
Background + seed treatment with molybdenum	19.03	03.04	04.06	24.06	02.04	14.04	08.06	23.06
Background + seed treatment with boron and molybdenum is compatible	19.03	04.04	03.06	24.06	02.04	14.04	09.06	30.06

Table 2. *The duration of the interphase period of vegetable peas depending on agricultural technology (2017–2018)*

Research options	The duration of the interphase period, days							
	Sowing – seedling	Seedling - whisker formation	Whisker formation – budding	Budding – flowering	Flowering – pouring seeds	Pouring seeds – milky ripeness	Milky ripeness – technical ripeness	Seedlings – harvesting
Sowing period is the third decade of March								
$N_{30}P_{40}$ – background	12	12	29	9	8	9	2	70
Background + treatment of seeds with boron	12	12	29	8	9	8	2	69
Background + seed treatment with molybdenum	12	14	31	9	8	9	2	74
Background + treatment of seeds with boron and molybdenum	14	15	32	9	7	9	2	75
The period of sowing is the first decade of April								
$N_{30}P_{40}$ – background	8	10	28	8	8	8	2	64
Background + treatment of seeds with boron	7	10	29	7	9	8	3	66
Background + seed treatment with molybdenum	11	11	27	9	7	7	2	63
Background + treatment of seeds with boron and molybdenum	11	14	27	9	8	8	2	68

As for the duration of the period of technical maturity of the seeds, it was a maximum of 4 days in all variants, after which the phase of waxy maturity of the seeds came and it sharply lost its quality due to the change of green color to yellow, the amount of sugars in it decreased (up to 3%) and the amount of starch up to 9-12%, which, according to many authors, makes it impossible to process it into canned green peas [6]. The total duration of the vegetation period "seedlings - technical maturity of seeds" in the control version was 70 days for the first and 64 days for the second sowing period. It was the longest in the "background + seed treatment with boron and molybdenum" option during the first sowing period

The effect of molybdenum was reversed: in all cases, it delayed the onset of the technical maturity phase by an average of 4 days, both when applied in its pure form and in combination with boron.

Also, in our research for 2017-2018, we expected to achieve an increase in productivity due to an increase in the number of seeds per 1 vegetable pea plant both by increasing the productivity of beans and increasing their number. Data showing the influence of boron and molybdenum treatment of seeds on the number of flowers, beans and the distance between them in the interphase period of "flowering-bean formation" are given in Table 3.

The data indicate that the number of flowers and beans during the years of research, both in the early and late sowing periods, did not differ significantly, and the influence of the studied factors on them was significant. The yield increase in our experiments was due to the number of beans on one plant, and not the number of seeds in one bean.

Table 3. *The influence of seed treatment with microfertilizers on reproductive indicators of pea in the interphase period "flowering – pod formation" (average for 2017-2018)*

Options	Phases of development		
	Number of flowers, pcs.	Distance between flowers, cm	The number of seed primordia, pcs.
The first sowing period			
$N_{30}P_{40}$ – background	7.9	5.3	8.1
Background + treatment of seeds with boron	10.9	5.9	10.1
Background + seed treatment with molybdenum	12.5	6.5	10.7
Background + treatment of seeds with boron and molybdenum	13.5	7.2	11.3
The second sowing period			
$N_{30}P_{40}$ – background	7.5	5.1	7.4
Background + treatment of seeds with boron	10.1	7	9.6
Background + seed treatment with molybdenum	11.4	6.0	10.5
Background + treatment of seeds with boron and molybdenum	12.6	6.6	11.1

Analyzing the data in the Table 3, it can be seen that the number of beans on the plants of the boron and molybdenum seed treatment option was 13.5 during the first sowing period, compared to the control 7.9, i.e. the increase was 1.7 times. Despite the decrease in the weight of 1,000 seeds, the average yield increase for 2017-2018 in this variant was 30.3% in the first sowing period, and 30.7% in the second sowing period. The greatest yield increase in the second term (30.7%) was found in the variant with molybdenum and molybdenum seed treatment.

When conducting biometric studies on the measurement of the height of the vegetable pea in the main phases of development, it was simultaneously established that the studied factors had a positive effect on the growth and development of the plant.

CONCLUSIONS

The analysis of experimental data shows that treatment of peas with boron and molybdenum, as well as the timing of sowing, significantly affect the timing of the onset of the technological phase of crop maturity, which is also observed by other researchers. Summarizing the above, the following conclusions can be drawn:

– the maximum delay in the onset of subsequent phenophases of the development of pea is observed during the period of intensive growth of the vegetative mass of the crop;

– during the development of generative organs, seed treatment with trace elements has almost no effect on the length of interphase periods;

– the use of two sowing periods with a difference of 14-16 days allows delaying the onset of the phase of technical seed maturity by 4-6 days, and in combination with seed treatment with trace elements in various combinations - delays this phase by 11 days compared to the control, and this allows to extend the crop harvesting period in southern Ukraine with minimal crop losses;

– the number of flowers and beans during the years of research, both during the early and late sowing periods, did not differ significantly, but the influence of the studied factors on them was significant. The yield increase in our experiments was due to the number of beans on one plant, and not the number of seeds in one bean.

The obtained data can be used at enterprises in the south of Ukraine, which are engaged in the processing of products for the cannery, in order to make pea puree for baby food and green peas for salads.

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Вплив обробки насіння гороху овочевого бором і молібденом на ріст і розвиток рослин залежно від строків сівби

Вікторія Алмашова

Кандидат сільськогосподарських наук, доцент
Херсонський державний аграрно-економічний університет
73006, вул. Стрітенська, 23, м. Херсон, Україна
https://orcid.org/0000-0001-6180-1096

Сергій Онищенко

Кандидат сільськогосподарських наук, доцент
Херсонський державний аграрно-економічний університет
73006, вул. Стрітенська, 23, м. Херсон, Україна
https://orcid.org/0000-0001-6983-6090

Ольга Євтушенко

Кандидат сільськогосподарських наук
Херсонський державний аграрно-економічний університет
73006, вул. Стрітенська, 23, м. Херсон, Україна
https://orcid.org/0000-0002-0895-2407

Анотація. Наразі актуальним та доцільним є питання збереження органічної речовини, на заміну якої усе частіше приходять синтетичні альтернативи. Але ці замінники насторожують своєю можливою загрозою небезпечності післядії, адже організм людини взагалі складається з того, що вона споживає у повсякденну їжу. Під видом небезпечної їжі потрапляють і всі небажані для організму хімічні елементи, що можуть спричинити появу хвороб та ускладнень здоров'я. З огляду на це, з метою збереження об'ємів виробництва натуральних харчових продуктів постає необхідність розширення частки зернобобових культур. Окрім позитивного впливу на родючість ґрунтів, бобовим властиво наповнюватися біологічно чистим азотом. Також ця культура має вищий вміст цінного рослинного білка у порівнянні із злаковими колосовими культурами. Задля збільшення виробництва зерна гороху потрібно використовувати високопродуктивні сорти вусатого морфологічного типу. Метою статті є виявлення впливу строків сівби та обробки насіння гороху овочевого молібденовим і борним добривами на показники розвитку рослин в умовах Півдня України. У дослідженні застосовувалися лабораторний метод, а також методи польового досліду та фенологічного спостереження. Встановлено, що дія бору та молібдену затримує настання фенологічних фаз розвитку культури, а застосування двох різних строків сівби дозволяє затримати настання фази технологічної стиглості на 6 діб. Це важливо при збиранні для мінімальних втрат врожаю гороху овочевого. Практична цінність результатів полягає у застосуванні комбінацій молібденових та борних добрив для підвищення врожайності та поживної цінності зернобобових культур

Ключові слова: горох овочевий, елементи живлення, борні та молібденові добрива, показники росту та розвитку рослин

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Engineering in the production technology of extruded feed additives

Kateryna Kostetska*

PhD in Agrisciences, Associate Professor
Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine
https://orcid.org/0000-0003-2387-5400

Ivan Ulianych

PhD in Technical Sciences
Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine
https://orcid.org/0000-0003-2342-188X

Valeriia Zheliezna

PhD in Agrisciences
Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine
https://orcid.org/0000-0002-1874-2155

Mykhailo Holubiev

PhD in Agrisciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-6647-4335

Abstract. The production of fodder from ecologically clean raw materials is an effective way of increasing the volume of fodder while reducing the economic costs of their production. The use of natural feed additives in feed improves their consumption. Innovative engineering in the technology of production of feed additives is carried out through the improvement of the technology of feed additives using fruit and vegetable raw materials. At present, sufficiently large stocks of fruit and vegetable raw materials are permanently accumulated in Ukraine, which are insufficiently used in fodder production. At the same time, improving the consumption and increasing the efficiency of the use of feed, as well as obtaining the maximum livestock productivity is increasingly ensured by the use of natural feed additives in the composition of feed. That is why the production of fodder from ecologically clean raw materials, as a transition to alternative technologies, is one of the most effective ways to increase the volume of fodder with a decrease in the economic costs of their production. Today, there is no such practice in private households. The inclusion of fruit and vegetable raw materials in feed formulations is relevant for improving their quality. The aim of the work was to expand the range of animal feed and to improve the production technology of extruded feed mixture. The laboratory and analytical method was used in the work. The authors presented the technology, which consists in preliminary preparation of raw materials: cleaning, grinding, dosing according to the composition of the recipe, mixing and special processing to improve technological properties and increase feed value with processes: pre-mixing, aging and extruding the mixture, cooling and grinding the product depending from the purpose of feed. The results can be used to improve the technology for the production of nutritious feed for animals and provide more farms

Keywords: grain, fruit and vegetable raw materials, feed additives, extrusion technology

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*Corresponding author

INTRODUCTION

Innovation is the process of applying advanced technologies, products, or the result of study in the form of new methods, products, technological processes, etc. Innovative engineering in the technology of production of feed additives is carried out through the improvement of the technology of feed additives using fruit and vegetable raw materials, aging and extrusion of feed mixtures according to the composition of the recipe, cooling and grinding of the extrudate.

Quite large stocks of fruit and vegetable raw materials are constantly accumulating in Ukraine, which are still insufficiently used in fodder production. At the same time, improving consumption and increasing the efficiency of feed use, as well as obtaining maximum animal productivity is increasingly ensured by the use of natural feed additives in the composition of feed. That is why the production of fodder from ecologically clean raw materials, as a transition to alternative technologies, is one of the most effective ways to increase the volume of fodder with a decrease in the economic costs of their production. Today, private households do not have technologies for extruding a mixture of grain and fruit and vegetable raw materials as a natural, ecological and safe feed for fattening animals.

In order to improve the nutrition of animals and improve the quality of feed, including in private farms of the population, it is important to add fruit and vegetable raw materials to the recipe composition of the feed.

To ensure the successful development of highly productive animal husbandry, it is necessary to constantly expand the raw material base and the range of products of compound feed production [1].

Feed additives are used to balance feed rations due to the lack of certain nutrients, improve the consumption of basic feeds, increase the digestibility and assimilation of feed nutrients, and are used as prevention of the stressful state of farm animals, etc. [2; 3]. The main feed additives include non-protein nitrogenous substances, energy, mineral, vitamin substances, as well as antibiotics, probiotics, enzymes, antioxidants, organic acids, etc.

The methods of production of feed additives are different and depend on the enterprises that produce them and on the physical and technological properties of the raw materials. The preparation of additives for introduction into compound feed takes place along separate technological lines depending on the variant of the technological process, for example, minerals, vitamin substances, antibiotics, probiotics, enzymes, antioxidants, organic acids are introduced into the composition of premixes along the lines of the same name; supply to production – along the supply line of protein and mineral raw materials [4-6].

The purpose of the work is to expand the range of compound feed for animals by improving the technology of extruding a mixture of grain raw materials with fruit and vegetable components. Methods of determining the physical and technological properties of compound feed components. Sampling and separation of the weight from the extruded mixture was carried out in accordance with DSTU ISO 6497:2005 "Feed for animals. Sampling methods" (ISO 6497:2002, IDT) and DSTU ISO 6498:2006 Animal feed. Preparation of samples for research (ISO 6498:1998, IDT), which were adopted to replace GOST 13496.0-80 "Compound feed, compound feed raw materials. Sampling methods".

The modulus of grain size was determined based on the results of studying the residues on sieves (GOST 13496.8-92). For this, a laboratory classifier and sieves with round holes with a diameter of 5.0 were used; 4.0; 3.0; 2.0; 1.0 mm. A sample weighing 100 g was taken from the sample of the crushed product. It was then sifted on a laboratory classifier for 5 minutes. Residues from each sieve and collection bottom were weighed on PS/X2 "Radwag" scales with an accuracy of 0.01 g.

The coarseness module (M) of the crushed product is determined by the formula:

$$M = \frac{d_1P_1 + d_2P_2 + \cdots + d_nP_n}{100} = \frac{\sum_{i=1}^{n} diPi}{100}, \tag{1}$$

where d_1 is the average size of the holes of two adjacent sieves, mm; P_1 – fraction mass yield (residue on each sieve), %; n is the number of fractions into which the weight is divided. The degree of crushing of root crops was determined in the same way as for grains. But considering that chopped vegetables have low flowability, the technique is slightly different. Determination of the dispersity of pulp (the VNIIICOP method). The size of the particles and their number are determined using a sieve analysis

Equipment: a set of metal sieves with perforations from 5 to 3 mm; chemical beaker for 300 ml; technical scales for 200 g; kapron sieve No. 18.

MATERIALS AND METHODS

From the average pulp sample, after thorough mixing, weigh 150 g in a chemical beaker on technical scales. Blot with paper towels to remove residual moisture. A set of sieves is collected so that their perforation gradually decreases. A kapron sieve is put on the lower sieve with a perforation of 3 mm from the lower side. Pour water almost to the top in a glass with a sample, stir gently and pour the mixture onto the top sieve. The pulp is slightly leveled on the surface of the sieve and the entire set of sieves with perforations of 5.0, 3.0 mm and kapron mesh, without disassembling, is brought to the water tap under a calm stream of water. Washing is carried out for 5 minutes, slowly rotating the sieve so that the entire mass on the sieve is evenly washed with a stream of water. After washing, pulp particles are carefully collected from each sieve into a napkin made of two layers of gauze and squeezed by hand until the release of water stops. Then each fraction is carefully collected with gauze on filter paper, soaked on both sides with filter paper and weighed on a technical scale with an accuracy of 0.1 g.

RESULTS

Fruit and vegetable crops are used to improve the taste and nutritional qualities of feed. As experimental samples, we selected root vegetables of standard quality: table beet, table carrot, parsnip, potato, fruit: grape pomace and extruded products from their mixtures with grain crops. The organoleptic evaluation of fruit and vegetable crops revealed full correspondence of the characteristics of these plants to certain species. The physical properties of fruit and vegetable cultures indicate the possibility and favorable conditions for their use at all stages of the technological process [11].

An analytical review of the literature on the study of the assortment, nutritional value of compound feed and means for improving the taste of feed [1-3; 6], as well as research on the physical and technological properties of fruit and vegetable raw materials – table beets, carrots, parsnips, potatoes [11] testify to the possibility of using these plants in the production of feed additives. That is why the next stage of the work was the improvement of the technology for the production of feed additives using fruit and vegetable raw materials – beets, carrots, potatoes, parsnips and grape pomace (Fig. 1).

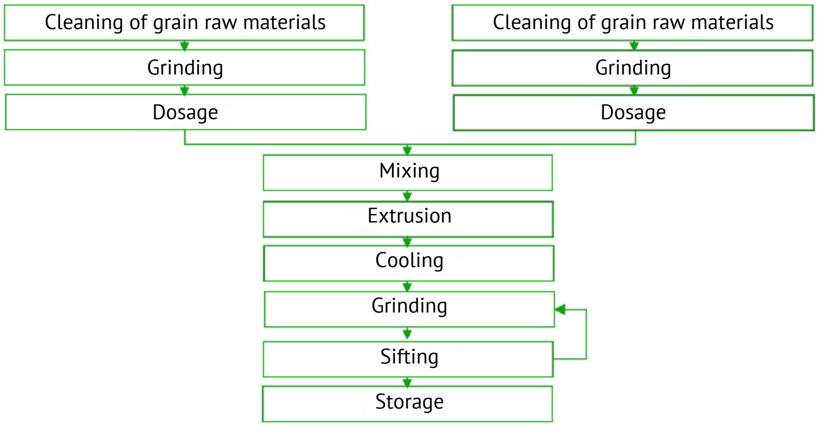


***Figure 1**. Block diagram of advanced extrusion technology*

One of the stages of studying the process was extrusion in laboratory conditions of UNUS on a Ukrainian-made KMZ-2M press-extruder. Research was also conducted on a PEK-40x5B laboratory extruder at the National University of Food Technologies [7].

The grain was crushed on a hammer crusher (brand DM-03), using sieves with different hole diameters (6.0, 4.0, 3.0 mm). We obtained a product with different grind size and different granulometric composition. Vegetable components were cleaned from soil and other impurities by sorting and washing. Mixtures with the addition of vegetable components to the grain in their native form were created by hand, by mixing different ratios of components. The product was fed into the extruder manually and with the help of a vibratory feeder. During the extrusion process, the readings of the ammeter and thermometer were recorded and the time was recorded. After extrusion, the product was cooled at room temperature and relative humidity of 60%. After cooling, the product samples were packed in a separate hermetic container, part of which was previously crushed.

Our improved technological scheme for the production of feed additives using fruit and vegetable raw materials is presented in Figure 2.

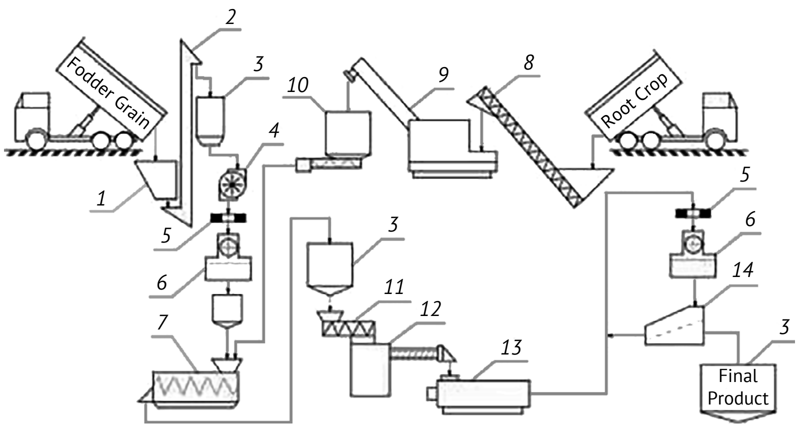
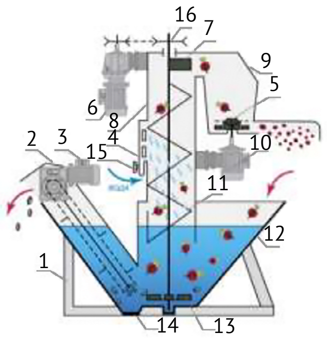


***Figure 2**. An improved technological scheme for the production of extruded feed additives using fruit and vegetable raw materials: 1 – bulk bunker; 2 – transporter-noria; 3 – storage hopper; 4 – dispenser; 5 – magnetic catcher; 6 – hammer crusher; 7 – mixer; 8 – conveyor; 9 – root crop washer-shredder; 10 – hopper-dispenser of crushed root crops; 11 – extruder feeder; 12 – extruder; 13 – cooler; 14 – sifter*

The production of a high-quality product at a large-tonnage production involves preliminary cleaning of grain raw materials from foreign impurities on a two-chamber pneumatic separator CA-4, with a capacity of up to 6 t/h, which does not require connection to the power grid, because it works due to the flow of air created by the crusher. Next, the grain is sent by pneumatic transport for grinding on the DKR-5D hammer crusher with a capacity of up to 5 t/h. The required grinding size is determined by the sizes of the sieve holes on the crusher.

The crushed product is unloaded by pneumatic transport into a 3-ton super-dosing hopper, and then dosed into a mixer to create a mixture of the required composition.

Cleaning of root crops – table beets, carrots, parsnips, potatoes from extraneous impurities takes place on the CSC-5 installation (Fig. 3), which simultaneously cleans and grinds raw materials. Before starting work, the bath is filled with water. The necessary level of water in the bath is maintained by a drain nozzle located on the conveyor casing. The rotating movement of water in the bath is created by an impeller fixed on the auger shaft.



1 – Frame
2 – Transporter-stone catcher
3, 6, 10 – Electric motors
4 – Water sprayer
5 – Casing
7 – Ejector
8 – Shredder
9 – Shredder cover
11 – Sink auger
12 – Bath
13 – Impeller
14 – Luke
15 – Water supply valve
16 – Auger drive pulley

***Figure 3**. CSC-5 vegetable chopper*

The root crops loaded into the bath are suspended under the action of the rotating water flow, picked up by the auger and sent to the chopper. Partially washed roots and tubers in the bath are additionally washed with a jet of water in the auger housing. Stones and other heavy objects fall to the bottom of the tub and are thrown by the impeller into the conveyor-stone catcher. After cleaning, the root crops are chopped with horizontal knives and sent to the lower disk, where they are finally chopped with vertical knives. To obtain fine grinding, the product is additionally passed through a tray. The crushed product is discharged through the tray using the blades of the lower disc.

Cleaning and grinding of grain is carried out using the modes that are given in the "Rules for the organization and management of the technological process of the production of compound feed products" [9].

The raw material prepared in this way is fed into the periodic weighing doser, where it is dosed in the specified ratios. The dosed mixture enters the mixer, where the components are evenly mixed, then it is fed to the 5-ton hopper for aging before extrusion.

The mixture of crushed grain and wet components is fed to the KMZ-2M extruder or another brand, with a grain processing capacity of 380 kg/h. The resulting product is cooled in a vertical or horizontal cooler to a temperature that does not exceed the ambient temperature by more than 15-18°C, if necessary, it is crushed on hammer crushers and sifted on separators using sieves that provide the required size prescribed by the standard. Extrusion and cooling of the mixture is carried out using the established modes "Rules of organization and management of the technological process of compound feed production" [10].

We calculated the cooling process of the mixture of extruded grain with fruit and vegetable raw materials after processing in KMZ-2M and PEK-40x5B extruders.

Output data: temperature of the mixture at the exit from the extruder, $Q1=120°C$; moisture content of the extruded mixture, $W1=11.0\%$; productivity of the KMZ-2M extruder for wet product $G1=430$ kg/h; PEK-40x5V extruder for wet product $G1=30$ kg/h; number of extruders – 1 pc.; temperature of the extruded mixture after cooling, $Q2=28°C$; moisture content of the extrudate after cooling, $W2=10.0\%$; air temperature, $t1=15°C$; relative air humidity, $\varphi1=67\%$; exhaust air temperature, $t2=25°C$; relative humidity of exhaust air, $\varphi2=40\%$.

The amount of moisture that evaporates during cooling of the extruded mixture:

$$W = G1\left(W1 - \frac{W2}{100} - W2\right), \frac{kg}{hr}, \tag{2}$$

for KMZ-2M:

$$W = 430\left(11{,}0 - \frac{10{,}0}{100} - 10{,}0\right) = 4{,}8\frac{kg}{hr}, \tag{3}$$

for PEK-40x5V:

$$W = 30\left(11{,}0 - \frac{10{,}0}{100} - 10{,}0\right) = 0{,}33\frac{kg}{hr}. \tag{4}$$

The average performance of the extruder on the dry mixture:

$$G2 = G1 - W, \frac{kg}{hr}, \tag{5}$$

for KMZ-2M:

$$G2 = 430 - 4{,}8 \ = \ 425{,}2\,\frac{kg}{hr}, \quad (6)$$

for PEK-40x5V:

$$G2 = 30 - 0{,}33 \ = \ 29{,}67\,\frac{kg}{hr}. \quad (7)$$

The amount of heat introduced into the cooling unit by the hot mixture:

$$q\text{пр} = \left(\frac{G2}{W}\right) \cdot C(Q1 - \ Q2), \frac{kJ}{kg} \ of\ evaporated\ moisture. \quad (8)$$

The average specific heat in the mixture is 1.927 J/(kg·degree):
for KMZ-2M:

$$q\text{пр} = \left(\frac{425{,}2}{4{,}8}\right) \cdot 1{,}927(120 - 28) = 15704\ \frac{kJ}{kg} \ of\ evaporated\ moisture, \quad (9)$$

for PEK-40x5V:

$$q\text{пр} = \left(\frac{29{,}67}{0{,}33}\right) \cdot 1{,}927(120 - 28) = 15939\ \frac{kJ}{kg} \ of\ evaporated\ moisture. \quad (10)$$

The difference between the amount of heat introduced into the cooler together with the extruded mixture and its amount removed from the cooling unit:

$$\Delta\ cool\ = \ q\text{пр}\ + (Q1 - \ q\text{н.сер}), \frac{kJ}{kg} \ of\ evaporated\ moisture, \quad (11)$$

for KMZ-2M:

$$\Delta\ \text{охл.} = \ 15704 + (120 - 0) = 15824, \frac{kJ}{kg} \ of\ evaporated\ moisture, \quad (12)$$

for PEK-40x5V:

$$\Delta\ cool\ = \ 15939 + (120 - 0) = 16059, \frac{kJ}{kg} \ of\ evaporated\ moisture. \quad (13)$$

According to the I-d diagram of moist air, we determine the specific air consumption for cooling the extruded mixture, which is l=555 dry air/kg of evaporated moisture.

Total weight consumption of air for cooling the extruded mixture:

$$L = l \cdot W, \frac{kg}{hr}, \quad (14)$$

for KMZ-2M:

$$L = 555 \cdot 4{,}8 = 2664\,\frac{kg}{hr}, \quad (15)$$

for PEK-40x5V:

$$L = 555 * 0{,}33 = 183\,\frac{kg}{hr}. \quad (16)$$

Volume flow rates of moist air at the entrance to the cooling unit:

$$V_{in} = L \cdot V_0, \frac{m^3}{h}, \quad (17)$$

for KMZ-2M:

$$V_{in} = 2664 \cdot 0.8421 = 2243, \frac{m^3}{h}, \quad (18)$$

for PEK-40x5B:

$$V_{in} = 183 \cdot 0.8421 = 154, \frac{m^3}{h}, \quad (19)$$

at t1=15°C, φ=67%, V0=0.8421 m^3/h of dry air.

The amount of air at the outlet of the cooling unit:
for KMZ-2M:

$$Vout = 2664 \cdot 0.9727 = 2591\,\frac{m^3}{h}, \quad (20)$$

for PEK-40x5B:

$$Vout = 154 \cdot 0.9727 = 150\,\frac{m^3}{h}, \quad (21)$$

at t1=25°C, φ=40%.

Specific air flow in the cooling unit:
for KMZ-2M:

$$\frac{2243}{430} = 5.22\,\frac{\frac{m^3}{h}}{kg}\,of\ mixture, \quad (22)$$

for PEK-40x5V:

$$\frac{154}{30} = 5.13, \frac{\frac{m^3}{h}}{kg}\,of\ mixture. \quad (23)$$

According to the above calculations, the specific air consumption in the cooling unit should be 5.1-5.2 (m^3/h)/kg of the mixture.

At the final stage of production, the finished product is checked in magnetic separators for the presence of metallomagnetic impurities, weighed on automatic scales and sent to packaging and storage. It is also possible to use a feed additive as a raw material for the production of compound feed for farm animals.

In order to find out the behavior of vegetable raw materials in the mixing process, we conducted a study to determine the effectiveness of the mixing process based on the statistical characteristics of the mixtures that included vegetable raw materials. Such a characteristic is the coefficient of variation (heterogeneity) of the distribution of the key component in the mixture. Research has established that the coefficient of variation of the distribution of the key component is 4.6...5.4%, which indicates a good distribution of the key component - salt. Therefore, it can be concluded that other components of feed additives are well distributed in the mixture.

The traditional technological scheme for the production of compound feed involves the following main lines: line of grain raw materials; film separation line; a line of floury raw materials; line of loose herbal flour; line of pressed and lumpy raw materials; line of fodder products of food industries; line of meal; salt preparation line; chalk and other mineral raw material preparation line; a line for processing packaged raw materials and a line for introducing premixes [10].

Based on the results of the conducted research, we recommend introducing feed additives into the composition of compound feed at the meal line. The technological line for the introduction of feed additives is included in the technological scheme, which is shown in Figure 4.

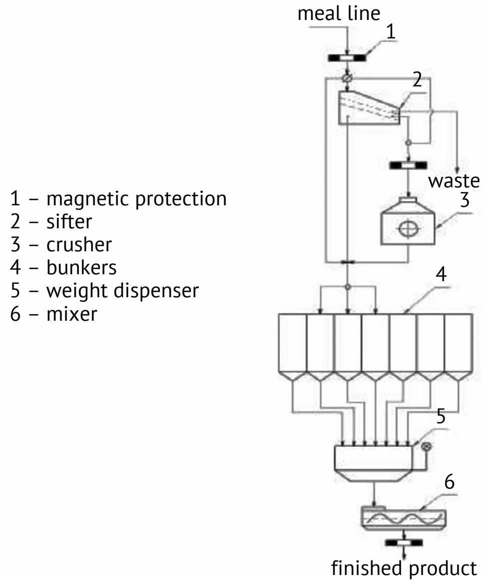


***Figure 4**. Technological diagram of the extruded raw material input line*

According to the given technological diagram (Fig. 4), feed additives are fed to the hopper, from where to the sieve (2) to remove random impurities. For this purpose, the installation of sieve frames No. 100 with hole sizes of 10 mm diameter or No. 8 with cells of 8×8 mm size is provided, which are used to separate random impurities of large sizes. The passage from this sieve is sent through the magnetic separator (1) to the overdosing hoppers. Cleaning from extraneous impurities is carried out using the regimes established by the "Rules for the organization and management of the technological process of the production of compound feed products" [10].

Based on the fact that the macromolecules of the extrudates are packed rather loosely, cavities are often formed between the molecules, into which water enters, and as a result, the volume and degree of swelling increase. Physical indicators of mixtures of corn grain with vegetable root crops of different concentrations are given in Table 1.

***Table 1.** Physical indicators of a mixture of corn grain with root vegetables depending on their concentration (n=3, P≥0.95)*

Mixture of corn grain with root vegetables			Volumetric mass, kg/m^3	Swelling, ml/g	Angle of natural slope, degree	Flowability, cm/s	Swelling coefficient
			Beet				
Concentration of vegetable component, %	0 (K)	initial	637.1	4.17	32	22	-
		extruded	138.4	8.53	41.4	3.7	3.23
	2.5	initial	654.9	4.13	34.6	20	-
		extruded	149.5	8.43	41.3	3.5	3.06
	5.0	initial	668.7	4.07	36.7	19	-
		extruded	157.2	8.23	42.7	3.0	2.63
	10.0	initial	692.4	3.98	39.8	17	-
		extruded	198.3	7.42	43.2	2.7	1.73
	15.0	initial	732.1	3.89	41.5	15	-
		extruded	240.8	6.07	43.8	2.5	1.53
	22.5	initial	778.7	3.74	46.4	13	-
		extruded	270.9	4.43	45.4	2.3	1.02

Table 1, Continued

Concentration of vegetable component, %							
Carrot							
0 (K)	initial	625.2	4.17	32.0	22	-
	extruded	135.6	8.50	41.4	3.7	3.23
2.5	initial	667.7	4.12	34.6	20	-
	extruded	142.3	8.49	41.5	3.5	3.19
5.0	initial	700.4	4.06	36.2	19	-
	extruded	152.5	8.43	42.6	3.0	2.28
10.0	initial	700.4	3.92	39.3	17	-
	extruded	193.8	7.77	41.2	2.7	1.65
15.0	initial	733.1	3.83	42.4	15	-
	extruded	245.2	6.65	43.9	2.5	1.34
22.5	initial	774.3	3.73	45.9	13	-
	extruded	258.5	4.56	45.2	2.3	1.05

Thus, in extruded corn grain with root vegetables, the degree of swelling is 8.53 ml/g, while in the untreated form it is only 4.17 ml/g (Table 1).

Increasing the number of root vegetables in the corn feed mixture reduced the swelling of the mixture. Thus, the degree of swelling of the mixture with a concentration of components of 2.5%, depending on the root crop, was 8.43-8.49 ml/g. In turn, increasing the content of root vegetables to 10% caused a decrease in the indicator to 7.40-7.77%, and 15% of vegetable supplements reduced the degree of swelling to 6.07-6.65%. Increasing the concentration of root vegetables in the mixture to 22.5% reduced swelling to the level of 4.43-4.56%.

Thus, the swelling of a mixture of corn grain with vegetable root crops of different concentrations showed that with an increase in the amount of the vegetable component, the swelling of the extruded product significantly decreases, which indicates a decrease in the ability of the mixture with high concentrations of components to absorb water.

The angle of natural inclination in the raw material was 32 degrees. An increase in the concentration of vegetable components in the fodder mixture contributed to a gradual increase in the angle of natural inclination to 45-46 degrees. Extrusion helped increase this indicator by 1-9 degrees. The parameters of the raw mixture and the finished extrudate were equalized by the amount of root vegetables at 22.5%, and the angle of natural inclination was 45-46 degrees. In turn, with an increase in the concentration of vegetable components, the flowability of the products decreased. Significant changes were noted in the amount of swelling of the material, which is directly related to the volumetric mass. Thus, the coefficient of swelling of extruded corn was 3.23. In the extruded mixture of corn and table beet, as its concentration increased, the coefficient tended to decrease from 3.06 at 2.5% content to 1.02 at 22.5% content. On the other hand, in the extruded mixture of corn with table carrots, with an increase in its concentration, the coefficient of swelling tended to decrease from 3.19 at 2.5% content to 0.97 at 1.03% content.

The technological scheme for the production of compound feed provides for the installation of an additional extrusion line for carrying out special heat treatment of a mixture of grain crops and obtaining an extruded feed mixture.

The technological indicators of processing a mixture of corn grain with root vegetables in the extruder in the pre-matrix zone of the extruder are given in Table 2.

Table 2. *Technological indicators of grain-vegetable mixture processing in an extruder*

Content and type of vegetables, %	(K)	Beet, %					Carrot, %				
		2.5	5.0	10.0	15.0	22.5	2.5	5.0	10.0	15.0	22.5
Productivity, kg/h	27	28	27	25	23	18	27	25	23	20	17
Extruder motor load	6.4	5.8	5.2	4.8	4.5	4.3	5.7	5.4	4.7	4.4	4.2
Specific electricity consumption of energy, kWh/t	117	102	94	93	95	115	104	103	98	105	120
Temperature, °C	171	164	158	147	139	132	166	159	146	139	133

Productivity by adding 2.5% of crushed beets to corn grain increased by 1 kg/h. When the concentration of vegetables increases to 22.5%, productivity decreases to 15-17 kg/h.

The specific consumption of electricity when extruding corn grain is 117 kWh/t, and with the addition of fruit and vegetable raw materials it decreases by 2.5% to 102-104 kWh/t. The reduction process continues up to a concentration of 10.0% and is 93-96 kWh/t. A further increase in the concentration of fruit and vegetable raw materials caused an increase in the specific consumption of electricity to 115-120 kWh/t.

In general, the energy consumption for extruding mixtures with carrots was higher than for the addition of beets and differed by 2-5 kWh/t.

There is no significant difference in the extrusion parameters of mixtures of corn grain with carrots and beets.

CONCLUSIONS

The improved technology for the production of fodder mixture consists in preliminary preparation of raw materials: cleaned, crushed, dosed according to the composition of the recipe, mixing and special processing to improve technological properties according to the processes: pre-mixing, aging and extrusion of the mixture, cooling and grinding of the product depending on the purpose of the feed.

It was established that with an increase in the concentration of vegetable roots in the extruded mixture, the physical properties of the feed improve, in particular, the volumetric weight of the mixture with a concentration of vegetable roots up to 15% increases, with a simultaneous decrease in the flowability and swelling coefficient of the extruded mixture.

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Інжиніринг в технології виробництва екструдованих кормових добавок

Катерина Костецька

Кандидат сільськогосподарських наук, доцент
Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна
https://orcid.org/0000-0003-2387-5400

Іван Улянич

Кандидат технічних наук
Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна
https://orcid.org/0000-0003-2342-188X

Валерія Желєзна

Кандидат сільськогосподарських наук
Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна
https://orcid.org/0000-0002-1874-2155

Михайло Голубєв

Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-6647-4335

Анотація. Виробництво кормів із екологічно чистої сировини є ефективним способом збільшення об'ємів кормів зі зменшенням економічних витрат на їх виробництво. Використання природних кормових добавок у складі кормів поліпшує їх споживання. Інноваційний інжиніринг у технології виробництва кормових добавок здійснюється через удосконалення технології кормових добавок з використанням плодоовочевої сировини. Наразі в Україні перманентно накопичуються достатньо великі запаси плодоовочевої сировини, які є недостатньо застосовуваними у кормовиробництві. Водночас, поліпшення споживання та підвищення ефективності використання кормів, а також отримання максимальної тваринницької продуктивності все частіше забезпечується використанням природних кормових добавок у складі корму. Саме тому, виробництво кормів із екологічно чистої сировини, як перехід на альтернативні технології, є одним із найбільш ефективних способів збільшення обсягів кормів зі зниженням економічних витрат на їх виробництво. На сьогодні у приватних господарствах населення відсутня така практика. Включення плодоовочевої сировини до рецептури кормів є актуальним для підвищення їхньої якості. Метою роботи було розширити асортимент кормів для тварин та удосконалити технологію виробництва екструдованої кормової суміші. У роботі було застосовано лабораторний та аналітичний метод. Автори представили технологію, що полягає у попередній підготовці сировини: очищенні, подрібненні, її дозуванні відповідно до складу рецепту, змішуванні та спеціальній обробці для покращення технологічних властивостей і підвищення кормової цінності з процесами: попереднього змішування, відлежування та екструдування суміші, охолодження та подрібнення продукту залежно від призначення корму. Результати можуть бути використані для вдосконалення технології виробництва поживних кормів для тварин і забезпечення більшої кількості господарств

Ключові слова: зерно, плодоовочева сировина, кормові добавки, технологія екструдування

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The Danish model of organic agriculture

O. Clausen*

Ministry of Environment and Food of Denmark
2600, 31-33 Stationsparken Str., Glostrup, Denmark

Lyudmila Patryeva

Full Doctor in Agrisciences, Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0002-4242-0519

Abstract. The article discusses the main elements of the Danish model of organic agriculture, reveals the reasons for Denmark's choice of such a development path, shows the successes of farms that are based on organic production, demonstrates the relevance of the transition of all agriculture to organic production, as one of the bioetic components of the development of society in modern world and the implementation of large-scale shifts in the consciousness and actions of people around the world

Keywords: organic agriculture, Danish model, regulations, control

INTRODUCTION

Organic agriculture is a holistic production management system that promotes and improves the health of the agroecosystem, and in particular biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to them, to the use of inputs external to the farm, bearing in mind that regional conditions will require locally adapted systems. This is achieved by using, whenever possible, cultural, biological and mechanical methods, as opposed to the use of synthetic materials, to fulfill each function specific within the system (Codex Alimentarius Commission, 1999) [1].

The definition of organic agriculture was proposed by the IFOAM (International Federation of Organic Agriculture Movements) General Assembly in Australia, 1985 – "Organic Agriculture is a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved" [2].

As emphasized and interpreted by IFOAM, Organic Agriculture is based on 4 principles: health, ecology, fairness, care [3].

Principle of HEALTH. Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. Health is the wholeness and integrity of living systems. It is the maintenance of physical, mental, social and ecological well-being. Immunity, resilience and regeneration are key characteristics of health. The role of organic agriculture, whether in farming, processing, distribution, or consumption, is to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings. In particular, organic agriculture is intended to produce high quality, nutritious food that contributes to preventive health care and well-being. In view of this it should avoid the use of fertilizers, pesticides, animal drugs and food additives that may have adverse health effects.

Principle of ECOLOGY. Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. This principle roots organic agriculture within living ecological

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*Corresponding author

systems. It states that production is to be based on ecological processes, and recycling. Nourishment and well-being are achieved through the ecology of the specific production environment. For example, in the case of crops this is the living soil; for animals it is the farm ecosystem; for fish and marine organisms, the aquatic environment. Organic farming, pastoral and wild harvest systems should fit the cycles and ecological balances in nature. These cycles are universal but their operation is site-specific. Organic management must be adapted to local conditions, ecology, culture and scale. Inputs should be reduced by reuse, recycling and efficient management of materials and energy in order to maintain and improve environmental quality and conserve resources. Organic agriculture should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water.

Principle of FAIRNESS. Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities. Fairness is characterized by equity, respect, justice and stewardship of the shared world, both among people and in their relations to other living beings. This principle emphasizes that those involved in organic agriculture should conduct human relationships in a manner that ensures fairness at all levels and to all parties – farmers, workers, processors, distributors, traders and consumers. Organic agriculture should provide everyone involved with a good quality of life, and contribute to food sovereignty and reduction of poverty. It aims to produce a sufficient supply of good quality food and other products. This principle insists that animals should be provided with the conditions and opportunities of life that accord with their physiology, natural behavior and well-being. Natural and environmental resources that are used for production and consumption should be managed in a way that is socially and ecologically just and should be held in trust for future generations. Fairness requires systems of production, distribution and trade that are open and equitable and account for real environmental and social costs.

Principle of CARE. Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. Organic agriculture is a living and dynamic system that responds to internal and external demands and conditions. The new technologies need to be assessed and existing methods reviewed. Science is necessary to ensure that organic agriculture is healthy, safe and ecologically sound. Organic agriculture should prevent significant risks by adopting appropriate technologies and rejecting unpredictable ones, such as genetic engineering. Decisions should reflect the values and needs of all who might be affected, through transparent and participatory processes.

Currently, 179 countries of the world are developing organic agriculture, more than 2 million producers are employed in it, 89 countries have their own laws in the field of production and circulation of organic products. The annual production growth is 12-15% and, according to forecasts, such rates will remain until 2025.

In 2018, the global organic market expanded to € 90 billion. Among the largest markets, experts point out the United States (40 billion euros), Germany (10 billion euros), France (7.9 billion euros) and China (7.6 billion euros) [4].

Among all countries engaged in organic farming, Denmark is of particular importance. Her experience in this matter isinvaluable; therefore it is necessary to consider the Danish model of organic development.

MATERIALS AND METHODS

The study was conducted on the basis of open access materials of Internet resources on the Danish model of the organic way. Methods of analysis, synthesis and generalization are used.

RESULTS

Denmark was the first country in the world to introduce rules for organic production, to develop national organic standards and to launch an organic label. Denmark was also the first country in the world to introduce a target for 60 per cent organic products in public sector kitchens.

Denmark has the highest market share of organic food and beverages in the world. In 2017, the organic market share reached about 13.3%. Per capita consumption of organic food was DKK 2,500 in 2017 ~EUR 335. Organic sales have grown every year in the past decade. Growth rate in retail was 14% in 2017. 93% of all Danes occasionally buy organic products. 51.4% of all Danes bought organic food every single week in 2017.

In 2019, sales of organic food in Danish stores increased by 9% and accounted for 11.5% of total sales. The first place in the shopping list belongs to such products - organic milk, grains, flour and vegetables, but other product categories also account for a significant increase and indicate that organic food has become mainstream for most Danes.

Denmark's rapid growth in exports of organic products to EUR 400 million over the last 5 years has been ensured by a high level of food safety, healthy quality food and a unique organic control system.

Danish companies export to near markets such as Germany, Sweden and France and to distant markets in Asia, the Middle East and US. The three largest export markets in 2017 were Germany, Sweden and China respectively. Denmark has many livestock production companies – large and small – that are committed to organic production and to export. It is therefore not surprising that the largest export products are dairy products – fresh milk, cheese, butter and powdered milk – and pork. Danish companies are also well positioned to supply eggs and poultry as well as vegetable products such as feedstuffs, vegetables, groceries and drinks.

The fine reputation of organic products is based on the success of Denmark's agricultural sector, which has turned Denmark into a recognized and respected food nation that supplies high quality food to global consumers: food that is known for its high standards of food safety, traceability, quality and sustainability. Collaboration underpins the success of organic production. Collaboration that has involved all actors across the entire value chain for more than 30 years – farmers, companies, organizations, official bodies, advisers, politicians, the retail sector, food service and consumers. They have all helped to develop a market-driven organic sector – a type of production that takes account of the environment, nature, animal welfare and sustainability as demanded by many modern consumers.

How and why organic food has become one of the Danish food cluster's strengths in a world that is increasingly demanding sustainable food products?

Organic food is produced according to organic rules – all the way from farm to fork – and contributes to animal welfare, the environment and nature.

Organic production is an overall system of farm management and food production that combines best environmental practices, focus on preservation of natural resources, a high level of biodiversity and application of high animal welfare standards. Organic production is based on four principles: ecology, health, fairness and care. They have been formulated by the International Organic Organization, IFOAM, and provide the basis for organic producers and their way of thinking and acting. They also form the basis of the laws and rules regulating organic production. Before products can be sold as organic, organic farms have to go through a conversion period after starting organic plant and/or livestock production. The conversion period takes two years. During this transition period produce from the farm cannot be sold or labelled as organic [5].

Organic farmers work to preserve the natural environment, including soil fertility, water resources and biodiversity.

The most important agricultural principles are:

- Careful monitoring of the soil's fertility, what farmers put in and take out of the soil, and how their activities affect its composition.
- Adopting a wide and varied crop rotation to break weed and pest cycles and to allow soil recovery time while supplying useful nutrients.
- Nutrients are provided by legumes (via biological nitrogen fixation from the atmosphere) as well as effective recycling of organic material such as crop residues and livestock manures.
- The primary use of preventive natural methods or mechanical methods to control weeds, diseases and pests.
- Non-use of chemical plant protection or synthetic fertilizers in order to protect the environment as a whole, including lakes, rivers, drinking water, etc.
- Planting of hedges and meadows to prevent soil erosion and nutrient loss.

The impact on biodiversity: organic farmers preserve and enhance biodiversity as much as they can, i.e. by means of multi-annual crop rotations or by employing mechanical and physical methods of soil cultivation in order to achieve optimum results for soil health structure. Organic cultivation methods provide for more native plants and animals and a higher concentration of micro-organisms and earthworms in the soil.

The impact on emissions: studies from different universities in Europe have shown that organic agriculture can produce low carbon emissions per hectare of land and consequently may contribute to reducing climate change – even more so if yields in organic farming can be improved. Possible contributing factors include:

- Carbon sequestration in organic matter because organic farming enhances the humus content in the soil.
- Reduced energy consumption through recycling of waste and by-products. facts about organic food Organic food is produced according to organic rules – all the way from farm to fork – and contributes to animal welfare, the environment and nature.
- No use of synthetic fertilizers produced in energy intensive processes.
- Retention of more native and general vegetation.
- Animal welfare. Animal welfare is an important feature of organic farming. The aim is to provide suitable conditions for natural behavior. This means that:
- Animals have access to grassland or outdoor areas.
- Animals have ample space in their housing units.
- Animals eat organic feed.
- For cows, the number of animals is balanced with the area of available land.
- Any use of substances to promote growth or the use of hormones or similar substances to control reproduction or for other purposes is prohibited. Synthetic allopathic veterinary medicinal products are not used for preventive treatment.

Non-GMO: use of genetically modified organisms (GMOs) and products produced from, or by, GMOs is not allowed.

Processing of organic food: only ingredients of natural origin are accepted when processing organic food. Only 53 of the 390 food additives approved in the EU are allowed in organic production. Synthetic flavorings, colorants, sweeteners, GMOs and irradiation are strictly prohibited.

Healthy food. Studies comparing the nutritional quality of organic versus conventional products indicate the presence of certain health promoting factors in organic products:

- Organic dairy products and beef contain significantly higher levels of omega-3 fatty acid, linoleic acid and vitamin E.

- Organic fruit and vegetables have a higher level of antioxidants.

Food that matters:

- Organic food is authentic, high-quality and tasty.
- Organic labelling guarantees that all enterprises in the organic sector are regularly inspected by authorities.
- Organic production provides food without synthetic flavorings, colorants and sweeteners.
- Organic fruit and vegetables rarely contain traces of plant protection agents.
- Only a limited number of mostly natural additives are allowed in the processing of organic products.

– Genetically Modified Organisms (GMOs) are prohibited in organic farming and in the further processing of the products.

- Organic farming contributes to a high level of biodiversity and the preservation of species and natural habitats.
- Organic farming enhances soil life and natural soil fertility.
- As chemical plant protection is prohibited, organic farming contributes to the protection of the environment and can be practiced in drinking water protected areas.
- Organic farming promotes animal welfare and provides good conditions for natural behavior. All organic animals have access to outdoor areas.
- Use of antibiotics and other drugs is severely restricted. Organic animals are raised without the use of hormones.

Regulations and control:

- Consumers across the world have great confidence in Danish organic food.
- Many rules and regulations govern all aspects of food production.
- Rules and regulations are monitored by meticulous government control.
- Focus on food safety and traceability.
- Organic control from farm to fork.
- Denmark was the first country in the world to establish government organic control in 1987.
- Yearly physical inspections of all organic farms and companies.
- Organic food labels (Fig. 1).

a) b) c)

***Figure 1**. Organic food labels:*
a – organic state-authorized label certifying that the product has been controlled by the Danish food authorities; b – Mandatory label on all organic products sold in the EU; c – Danish certification system for large-scale kitchens (restaurants, school kitchens, catering etc.) indicating the percentage of organic raw material used in the kitchen

The widespread success of organic food products in Denmark was facilitated by the established Danish organic brand – a unique and state-certified ø-label certificate.

Denmark was the first in the world to introduce state control over organic products, which helped to increase consumer confidence in organic products. In 2020, the Danish label Red Organic celebrated its 30th anniversary.

A "farm-to-fork" philosophy of organic production takes into account nature, the environment and animal welfare as much as possible. The Danish red Ø label as well as EU's green organic logo are guarantee of organic quality [6]. Organic producers are inspected at least once a year. Checks are carried out in accordance with government regulations for organic production by agencies of the Ministry of Food, Agriculture and Fisheries. Danish AgriFish checks primary products and Danish Veterinary and Food Authority checks food companies.

As noted in the source "Organic Denmark", in 2009, The Ministry of Food, Agriculture and Fisheries introduced labels for the marketing of organic food in large-scale kitchens, restaurants, cafés, hospitals, schools and larger businesses. The Organic Cuisine Label is a free state-controlled labelling scheme for eateries. The Organic Cuisine Label shows the total share (in %) of organic raw ingredients and beverages used in preparing the entire menu.

The Organic Cuisine Label is available in three versions: Gold (90-100%), Silver (60-90%) and Bronze (30-60%) [7].

Paving the way to success – Cooperation:

- Cooperation is the key driver behind organic sales growth in Denmark.
- Close collaboration on organic market development.
- Cooperation with all supermarkets at strategic level.
- Support to supermarkets in their expansion of organic product lines.
- Courses for small organic companies in their collaboration with retail and foodservice sectors.
- Advisory service on product development.
- Motivating consumers – 80% of Danes purchase organic products – more than 50% buy organic food every week.

Paving the way to success – policy development:

- Danish organic policy is a catalyst for organic innovation and growth.

Involvement of many stakeholders in political policy development.

Interaction between organic farms and food companies, consumers, the labour market and environmental and farm organizations in the creation of organic food policy in Denmark.

Organic farming as a tool in broad national policies for the protection of nature, drinking water supply, climate, green growth and rural development.

Push and pull strategy. "Pull" from the market – "push" towards the farmers.

Funding of organic development activities in the Fund for Organic Agriculture.

Paving the way to success – Organic research:

The development of organic production is based on knowledge and innovation.

Denmark has a strong research tradition in organic farming and food systems.

Organic research supports development of new solutions and new knowledge throughout the supply chain.

ICROFS – International Centre for Research in Organic Food Systems – coordinates the research.

Stakeholder driven research – scientists, practitioners and advisers work together.

Short pathway from new knowledge to practical implementation on farms and at companies.

More than 20 years of targeted research has contributed to the success of organic production in Denmark.

General reasons for buying organic food:

Safe, healthy and natural food – without synthetic flavorings, colorants and sweeteners. GMOs are prohibited.

Good animal welfare – natural behavior with access to outdoor areas.

Protection of the environment and drinking water – chemical pesticides are prohibited.

Strong focus on sustainability.

High consumer confidence in organic food due to state certification system.

Food trends: local, healthy & natural, and "easy-to-make".

The organic market share is presented in Figure 1. The largest share of total sales of organic products was recorded in Denmark, in second place is Switzerland, in third place – Sweden [8].

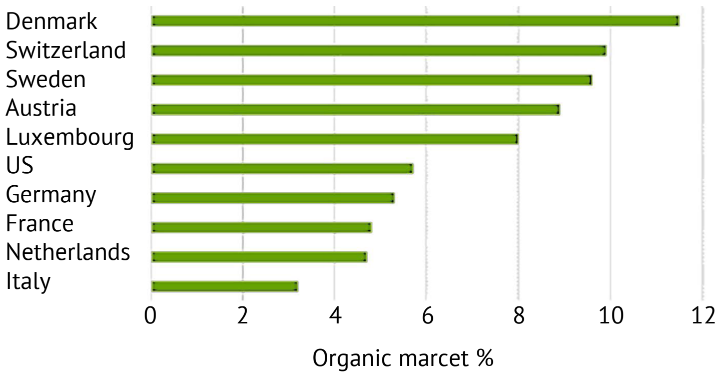

Figure 2. *Organic market share*

Source: *FiBL (2019)*

According to statistics GfK Consumer Scan the 10 most popular, organic products of Danish consumers anno 2019 are: natural yoghurt (48.6%), carrots (45.2%), oatmeal (43.1%), bananas (36.5%), cooking oil (34.3%), milk (32.3%), oranges (29.9%), eggs (29.6%), pasta (29.0%), flour (29.0%) [9].

Let us summarize the main positions regarding the organic production of individual industries.

1. 10% of Danish farms are organic. They cultivate 11% of the agricultural land in Denmark. They produce good healthy raw materials with the utmost care for the environment, biodiversity and animal welfare. All farmers receive 3-5 years of specialist agricultural training. Some organic farms are highly specialized – others produce a diverse range of product for direct sales. The specialized farmers focus on either production of vegetables, cattle, pigs or poultry. Focus is on developing and improving their products and yields through sound organic practice. Organic Farming – plant production. Chemical plant protection and synthetic fertilizers are not allowed. Nutrients provided by legumes and recycling of organic materials as crop residues and livestock manures. Enhances soil life and natural soil fertility. Contributes to a high level of biodiversity and the preservation of species and natural habitats. Contributes to the protection of the environment. The yield from organic fields is typically 10-30% lower compared to conventional plant production.

2. Animal welfare in organic milk and beef production. Good conditions for natural behavior. Access to pasture from 15th April to 1st November. Ample space in their housing units. The winter housing system must ensure freedom of movement. Feed must be 100% organic with a lot of roughage. Use of antibiotics and other drugs is severely restricted. If treated with veterinary medicine - the withdrawal period is twice as long as the

non-organic withdrawal period. Cows are raised without the use of hormones.

3. Animal welfare in pig production. Good conditions for natural behavior. Access to grassland or outdoor areas. Ample space in their housing units. No tail docking. In Denmark, sows farrow in an outdoor hut with access to pasture. 100% organic feed in Denmark. Plenty of roughage, which benefits the pigs' digestion. Use of antibiotics and other drugs is severely restricted. If treated with veterinary medicine – the withdrawal period is twice as long as the non-organic withdrawal period. Organic pigs are raised without the use of hormones.

4. Animal welfare in organic egg production. Good conditions for natural behavior. Access to outdoor areas. Outdoor areas have to be covered with vegetation. The minimum outdoor stocking density is 4 m^2/hen. Indoor stocking density is maximum 6 hens/m2. The building must have natural day-light and a resting period of at least 8 hours is required. Organic feed with a lot of roughage. Access to perches and to areas for dust bathing and scratching. Beak trimming is not allowed. Use of antibiotics and other drugs is severely restricted.

5. Animal welfare in organic poultry Production. Slow-growing breeds. Good conditions for natural behavior. Access to outdoor areas. Outdoor areas have to be covered with vegetation. The minimum outdoor stocking density is 4 m^2/boiler Indoor stocking density is maximum 10 boilers/m^2. The building must have natural day-light and a resting period of at least 8 hours is required. Access to areas for dust bathing and scratching. Organic feed with a lot of roughage. Beak trimming is not allowed. Use of antibiotics and other drugs is severely restricted. Danish companies export to near markets such as Germany, Sweden and France and to distant markets in Asia, the Middle East and US. The three largest export markets in 2017 were Germany, Sweden and China respectively. Denmark has many livestock production companies – large and small – that are committed to organic production and to export. It is therefore not surprising that the largest export products are dairy products – fresh milk, cheese, butter and powdered milk – and pork. Danish companies are also well positioned to supply eggs and poultry as well as vegetable products such as feedstuffs, vegetables, groceries and drinks.

CONCLUSIONS

Organic agriculture is knowledge intensive and should be adapted to local conditions and the farmers' situation. Thus, there is need for further development in line with the principles of organic agriculture and there is a need for improved knowledge transfer systems which acknowledges traditional as well as scientific knowledge.

The Danish model of the organic path of development is of great importance for the perception of the population of the world around the principles of bioethics in their daily lives. This model has proven its effectiveness for more than 30 years. The difficult period of human development that the whole world is going through encourages the revision of traditional food production and the transition to organic farming. This path, of course, is not easy and requires great effort and will to implement such plans. The health and life of all living things on the planet will be the key to large-scale changes in the minds and actions of people around the world.

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Данська модель органічного сільського господарства

О. Клаусен

Міністерство навколишнього середовища та продовольства Данії
2600, Stationsparken Str., 31-33, м. Глоструп, Данія

Людмила Патрєва

Доктор сільськогосподарських наук, професор
Миколаївський національний аграрний університет
54008, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0002-4242-0519

Анотація. У статті розглянуто основні елементи данської моделі органічного сільського господарства, розкрито причини вибору Данією такого шляху розвитку. Показано успіхи фермерських господарств, які засновані на органічному виробництві. Продемонстровано актуальність переходу всього сільського господарства на органічне виробництво, як одного з біоетічних складових розвитку суспільства в сучасному світі і здійснення масштабних зрушень у свідомості і діях людей всіх країн світу

Ключові слова: органічне сільське господарство, Данська модель, регламент, контроль

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The influence of the main tillage and fertilization on weediness of sunflower crops

Roman Hutianskyi*

PhD in Agrisciences, Senior Research Fellow
Institute of plant breeding named after V.Ya. Yuryev of the National Academy of Sciences of Ukraine
61000, 142 Heroiv Kharkova Ave., Kharkiv, Ukraine
https://orcid.org/0000-0002-5953-9428

Sergiy Popov

PhD in Agrisciences, Professor
Institute of plant breeding named after V.Ya. Yuryev of the National Academy of Sciences of Ukraine
61000, 142 Heroiv Kharkova Ave., Kharkiv, Ukraine
https://orcid.org/0000-0002-1101-4454

Viktor Kostromitin

PhD in Agrisciences, Professor
Institute of plant breeding named after V.Ya. Yuryev of the National Academy of Sciences of Ukraine
61000, 142 Heroiv Kharkova Ave., Kharkiv, Ukraine
https://orcid.org/0000-0001-6098-2876

Nataliia Kuzmenko

PhD in Biological Sciences, Senior Research Fellow
Institute of plant breeding named after V.Ya. Yuryev of the National Academy of Sciences of Ukraine
61000, 142 Heroiv Kharkova Ave., Kharkiv, Ukraine
https://orcid.org/0000-0002-4373-0666

Oleksandr Hlubokiy

Research Fellow
Institute of plant breeding named after V.Ya. Yuryev of the National Academy of Sciences of Ukraine
61000, 142 Heroiv Kharkova Ave., Kharkiv, Ukraine
https://orcid.org/0000-0001-7589-5708

Abstract. On the international and domestic markets of agricultural products, there is an increase in demand for oilseed crops, in particular annual sunflower and its processing products. Sunflower seeds are in permanent demand, which proves their high relevance. Cultivation of this crop is quite profitable for agricultural producers and does not require significant additional costs. That is why the scientifically based observance of crop rotation in the process of growing sunflowers is gaining more and more importance. Soil pollution affects the productivity of cultivated crops. The order of fertilization and cultivation of the sown area is important in improving its microbiological condition. The search for a method of rational and effective application of fertilizers is an urgent task for workers in the agricultural sector. The purpose of the work was to determine the number of weeds and weeds in a field of stationary grain-row crop rotation, to compare the type of weediness between the unfertilized and control variant of the soil, and to choose a more effective method of soil cultivation. In the course of the work, the laboratory method, as well as methods of observation and generalization, were applied. The article examines

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*Corresponding author

the influence of the main tillage and fertilization system on the weediness of sunflower crops in a stationary crop rotation during 2016-2018 in the conditions of the eastern part of the Forest Steppe of Ukraine. The largest number of types of weeds and weeds in crops was found on the background without fertilizers (plowing) and on the organic-mineral intensive background (manure residue, 30 t/ha + $N_{30}P_{30}K_{30}$, chiseling). The type and level of weediness of sunflower crops depends significantly on the studied factors. The scientific novelty consists in establishing a method of soil fertilization that ensures maximum crop productivity

Keywords: crop rotation, fertilizers, weeds, herbicides, eastern Forest-Steppe of Ukraine, crop protection, plowing

INTRODUCTION

On the global and domestic markets of agricultural products, there is an increase in demand for oil crops, especially annual sunflower (*Helianthus annuas* L.) and its processing products. Sunflower seeds are in constant demand, which proves their high liquidity. Cultivation of this crop is quite profitable for agricultural producers and does not require significant additional costs. That is why the scientifically based observance of crop rotation in the process of sunflower cultivation is becoming more and more important [1].

The obtained scientific data indicate that sunflower should occupy no more than 20% of the crop rotation structure. An important factor in increasing the productivity of this oilseed crop in crop rotation is the main tillage, which ensures the preservation of productive moisture reserves, the improvement of the microbiological condition of the soil, and the control of weeds. The last factor is of great importance in modern sunflower cultivation technologies [2].

In the conditions of the left-bank Steppe of Ukraine, it was established that, regardless of the weather and agrotechnical conditions of sunflower cultivation, weed seedlings appear in the period from the beginning of field work to the closing of the rows of dominant agrophytocenoses. Typical for sunflower crops are such weeds as *Amaranthus retroflexus* L., *Sinapis arvensis* L., *Xanthium strumarium* L., *Chenopodium album* L., *Setaria viridis* (L.) Beauv., *Cirsium arvense* (L.) Scop., *Lactuca tatarica* (L.) C.A. Mey, *Lappula squarrosa* (Retz.) Dumort. The results of model experiments showed that the yield of sunflower is affected by both species and quantity of weeds. Under the short-term type of weeding, the yield of sunflower decreases by 1.42 t/ha, under the mixed type – by 1.56 t/ha, and by the predominance of perennials – by 1.69 t/ha, compared to areas without weeds. On average, the presence of one Tatar lettuce plant per 1 m^2 reduces the yield of sunflower by 0.035 t/ha, white quinoa – by 0.016 t/ha, common sedge – by 0.024 t/ha, and bent scotch – by 0.012 t/ha [3].

For the entire north-central moderately arid subzone of the Steppe northern zone of Ukraine, the main agrophytocenoses with the participation of sunflower are the following weed species: wild radish (*Raphanus raphanistrum* L.); the bent sphincter; *Echinochloa crus-galli* (L.) Roem. et Schult.; field mustard; *Xanthium albinum* (Widder) H. Scholz; *Ambrosia artemisiifolia* L.; white quinoa; *Setaria glausa* (L.) Beauv. As single plants in the crops, there are *Persicaria Maculosa* S.F. Gray, *Lycopsis arvensis* L., mousey green, black solanum (*Solanum nigrum* L.), one-year primrose (*Stachys annua* L.), etc. It was established that the highest crop losses are observed during the simultaneous vegetation of the crop with young species from the beginning of development to harvesting. In particular, the presence of 10 pcs./m^2 of these weeds with a raw above-ground weight of 170 g/m^2 leads to crop yield losses of 8.6%, compared to the control. Such indicators as the diameter of the basket (by 3.4 cm), the number of seeds from one basket (by 6 pcs.), the weight of 1,000 seeds (by 5.6 g) are reduced. In the case of an abundance of young species of 20 pieces/m^2 with a biomass of 197.5 g/m^2, sunflower seed yield losses reach 14.1%; 30 pcs./m^2 (241.3 g/m^2) – 19.6%; 40 pcs./m^2 (300.5 g/m^2) – 23.9%; 50 pcs./m^2 (327.5 g/m^2) – 28.2%. Natural weeding by young species (293 pieces/m^2 with a weight of 455 g/m^2) leads to a decrease in the yield of sunflower seeds by 44.2%, with a significant decrease in all indicators of the yield structure: the diameter of the basket – by 8.3 cm, the number of seeds from one basket – for 91 pieces, weight of 1,000 seeds – for 19.1 g [4].

According to the results of A.I. Babenko's research, the main polluters of sunflower crops in the right-bank Forest-Steppe of Ukraine are young monocotyledonous and dicotyledonous weeds (94%). Root weeds, represented by pink thistle (*Cirsium arvense* (L.) Scop.) and field birch (*Convolvulus arvensis* L.), occupy 6%. Among the young weeds, the main specific weight is the early spring ones – common plantain and common bittersweet (*Amaranthus retroflexus* L.). Among the early spring varieties, white quinoa is preferred. It was established that the critical period of competition between sunflower and weeds depends on the level of weediness, the duration of competitive relations, and the length of the growing season. In particular, the lowest yield of sunflower seeds was obtained in the variant where cultivated plants competed with weeds for life factors throughout the growing season. On these plots, 97 weeds/m^2 were counted, the raw above-ground mass of which was 2,131 g/m^2, and the seed yield was 1.4 t/ha, which is 2.9 t/ha or 67% less than in the version without competition from weeds. In the variants where sunflower plants competed with weeds for a certain growing season, the number and mass of weeds depended on the duration of the competition. The fewest weeds were in the option where they were removed within 60 days after the emergence of seedlings (25 pcs./m^2, based on the raw above-ground mass of 307 g/m^2). Yield reduction occurred by 0.4 t/ha or 9%. It was also established that weeds have the most significant effect on sunflower productivity when they are present in the first 60 days after the emergence of crop seedlings. For example, with the presence of weeds in the crops within 20 days after sunflower germination, the yield reduction was 11%, and 60 days after germination – 41% [5].

The sunflower crop is significantly reduced by a weed parasite, the sunflower wolfberry (*Orobanche cumana* Wallr.), the seeds of which can be stored in the soil for many years. Thus, according to the long-term data of the Mykolaiv State Agricultural Research Station, when sunflower is returned to its previous place in the crop rotation after 10, 6 and 4 years, the number of sunflower beetles in crops is 2, 12 and 38 pcs./m^2, respectively. The yield of sunflower when returning it to its previous place in crop rotation after 10, 6 and 4 years was 2.01, respectively; 1.33 and 1.11 t/ha [6].

In the last decade, there has been a massive spread of the virulent spring annual weed (*Cyclachaena xanthifolia* (Nutt.) Fresen.) in sunflower crops. It leads to huge losses of the harvest and deterioration of its quality, causes mass diseases of people due to polynomia. The dynamics of the emergence of black-leaved black-leaved weevil in sunflower crops is unfriendly and depends on weather and geographical conditions. In the Steppe zone, most of the seedlings of this weed in crops appear in the first decade of May, and in the Forest-Steppe zone - in the second decade of May. The total number of black-leaved aphids in sunflower crops in the Forest Steppe, southern Steppe, northern Steppe, and Dry Steppe zone is 40, 44, 43, and 47 pcs./m^2, respectively [7].

According to V.S. Zuza's long-term research, cereal annual weeds and millet weeds (*Panicum miliaceum* L.) are very common in sunflower crops in the conditions of northeastern Ukraine. The second place by mass and the third in number among weeds belongs to dicotyledonous perennial species. Dicotyledonous weeds stand out due to the variety of their species composition, among which the most harmful are vigorous species. At the same time, overwintering species are not inferior to warm weeds in terms of number, but they take second place in terms of mass. In total, about 50 types of weeds were found in the sunflower crops, of which the most numerous are common flat grass, gray mouse and common schirytsia. Also, the definition of the types of weediness shows that in the conditions of ordinary farms, in almost half of the fields under sunflower, the dominant position among the weeds is occupied by rhizome species. In the fields of experimental farms and experimental plots, under the conditions of observing the crop rotation system and carrying out the main cultivation of the soil under the culture by the method of improved sedge, rhizome species prevail in only 20% of sunflower crops [8].

According to A.M. Kovalenko, sunflower crops were the least weedy in crop rotation with black steam, while in crops of other crop rotations, the number of weeds increased by 12.6-30.2%, and their mass increased by 1.4-2.0 times. The most widespread were early spring weeds, the share of which in crop rotation with peas was 52.2%, and in other crop rotations – 63.2-67.8%. In crop rotation with peas, the share of early spring weeds increased slightly - up to 28.9% and perennial weeds – up to 19.2%, compared to other crop rotations – 15.0-24.2% and 13.0-19.2%, respectively [9].

As evidenced by the results of M.V. Shevchenko's research, the use of various methods of tillage for sunflower, compared to plowing, led to an increase in the number of weeds in crops by 12-29% [10]. I.D. Tkalich and co-authors point out the increase in weediness of cultivated areas and the decrease in sunflower yield in the direction from plowing to zero tillage. In their opinion, this is caused by the deterioration of the physical condition of the soil and its moisture regime [2].

The conducted studies show that in the sowing of agricultural crops, including sunflower, against the background without herbicides in variants of the use of tillage, the number of short-term and perennial weeds, compared to plowing, increases by 10-20% and by 1.5-2%, respectively ,0 times. Accordingly, the mass of weeds also increases – by 20-30%. The use of herbicides before sowing sugar beets and sunflowers, as well as during the growing season for crops of continuous sowing, reduced the number of weeds by 4-4.5 times, compared to the herbicide-free background. That is, the introduction of herbicides against the background of tillage significantly reduces the difference in weediness, compared to systematic plowing [11; 12]. It is also possible to replace plowing with chisel tillage when growing sunflowers without herbicides, or diagonal loosening with a combination of mechanical and chemical methods of weed control [10].

Research by S.P. Tanchyk and A.I. Babenko indicate that the number of weed seedlings in the agrocenosis depends on the sunflower cultivation technology, the biological characteristics of the culture and weeds, as well as weather conditions. Thus, in the phase of 6-7 leaves in sunflower, there were the fewest weed seedlings after plowing. In the variant without herbicides and mechanical weeding during the growing season, 83 pieces/m^2 of wild plants were counted. Against the background of chisel cultivation, the number of weeds increased by 2.3 times and amounted to 195 pcs./m^2. Carrying out shallow and surface cultivation with disk tools contributed to the increase of vegetative weeds by 2.6 and 3.0 times, respectively. Protection of sunflower crops from weeds significantly reduced their number. Thus, when applying herbicides against the background of plowing, their number decreased by 87-92%. At the same time, against the background of tillage, the effectiveness of herbicides was lower, compared to plowing. This is explained by the fact that the post-harvest residues and applied organic fertilizers are contained in the upper layer and adsorb part of the chemicals, which reduces their phytotoxicity, especially in dry years. The survival rate of weed seedlings in the phase of 6-7 leaves of the crop ranged from 38 to 14%. Carrying out one pre-emergent and post-emergent harrowing against the background of plowing, as well as one inter-row loosening in the phase of 5-6 leaves of the culture contributed to the reduction of weediness by 86%, and against the background of no-shelf cultivation – by 75-80%. With the use of mechanical measures, the weeds grew mainly in the row, especially under shelf-less tillage, and in the inter-rows they were destroyed by the working bodies of the tooth harrow and the cultivator [13]. In other studies, no regular influence of the main tillage on the effectiveness of herbicides was found. In addition, the introduction of soil herbicides against the background of direct sowing is ineffective, because the drug, remaining on the surface of the soil, evaporates under the influence of wind and solar energy. At the same time, it was shown that the species composition of weeds is formed under the influence of different methods of soil cultivation and herbicides [14].

The results of research by O.I. Polyakov and his co-authors show that the number of weeds in sunflower crops changes under the influence of the method of main soil cultivation and is almost independent of the fertilizer option. So, after caring for the crops (two inter-row cultivations) at the end of the growing season, the following was calculated: 7.2-7.6 pcs./m^2 – for the classical system of the main soil cultivation (discussion in two tracks, plowing); 9.1-9.3 pcs./m^2 – for bladeless (disking in two tracks, bladeless processing); 15.0-16.1 pcs./m^2 – for the minimum (disking in two tracks, cultivation). At the same time, the air-dry mass of weeds changed under the influence of the main tillage system and the background of mineral nutrition. Under the classical system of basic tillage, it was equal to 22.1-33.1 g/m^2. In sunflower crops under the no-till system, the air-dry mass of weeds increased by 11.5-13.5 g/m^2 in relation to the classic one, and by 16.1-18.3 g/m^2 under the minimum tillage system. In variants with mineral fertilizers, it increased by 5.7-11.0 g/m^2, 4.3-10.7 g/m^2, 4.9-12.4 g/m^2, respectively. Sunflower plants were the most competitive in the fight against weeds in the classic tillage system. The highest yield of sunflower was obtained when growing under the classical system of basic tillage and applying fertilizers in the dose of $N_{60}P_{90}K_{60}$ for pre-sowing cultivation [15].

The purpose of the research is to establish the influence of the methods of basic tillage, fertilization and protection systems on the weediness of sunflower crops placed in the semi-grain-row crop rotation of the eastern part of the Forest Steppe of Ukraine.

MATERIALS AND METHODS

The research was carried out during 2016-2018 in a stationary 9-type steam-grain-row crop rotation of the Department of Plant Breeding and Varietal Research of the Institute of Plant Breeding named after V.Ya. Yuryev National Academy of Agrarian Sciences (black steam – winter wheat – sugar beets – spring grain ears – peas for grain – winter wheat – corn for grain ½ + soybean ½ – spring grain ears – sunflower), where the plots of the first order were the backgrounds of nutrition, and the second order – methods of basic soil cultivation in crop rotation. The scheme of the experiment included options: 1 – without fertilizers (control) – the agro background formed due to the alternation of crop rotation; 2 – organic background (application of 30 t/ha of manure under corn and in the field of black steam, which amounted to 6.6 t of manure per 1 ha of crop rotation area); 3 – organic-mineral background (a trace of manure + $N_{15}P_{15}K_{15}$); 4, 5 – organic-mineral intensive background (a trace of manure + $N_{30}P_{30}K_{30}$). In options 1-4, fertilizers were applied under plowing, and in option 5 – under tillage (chiseling).

The system of protection of sunflower crops from weeds based on herbicides during the years of research was as follows: 2016 – Trophy 90 EC (active substance and its content – acetochlor, 900 g/l; preparation form – emulsion concentrate; applicant (registrant), manufacturer – "Dow Agro Sciences WmbH", Australia), 2.5 l/ha before seedlings + Fusilade Forte 150 EC (active substance and its content - fluazifop-P-butyl, 150 g/l; preparation form – emulsion concentrate; applicant (registrant), manufacturer – Syngenta, Switzerland), 2.0 l/ha during the growing season of the crop; 2017 – Hortus (active ingredient and its content – acetochlor, 900 g/l; preparation form – emulsifiable concentrate; applicant (registrant), manufacturer – Company Ukravit LLC, Ukraine, Agrochemical Factory LLC, Ukraine), 2.5 l/ha to seedlings + Queen Star Max (active substance and its content – hizalofop-P-ethyl, 125 g/l; preparation form – emulsifiable concentrate; applicant (registrant), manufacturer – Ukravit Company LLC , Ukraine, LLC "Factory of Agrochemicals", Ukraine), 1.2 l/ha during the growing season of the crop; 2018 – Teaser (active substance and its content – propisochlor, 720 g/l; preparation form – emulsifiable concentrate; applicant (registrant), manufacturer – Ukravit Company LLC, Ukraine, Agrochemical Factory LLC, Ukraine), 3.0 l/ha to seedlings.

The years of research were different in terms of meteorological conditions. Thus, in April and May 2016, the amount of precipitation exceeded the long-term norm by 29.2 and 43.9 mm, respectively, and the average daily air temperature exceeded the long-term norm by 4.6 and 1.5°C, respectively. In June, the average daily air temperature was higher than the norm by 1.9°C, and the amount of precipitation was lower than the norm by 21.7 mm. The average daily air temperature in July, August and September was higher than normal by 1.9; 2.7 and 0.6°C, respectively. However, the amount of precipitation in July exceeded the norm by 40.0 mm, and in August and September they fell below the norm by 8.8 and 24.4 mm, respectively.

The average daily air temperature in April 2017 was 1.2°C more than the optimal level, and in May it was almost at the level of the long-term norm. The amount of precipitation in April exceeded the norm by 5.7 mm, and in May it was less than the norm by 12.2 mm. In June, July, August and September, the average daily air temperature was 1.0; 0.3; 4.6 and 3.5°C higher than the climatic norm. The amount of precipitation in June, July, August and September was less than the norm by 46.6%; 34.8; 43.5 and 13.4 mm, respectively.

The average daily air temperature in April 2018 was 4.1°C more than the optimal level, and in May – by 4.4°C. The amount of precipitation in April was less than the climatic norm by 22.4 mm, and in May by 31.9 mm. In June, July, August and September, the average daily air temperature was higher than the climatic norm by 2.2; 1.6; 4.5 and 4.6°C, respectively. The amount of precipitation in June, July and September was less than the norm by 21.5%; 37.7 and 3.6 mm, respectively. There was no precipitation in August. In general, according to the indicator of the amount of precipitation, 2016 can be characterized as sufficiently moistened, and 2017-2018 – insufficiently moistened. An excess of average daily air temperatures for the spring-summer period was also noted, compared to the average long-term indicators.

Inspection of sunflower crops for weediness was carried out in September according to the method of V.S. Zuzy, R.A. Gutyanskyi [16]. For each option, a separate form was allocated, in which after the survey, the identified types of weeds or litterers (including carrion from the seeds of field crops) were entered. At the same time, both dominant and subdominant species of weed plants were counted. The dominant role of each species was assessed quantitatively, based on its share in the formation of the total mass of the segetal grouping on the variant. Those species whose weight exceeded 10% of the total weight of all weeds were considered dominant, and subdominant – 3-10%, respectively.

When determining the type of weediness in its name, the group that was most represented in the total mass of weeds was put on the first place, and on the second or third – groups of weeds in accordance with their participation in the segetal grouping. The level of weediness in each option was determined by the specific share of weeds in the total mass of agrophytocenosis: up to 1% – very weak; 1-5% – weak; 6-15% – average; 16-45% – strong; more than 45% is very strong.

RESULTS

In the Table 1 summarizes the results of our three-year research, which shows ten main types of weeds, which according to the occurrence rate are classified from very widely (76-100%) to widely (51-75%) common species in sunflower crops. Among them, gray mouse, common flat and white quinoa were present in all variants every year. In addition, the following were found annually: in option 1 – common sedum, bitter gorse (*Polygonum lapathifolium* L.), pink thistle and field birch; in option 2 – nightshade black and bitter gorse; option 3 – common sedum, black nightshade and bitter gorse; option 4 – common scotch, nightshade, bitter gorse and field birch; option 5 – common sedum, nightshade, garden purslane (*Portulaca oleracea* L.), ragweed and malva neglecta Wallr.

The category of moderately common (26-50%) weed plants in terms of the species occurrence rate in sunflower crops includes: birch fallopium (*Fallopia convolvulus* (L.) A. Love), waste millet (*Panicum miliaceum var. ruderale* Kitag.), netreba common, black-leaved black-leaved, the curls are neglected, triticale (*Triticosecale* Witt.), field plantain (*Thlaspi arvense* L.), hairy pea (*Vicia villosa* Roth.).

The category of rare (1-25%) species in crops includes: green mouse, common sedge (*Avena fatua* L.), annual sedge, common bitter gourd, bird's sedge (*Polygonum aviculare* L.), sunflower sedge, spring barley (*Hordeum vulgare* L.), spring wheat (*Triticum* L.), buckwheat (*Capsella bursa-pastoris* (L.) Medik.), spring sedge (*Senecio vernalis Waldst.* et Kit.), Canadian sedge (*Erigeron canadensis* L.), *Sisymbrium Loeselii* L., field violet (*Viola arvensis* Murr.), medium star (*Stellaria media* (L.) Vill.), white milkweed (*Melandrium album* (Mill.) Garcke), spotted hemlock (*Conium maculatum* L.), yellow field thistle (*Sonchus arvensis* L.), common wormwood (*Artemisia vulgaris* L.), wild chicory (*Cichorium intybus* L.), large burdock (*Lappa major* Gaertn.), dandelion (*Taraxacum officinale* Web. et Wigg), meadow clover (*Trifolium pratense* L.), common flax (*Linaria vulgaris* Mill.), curly sorrel (*Rumex crispus* L.), mo Tatar locan (*Lactuca tatarica* (L.) S.A. Mey).

In total, 42 species of weeds and weeds (including carrion from the seeds of field crops) were detected in sunflower crops after spring grain ear crops. Bright species predominated among them. Thus, 21 species were included in the group of early and late spring weed plants: gray mouse, green mouse, common plantain, common millet, white quinoa, common sorrel, black solanum, garden purslane, ragweed, broad-leaved mustard, Birch-like fallopium, common netreba, black-leaved black-leaved, neglected curlews, common spore, common sedge, sunflower wolfberry, spring barley, spring wheat, spring triticale. The group of overwintering, winter and two-year weeds was represented by 10 species: common buckwheat, spring sedge, Lozel's dry rib, field sedge, field violet, Canadian sedge, medium star, white hemlock, spotted hemlock, and hairy pea. The group of perennial weeds included 11 species: pink thistle, yellow field thistle, field birch, common wormwood, wild chicory, large burdock, medicinal dandelion, meadow clover, common flax, curly sorrel, Tatar molokan.

The highest number of the weed component was recorded in the control (option and on the organic-mineral intensive background, where fertilizers were applied under no-till tillage (option 5). Thus, in options 1, 2, 3, 4 and 5, respectively, 29, 23, 21, 23 and 27 types of weeds and clogs. The share of spring early and late types of weed plants in variants 1, 2, 3, 4 and 5 was 62, 65, 62, 56 and 63%, respectively, wintering, winter and two-year – 24, 22, 9, 22 and 11%, perennial - 14, 13, 29, 22 and 26%.

Table 1. *Species composition, dominant role and share of the occurrence of main weeds in sunflower crops depending on the methods of the main tillage and fertilization system (2016–2018)*

Types of weeds	Option															Meeting share, %
	1			2			3			4			5			
	d	s	p	d	s	p	d	s	p	d	s	p	d	s	p	
Yellow bristle gras	33		33	11	11	33		22	33		22	33	11	11	33	100
Echinochloa crus-galli	11	11	33		11	33		11	33		11	33	11	11	33	100
Common lambsquarters			33	22		33	22		33	2		33	22		33	100
Livid amaranth			33	11		22	11		33	22		33	11		33	93
Solanum nigrum			22			33			33	11		33			33	93
Purslane			22			11			22			22			33	67
Common ragweed		11	22		11	11	11	1	22	11		22	11		33	67
Pale smartweed		11	33			33			33			33			33	93
Pink sow thistle	11	22	33		12	22		12	22		11	22	22		22	73
Field bindweed			33			11			22			33			22	73

Note*: Dominance (d), subdominance (s) and presence (p) of weed plants in sunflower crops during: 1 – one year; 2 – two years; 3 – three years of research*

The system of protection of sunflower crops from weeds was different in the years of research, but each year soil herbicides from the chloracetomidine group were used in crops: Trofi 90 ES, Hortus and Tizer. This affected the indicators of dominance and subdominance of certain weed species in the years of research. Thus, in 2016, after the composition of Trofi 90 EC and Fusilade Forte 150 EC, sunflower crops were significantly dominated by white quinoa, primarily in the variants with fertilizer application. In addition, the dominant and subdominant positions in individual variants were occupied by the pink thistle, the gray mouse and the flat common thistle. This is explained as follows: white quinoa is moderately sensitive to Trofi 90 EC, pink thistle is resistant to these drugs, and overgrown plants of annual cereals did not completely die under the action of the graminicide Fusilade Forte 150 EC.

In 2017, sunflower crops were dominated by pink thistle, gray mouse thistle, and common flatleaf thistle. The presence of pink thistle in crops is due to the lack of influence on it by the soil herbicide Hortus and the graminicide Queen Star Max. The incomplete effectiveness of the anti-grass herbicide Queen Star Max against gray mouse and common flat mouse is associated with adverse weather conditions during the treatment period.

Sunflower crops in 2018 were dominated and sub-dominated by white quinoa, common sedum, and ragweed in most variants. The insufficient effectiveness of the Tizer soil herbicide in relation to white quinoa and ragweed is associated with their moderate sensitivity to this drug, and in the case of common vetch – with a lack of precipitation during its application. In addition, according to our observations, the process of forming resistance to chloracetomidine herbicides, especially to the active substance propisochlor (in our case, to the Tizer drug), is currently taking place in common sedum.

It was found that 6 types of weediness were formed in sunflower crops depending on fertilizer, tillage and weed protection system over the course of three years of research (Table 2):

1) dicotyledonous-cereal annual-rhizome;
2) dicotyledonous-rhizophilic-cereal annual;
3) dicotyledonous-cereal annual;
4) annual cereal-rhizome-perennial dicotyledonous;
5) cereal annual-dicot nomaloric-rhizome;
6) rhizome-cereal annual-dicotyledonous annual.

Table 2. *Type of weediness of sunflower crops depending on the methods of the main tillage and fertilization system*

Option	A year of research		
	2016	2017	2018
1	dicotyledonous-cereal annual-rhizome	cereal annual-rhizome-dicotyledonous annual	dicotyledonous-cereal annual
2	dicotyledonous-cereal annual-rhizome	cereal annual-rhizome-dicotyledonous annual	dicotyledonous-cereal annual
3	dicotyledonous-cereal annual-rhizome	cereal annual-rhizome-dicotyledonous annual	dicotyledonous-cereal annual
4	dicotyledonous-cereal annual-rhizome	cereal annual-rhizome-dicotyledonous annual	dicotyledonous-cereal annual
5	dicotyledonous-cereal annual-rhizome	cereal annual-rhizome-dicotyledonous annual	dicotyledonous-cereal annual

It was established that in 2016, in all variants, dicotyledonous species predominated in the total mass of weeds.

In 2017, cereal annual weeds prevailed in the fertilized variants, and rhizomes prevailed in the control. At the same time, in 2018, dicotyledonous annual species prevailed in the fertilized variants, and cereal annual species prevailed in the control.

That is, in 2017-2018, the type of weediness of sunflower crops in the control variants differed from the type of weediness in the fertilized variants.m The level of weediness in 2016 and 2018 in option 1 was medium, and in options 3-4 and 5 – strong and very strong, respectively. In 2017, options 1 and 5 showed a high level of weediness, while the others showed a medium level.

That is, a higher level of weediness was observed annually in the option with no-shelf main tillage (chiseling) than in most options with plowing (Table 3).

Table 3. *The level of weediness of sunflower crops depending on the methods of the main tillage and fertilization system*

Option	A year of research		
	2016	2017	2018
1	average	strong	average
2	average	average	strong
3	strong	average	strong
4	strong	average	strong
5	very strong	strong	very strong

CONCLUSIONS

When sunflower was placed in the last field of a stationary 9-field steam-grain-row crop rotation after the predecessor of spring grain ear crops, 42 types of weeds and weeds were found in its crops. The main types of weeds in the crops were yellow bristle grass, Echinochloa crus-galli, common lambsquarters, livid amaranth, solanum nigrum, purslane, common ragweed, pale smartweed, pink sow thistle and field bindweed. The herbicide application system significantly influenced the indicators of dominance and subdominance of certain weed species in the years of research. The largest number of different types of weeds and polluters was determined in the control (without fertilizers, plowing) and on the organic-mineral intensive background (manure residue, 030 t/ha + $N_{30}P_{30}K_{30}$, chiseling). For the most part, the type of weediness of sunflower crops in the control variants differed, compared to the non-fertilized variants. The level of weediness in the no-till option was strong and very strong, and in the other options – medium and strong.

So, on the basis of the obtained data, it can be stated that plowing, which has advantages in reducing the weediness of crops, is the best method of the main cultivation of the soil for sunflower in the conditions of the eastern part of the Forest Steppe of Ukraine, compared to plowing the soil without tilling (chiseling).

Further research should be directed to a detailed study of the impact of long-term fertilization systems on the weediness of sunflower crops under the conditions of a semi-grain-row crop rotation.

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Вплив основного обробітку ґрунту та удобрення на забур'яненість посівів соняшнику

Роман Гутянський

Кандидат сільськогосподарських наук, старший науковий співробітник
Інститут рослинництва імені В.Я. Юр'єва НААН України
61000, просп. Героїв Харкова, 142, м. Харків, Україна
https://orcid.org/0000-0002-5953-9428

Сергій Попов

Доктор сільськогосподарських наук, професор
Інститут рослинництва імені В.Я. Юр'єва НААН України
61000, просп. Героїв Харкова, 142, м. Харків, Україна
https://orcid.org/0000-0002-1101-4454

Віктор Костромітін

Доктор сільськогосподарських наук, професор
Інститут рослинництва імені В.Я. Юр'єва НААН України
61000, просп. Героїв Харкова, 142, м. Харків, Україна
https://orcid.org/0000-0001-6098-2876

Наталія Кузьменко

ДКандидат біологічних наук, старший науковий співробітник
Інститут рослинництва імені В.Я. Юр'єва НААН України
61000, просп. Героїв Харкова, 142, м. Харків, Україна
https://orcid.org/0000-0002-4373-0666

Олександр Глубокий

Науковий співробітник
Інститут рослинництва імені В.Я. Юр'єва НААН України
61000, просп. Героїв Харкова, 142, м. Харків, Україна
https://orcid.org/0000-0001-7589-5708

Анотація. На міжнародних та вітчизняних ринках продукції сільськогосподарської сфери спостерігається підвищення попиту на олійні культури, зокрема соняшник однорічний та продукти його переробки. Соняшникове насіння користується перманентним попитом, що доводить його високу релевантність. Вирощування цієї культури є досить рентабельним для сільськогосподарських товаровиробників і не вимагає суттєвих додаткових витрат. Саме тому все більшого значення отримує науково обґрунтоване дотримання сівозміни у процесі вирощування соняшнику. Забур'яненість ґрунту впливає на продуктивність вирощуваних сільськогосподарських культур. Порядок удобрення та обробітку посівної площі має важливе значення у поліпшенні її мікробіологічного стану. Пошук способу раціонального та ефективного застосування добрив є нагальним завданням працівників аграрної сфери. Метою роботи було визначення кількості бур'янів і засмічувачів у полі стаціонарної зерно-просапної сівозміни, порівняння типу забур'яненості між неудобреним та контрольним варіантом ґрунту, вибір ефективнішого способу обробітку ґрунту. У ході проведення роботи застосовано лабораторний метод, а також методи спостереження та узагальнення. У статті досліджено вплив основного обробітку ґрунту та системи удобрення на забур'яненість посівів соняшнику в стаціонарній сівозміні впродовж 2016-2018 рр. в умовах східної частини Лісостепу України. Найбільшу кількість різновидів бур'янів і засмічувачів у посівах виявлено на фоні без добрив (оранка) та на органічно-мінеральному інтенсивному фоні (післядія гною, 30 т/га + $N_{30}P_{30}K_{30}$, чизелювання). Тип і рівень забур'яненості посівів соняшнику суттєво залежить від досліджуваних факторів. Наукова новизна полягає у встановленні методу удобрення ґрунту, що забезпечує максимальну продуктивність культури

Ключові слова: сівозміна, добрива, бур'яни, гербіциди, східний Лісостеп України, захист посівів, оранка

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Characteristics of growth, development and meat qualities of young sheep of different genotypes

Vasyl Iovenko*

Full Doctor in Agrisciences, Professor
Institute of Animal Husbandry of Steppe Regions named after M.F. Ivanov "Askania-Nova"
75230, 1 Soborna Str., Askania-Nova, Kherson region, Ukraine
https://orcid.org/0000-0002-0829-7844

Ilona Hladiy

Postgraduate Student
Institute of Animal Husbandry of Steppe Regions named after M.F. Ivanov "Askania-Nova"
75230, 1 Soborna Str., Askania-Nova, Kherson region, Ukraine
https://orcid.org/0000-0003-3078-1103

Abstract. The study of the development of the organism, taking into account the genotype of animals and environmental conditions, makes it possible to significantly speed up the process of improving existing breeds. The intensity of growth and development is of great importance, because premature young animals reach the term of economic use faster with lower feed costs per unit of growth. By the dynamics of live weight with age, it is possible to characterize the intensity of growth, the nature of metabolism, prematurity and the state of the body as a whole. Therefore, it is of scientific and practical interest to study the features of growth and development of purebred and cross-breed sheep of the meat direction of productivity. Precocious young animals reach the term of economic use faster with lower feed costs per unit of growth. The dynamics of live mass indicate the intensity of growth, the nature of metabolism, precociousness and the state of the organism. The purpose of the article was to determine the crossbreeding option that has the highest genetic potential for meat productivity and growth intensity. In the course of the study, the authors used the method of laboratory analysis, comparison, synthesis and forecasting. Peculiarities of growth and development of lambs of three different genotypes from birth to six months of age were studied, in particular: purebred young Askanian thin-wool breed (ATB); crosses of this gene pool with Texel (ATBxT) and Merinolandscape (ATBxM) breeds. Control over the growth and development of experimental animals was carried out by the method of weighing in different age periods. Evaluation of meat qualities was carried out based on the results of slaughter. It was established that the best development parameters were characterized by crossbreeds of the Texel with the Ascanian fine-wool breed, therefore this crossbreeding option has the highest genetic potential for meat productivity. The practical value consists in obtaining a potentially greater increase in the live weight of sheep in a shorter period of time and in the laboratory study of the properties of the offspring of the obtained breed

Keywords: sheep, genotype, live weight, linear parameters, growth intensity

INTRODUCTION

Studying the development of the organism taking into account the genotype of animals and environmental conditions makes it possible to significantly accelerate the process of improving existing breeds. The intensity of growth and development, as well as the increase in live weight in different age periods, are of great importance, since premature young animals reach the term of economic use faster with lower feed costs per unit of growth. The dynamics of live weight with age can be used to judge the intensity of growth, the nature of

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*Corresponding author

metabolism, prematurity and the state of the body as a whole. Therefore, it is of scientific and practical interest to study the features of growth and development of purebred and cross-breed sheep of the meat direction of productivity.

Today, a new domestic breed of sheep is being created at the Askania-Nova Institute of Animal Husbandry by crossbreeding using imported high-yielding meat rams of the Texel and Merinolandscape breeds on ewes of the local Merenos breed.

The Askanian thin-fleece breed belongs to the wool-meat direction of productivity. Due to its valuable hereditary and productive qualities, good adaptability to environmental conditions, it has received general recognition and wide distribution and is the main breed for obtaining merino wool [1].

Taking into account the current state and trends in the development of sheep breeding in Ukraine and the world, the question arises as to the feasibility of using the Askanian fine-wool breed in industrial crossing with breeders of foreign selection.

The Texel is one of the most common breeds in the world and is extremely popular in Europe, America, New Zealand and Australia. They easily adapt and adapt to the external environment, are characterized by increased resistance. The main distinguishing feature of the animals is the high content of muscle tissue in the carcasses. This breed is widely used for selection purposes when crossing with other genotypes to increase the meat productivity of existing and create new genetic formations [2; 3].

The Merinolandscape breed has a meat-wool production direction. Old types of German and French Prekos and a number of English breeds took part in its creation. Today, in Germany, meat merino, thanks to high indicators of productivity and competitiveness, occupies a leading place [4].

Taking into account the mentioned useful features and biological features, the use of Texel and Merino Ladshaff breeders is promising, therefore it is appropriate to study the growth and development of young sheep obtained using these genotypes.

Scientists note that the relationship between the processes of growth and development is the correspondence between the quantitative and qualitative changes that occur in the animal's body during ontogenesis [5]. Many scientists studied the impact of the intensity of animal growth on their productive qualities, which was reflected in their scientific works [6-9]. The intensity of formation is determined by heredity and conditions of keeping, as evidenced by the breed and constitutional features of animals [10-13].

Since the productivity of adult animals is related to growth and development in early ontogeny, and their level is established during the period of growing young animals, live weight is the subject of in-depth study. K.B. Svechin in his works emphasized the importance of the peculiarities of the periodization of individual growth and development of animals in ontogenesis [8].

Modern researchers, when studying the intensity of growth of young animals of various options for selecting parental pairs, found that the best indicators of average daily growth have animals obtained in selections using rams of meat types [14].

In view of the above, studying the patterns of growth and development of young animals of various origins is relevant and has both scientific and practical significance.

The purpose of the article is to study the efficiency of using breeding rams of the specialized meat breeds Merinolandshaf and Texel with ewes of the Askanian fine-wool breed and their effect on the meat qualities of the obtained young, in particular on the live weight, absolute, average daily, relative growth of crossbred lambs in steppe conditions zones of Ukraine.

MATERIALS AND METHODS

The research was carried out in the conditions of the SEEF "Askania-Nova", which is subordinate to the Institute of Animal Husbandry of Steppe Regions named after M.F. Ivanov "Askania-Nova" and is located in the village of Askania-Nova, Chaplin district, Kherson region.

Lambs of three experimental groups served as the object of research: 1st group – purebred Ascanian merinos (ATB), n=20; 2nd group – crossbreeds of half blood Merino x Merinolandshaf (ATBxM), n=21; 3rd group – crossbreeds of ½ blood Merino x Texel (ATBxT), n=15.

Growth and development of lambs was monitored by individual weighing for six months.

Exterior evaluation was carried out by measuring the main dimensions: height at the withers, height at the withers, width of the chest, depth of the chest, oblique length of the trunk, width at the withers, chest girth, wrist girth, head length, head width. Based on the results of the measurements, the following indices of body structure were calculated: long-legged, stretched, pelvic-thoracic, massive, bony, thoracic, short, deep-chested, large-headed. Measurements were taken from animals at birth at 2, 4 and 6 months of age.

Based on the data on the dynamics of live mass, the indicator of the intensity of the formation of live mass of young animals (dt) was determined, according to the method of Yu.K. Svechyn [9]:

$$\Delta T = \frac{W_4 - W_0}{0.5(W_4 + W_0)} - \frac{W_6 - W_4}{0.5(W_6 + W_3)}, \qquad (1)$$

where ΔT is the intensity of formation; W_0, W_4, W_6 – live weight of lambs at birth and at the age of 4 and 6 months, respectively, kg.

The index of uniformity (Iu) and tension (It) of growth was calculated according to the method of V.P. Kovalenko [16]:

$$\Delta T = \frac{W_4 - W_0}{0.5(W_4 + W_0)} - \frac{W_6 - W_4}{0.5(W_6 + W_3)}, \qquad (2)$$

where I_u is the growth uniformity index; *AG* – average daily growth from birth to 6 months of age, kg.

$$I_t = \frac{\Delta t}{\mathrm{RG}} AG, \qquad (3)$$

where *AG* is the average daily growth from birth to 6 months of age; RG – relative growth from birth to 6 months of age.

All quantitative indicators were determined by the method of variational statistics according to the algorithms of M.O. Plokhinsky [16].

The study of meat productivity was carried out based on the results of the control slaughter of lambs at the age of 6 months (3 heads from each group). At the same time, the live weight after a 24-hour starvation period and the results of the initial processing of carcasses were taken into account.

Biometric data processing was carried out using MS Excel software using statistical functions.

RESULTS

Growth and development indicators are one of the criteria for evaluating sheep genotypes, in particular their meat qualities.Animal growth is a process of increasing, first of all, live mass. At the same time, knowledge of the prematurity of lambs in the period from birth to weaning from ewes makes it possible to assess their biological capabilities in relation to growth speed.

The development of sheep and the shape of their physique are judged by live weight and linear parameters. This assessment allows you to identify positive and negative features of the animals' exterior and get a more complete picture of them.

The growth rate has an important economic value because animals with high growth intensity have a better feed conversion. The live weight of lambs at birth is an indicator of the interaction of a large number of external and internal factors that affect the degree of fetal development in the embryonic period. In general, as the results of our research show, the development in the post-embryonic period and the formation of subsequent productivity are related to the parameters of live weight of lambs at birth (Table 1).

Table 1. *Live weight dynamics of lambs in different age periods*

Age, months	Genotype					
	ATB (n=20)		ATBxM (n=21)		ATBxT (n=15)	
		C_v, %		C_v, %		C_v, %
At birth	4.7±0.18	17.48	4.7±0.23	24.42	5.8±0.36*	26.24
2	20.1±0.61	10.84	19.8±0.94	22.71	20.9±0.93	18.23
4	26.3±0.87	14.37	27.7±1.43	23.06	32.4±1.51**	17.42
6	33.7±1.15	13.67	34.5±1.73	20.69	39.1±2.19*	18.56

Note: ** – p≤0.1; ** – p≤0.01; *** – p≤0.001*

It was established that at birth and during the entire period of the experiment, the lambs were characterized by a relatively high live weight. With regard to their growth, it was found that crossbreeds obtained from crossing ATBxT had a probably higher live weight at birth – 5.8 kg (P<0.1). Peers of other genotypes are inferior to them by 1.1 kg (P<0.1). A similar situation occurred up to the age of 6 months. At the same time, the variability of this feature in the presented group at birth was the highest, Cv=26.24%. For comparison, in the environment of purebred animals, the coefficient of variability was only 17.48%. During the next growing period, the identified difference was preserved and, for example, at the age of 6 months, purebred animals were inferior to their counterparts in this indicator by 4.89-7.02. That is, the established dependence indicates that local sheep with a long history of breeding are more consolidated in terms of body weight and are better adapted to environmental conditions compared to newly created genotypes.

A more detailed result of the growth and development of lambs was obtained by means of a complex analysis through the assessment of average daily, absolute and relative growth (Table 2).

Table 2. *Dynamics of increases in live weight of lambs,* $\bar{X} \pm S\bar{x}$

Age, months	Genotype		
	ATB	ATBxM	ATBxT
	Absolute gains, kg		
0-2	15.1±0.53	15.1±0.84	15.0±0.70
2-4	7.1±0.65	7.6±0.69	11.3±0.74***
4-6	7.7±0.50	7.1±0.42	6.8±0.80
0-6	27.5±1.93	29.9±1.65	33.1±1.92*
	Average daily increments, g		
0-2	247.9±8.28	271.1±14.15	255.6±13.39
2-4	88.8±7.46	98.7±8.46	140.0±8.54***
4-6	108.1±7.01	100.2±5.88	95.1±11.32

Table 2, Continued

Age, months	Genotype		
	ATB	ATBxM	ATBxT
0-6	130.5±8.48	147.0±7.10	156.6±8.52
Relative gains, %			
0-2	120.2±2.07	122.1±3.02	111.9±2.86*
2-4	29.9±2.23	31.9±2.20	42.4±2.31***
4-6	25.9±1.74	24.1±1.79	19.1±2.03
0-6	148.0±2.24	152.6±2.41	146.3±2.62
Growth rate			
0-2	4.1±0.14	4.3±0.20	3.6±0.16
2-4	1.4±0.03	1.4±0.03	1.5±0.04
4-6	1.3±0.02	1.3±0.02	1.2±0.02
0-6	6.8±0.35	7.8±0.47	6.7±0.42

Note: * – $p \leqslant 0.1$; ** – $p \leqslant 0.01$; *** – $p \leqslant 0.001$

It was established that the ATBxT group exceeded its peers in terms of absolute growth during the entire study period (ATB – 27.5; ATBxM – 29.9; ATBxT – 33.1). That is, at that time, the animals obtained from crossing the Ascanian fine-wool breed with the Texel breed were more stress-resistant.

During the period from birth to 6 months of age, these same genotypes had the highest average daily gains (156.6 g versus 130.5 and 147.0 g).

As for relative growth, a rather interesting situation is observed. From birth to 2 months of age and from birth to 6 months of age, ATBxM hybrids had a significant advantage, and the ATBxT group had the lowest indicators throughout the entire period, except for the period from 2 to 4 months of age: I – 29.9%; II – 31.9%; III – 42.4%.

During the period from birth to 6 months of age, these same genotypes had the highest average daily gains (156.6 g versus 130.5 and 147.0 g).

As for relative growth, a rather interesting situation is observed. From birth to 2 months of age and from birth to 6 months of age, ABTxM hybrids had a significant advantage, and the ATBxT group had the lowest indicators throughout the entire period, except for the period from 2 to 4 months of age: I – 29.9%; II – 31.9%; II – 42.4%. Regarding the overall growth factor, in general, differences between individual genotypes of lambs were observed only in the period from birth to 2 months of age (4.1; 4.3; 3.6) and from birth to 6 months of age (6.8; 7,8; 6,7), where the ATBxM group predominates.

In this way, it was established that the best indicators of the development of live body weight during the six-month period of ontogenesis are characterized by local young animals of the Ascanian fine-wool breed and the Texel breed.However, there is no linear dynamics of the value of this feature, which is related, in our opinion, to different feeding conditions of these animals at different stages of growth.

The value of the linear parameters of young animals was studied at birth at the age of 2, 4 and 6 months (Table 3).

The superiority of the specified genotype over peers of other groups of lambs under investigation is fully confirmed by body structure indices (Table 4).

Table 3. *Linear parameters of body sexes of lambs in different age periods,* $\overline{X} \pm S\overline{x}$

Genotype	Measure, sm					
	height at the withers,	height at the withers,	chest width	chest depth	braid, body length	chest girth
At birth						
ATB	38.1±0.45	39.1±0.46	9.4±0.22	14.2±0.19	31.2±0.54	40.7±0.57
ATBxM	39.3±0.57	40.1±0.60	9.5±0.21	14.2±0.24	32.5±0.67	40.6±0.56
ATBxT	40.5±0.58*	41.3±0.58	10.9±0.30***	14.9±0.25	33.8±0.77	43.4±0.86*
2 months						
ATB	53.3±0.84	54.2±0.83	17.0±0.37	24.3±0.25	57.5±1.03	71.8±1.03
ATBxM	53.7±0.73	54.1±0.77	17.5±0.42	23.6±0.39	56.1±1.00	70.6±1.84
ATBxT	54.1±0.77	54.4±0.78	18.5±0.41**	24.3±0.46	55.8±0.72	75.0±1.38
4 months						
ATB	58.2±0.46	58.7±0.50	22.3±0.41	27.7±0.28	60.7±0.74	81.6±2.12
ATBxM	60.9±0.90	60.7±0.93	20.7±0.63	28.9±0.50	61.9±1.33	83.0±1.81
ATBxT	61.1±1.01	61.2±0.97	23.5±0.41*	30.1±0.61	62.9±0.96	87.5±2.03*

Table 3, Continued

Genotype	Measure, sm					
	height at the withers,	height at the withers,	chest width	chest depth	braid, body length	chest girth
			6 months			
ATB	58.7±0.82	59.8±0.87	22.1±0.42	27.7±0.37	61.6±0.86	96.1±1.22
ATBxM	57.1±1.04	58.5±1.23	21.8±0.57	27.0±0.44	64.2±1.31	94.4±2.22
ATBxT	59.1±1.15	60.4±1.33	24.0±0.41**	28.8±0.68	66.0±1.4*	104.0±2.3**

Note: ** – p⩽0.1; ** – p⩽0.01; *** – p⩽0.001*

Table 4. *Indices of body structure of lambs, $\overline{X} \pm S\overline{x}$*

Genotype	Index					
	Sprains	Overgrowth	Bones	Contusion	Chest	Massiveness
			At birth			
ATB	82.1±1.23	102.8±0.59	18.3±0.33	130.7±1.69	66.2±1.22	107.2±1.63
ATBxM	82.6±1.26	101.9±0.29	17.3±0.17	125.9±1.88	66.9±1.29	103.5±0.65
ATBxT	83.5±1.29	102.1±0.36	19.3±0.27	128.6±1.87	73.2±1.65	107.0±1.05
			2 months			
ATB	108.2±2.39	101.8±0.55	17.5±0.22	125.2±1.99	70.1±1.23	135.2±2.75
ATBxM	104.5±1.44	100.7±0.28	16.3±0.21	125.8±2.73	74.0±1.09	131.2±2.76
ATBxT	103.3±1.41	100.5±0.41	16.9±0.20	134.4±1.94**	76.7±1.68	138.6±1.61
			4 months			
ATB	104.3±1.06	100.9±0.49	16.7±0.28	134.6±3.47	80.8±1.38	140.2±3.54
ATBxM	101.5±1.16	99.8±0.48	15.9±0.28	134.4±2.01	71.6±1.68	136.2±1.96
ATBxT	103.2±1.24	100.3±0.73	16.3±0.32	139.1±2.35	78.3±1.29	143.5±3.01
			6 months			
ATB	105.1±1.64	102.0±1.01	17.3±0.52	156.1±1.29	79.9±1.67	164.0±2.02
ATBxM	112.6±1.72	102.3±0.81	17.5±0.52	147.2±2.67	80.7±1.55	165.1±2.00
ATBxT	111.6±1.47	102.1±1.05	16.7±0.61	157.6±1.64	83.5±1.40	175.9±2.53***

Note: ** – p⩽0.1; ** – p⩽0.01; *** – p⩽0.001*

Thus, at birth and at the age of two, four, and six months, these young animals had higher values of the indices of rump, thoracic, and massiveness. For example, chest at the age of 6 months was 83.5 cm against 79.9 and 80.7 cm. The index of collapse is 157.6 at the age of 6 months, which is 10.4 more than the age group; mass index at 6 months of age was 175.9 cm versus 164.0 and 165.1 cm in the other two groups (P<0.001). Differences between genotypes were also determined by indicators of growth intensity (Table 5). It was established that the higher intensity of formation is characteristic of ATBxT and was 1.21, which is 0.01-0.06 higher than peer groups.

Table 5. *Indices of growth intensity of lambs*

Genotype	Indicator		
	dt	I_u	I_t
ATB	1.15	0.06	1.01
ATBxM	1.2	0.06	1.15
ATBxT	1.21	0.07	1.29

According to the research results, it was also established that ATBxT animals were characterized by the highest growth tension (1.29), which is 0.14-0.28 higher than in other tested genotypes.

In the creation of new genotypes of sheep for meat productivity, in addition to growth parameters, the development of their meat qualities is extremely important. Sheep meat has a number of distinctive features compared to the meat of other farm animals and is in demand among the population. Mutton belongs to valuable human food products and is characterized by good taste, aroma and dietary properties. Sheep fat is distinguished by its high energy content and low cholesterol content. This product is obtained from sheep of all breeds, but breeds specialized in meat, meat-wool and meat-fat directions have the highest meat productivity.

Sheep meat productivity and meat quality are affected by many factors, including breed, sex, age, feeding and maintenance, belonging to a certain type of constitution [17-19]. Formation of fleshiness in young sheep also occurs under the influence of environmental factors.

The formation of meat qualities of animals occurs during the period of growth and development. Features of meat productivity manifest themselves at an early age and are closely related to the exterior of animals [20]. The highest increase in muscle tissue occurs in early ontogeny before puberty. In adult animals, weight gain occurs mainly due to fat deposition. It has also been proven that in the absence of fat deposition in the carcass, it is impossible to achieve maximum muscle growth. [21; 22]. It is known that the best quality parameters are characterized by young lamb obtained from animals at the age of 6-8 months. In this context, below are the results of research on the relevant local young. Objective indicators of sheep meat productivity are the pre-slaughter weight of the carcass, the slaughter weight, the ratio of bones and pulp in animal carcasses, and the slaughter yield.

Table 6 shows the slaughter qualities of rams in different age periods. It was shown that the carcasses of ATBxT rams significantly outperformed the indicators of the other two groups in terms of certain parameters.

Table 6. *Slaughter qualities of rams in different age periods*

Indicator	Genotype		
	ATB	ATBxM	ATBxT
Number of animals	3	3	3
Pre-slaughter weight, kg	34.7±0.67	37.8±0.44**	39.5±1.50***
Weight of the steamed carcass, kg	14.2±0.46	16.8±0.42**	18.3±0.91**
Mass of internal fat, kg	0.54±0.08	0.68±0.10	0.46±0.05
Slaughter weight, kg	14.8±0.54	17.5±0.33**	18.7±0.96*
Slaughter yield, %	42.6±0.76	46.3±0.33**	47.4±1.20*

Note*: * – p⩽0.1; ** – p⩽0.01; *** – p⩽0.001*

As for the slaughter yield, according to the data of many scientists [23; 24], it has been established that depending on the direction of productivity of sheep, this indicator ranges from 35-60% and depends on the sex, age, breed, fatness of the animals, as well as the number of lambs born. According to the results of our research, the slaughter yield of crossbred lambs at the age of 6 months was 46.3% (ATBxM) and 47.4% (ATBxT) of the pre-slaughter weight, respectively. In purebred lambs, this indicator was at the level of only 42.6%.

As for visceral fat, ATBxM animals had a higher index than peers, and ATBxT animals had the lowest.

The carcasses of crossbred animals are significantly and positively different from those of purebreds. There is also a noticeable difference between groups of hybrid genotypes in favor of the ATBxT variant.

In general, we can make a preliminary conclusion that domestic rams are characterized by better slaughter qualities, and ATBxT genotypes have a special advantage, which indicates their early maturity.

The morphological composition of the carcass depends on the breed, sex, age and fatness of the sheep. Lamb carcasses contain more bones, less pulp and fat than adult animal carcasses. With increasing fatness, the content of pulp and fat increases, the specific mass of bones decreases. At the same time, the output of the most valuable offcuts increases – the back part, shoulder blade, brisket and rear part.

The morphological composition of the carcass is established by deboning its individual cuts. Since deboning carcasses is a time-consuming process, indicators characterizing the meatiness of carcasses without deboning have been proposed. Indicators related to these data are presented in Table 7.

Table 7. *Morphological composition of carcasses of experimental animals*

Indicator	Genotype		
	ATB	ATBxM	ATBxT
Mass of chilled carcass, kg	13.3±0.42	15.9±0.43**	17.3±0.89**
Muscle and fat tissue, kg	9.6±0.39	11.2±0.27*	12.6±0.81*
Bones and tendons, kg	3.8±0.03	4.6±0.16**	4.7±0.13***
Yield, %: pulp	71.8±0.64	70.9±0.32	72.6±1.13
bones	28.2±0.64	29.1±0.29	27.4±1.13
Coefficient of fleshiness	2.5±0.08	2.4±0.04	2.7±0.14

Note*: * – p⩽0.1; ** – p⩽0.01; *** – p⩽0.001*

It was established that animals of the ATBxT crossbreed had the largest weight of the chilled carcass (17.3 kg), which is 1.4 kg more than ATBxM and 4 kg more than ATB. ATBxT crossbreds had the highest mass of muscle and fat tissue, and purebreds had the lowest, in particular, 12.6 kg versus 9.6 kg (p⩽0.1). And domestic animals ATBxM – 1.4 kg less than ATBxT. The same situation was observed with regard to bones and tendons (ATBxT – 0.9 kg more than ATB; and 0.1 kg from ATBxM).

According to the percentage of the yield of pulp and bones, the following is established. Local animals of ATBxT have the largest output of pulp and the smallest - bones. Their pulp yield was 72.6%, in ATBxM it was 1.7% less, and in purebred animals it was 0.8% less. The yield of bones in these lambs was 27.4%, which is 1.7% less than from cross-breeds and 0.8% from purebred animals.

The fleshiness coefficient of ATBxT was 2.7%, which is 0.3% more than that of ATBxM crossbred animals and 0.2% more than that of purebred Merinos.

CONCLUSIONS

It was established that the best development parameters were characterized by crossbreeds of the Texel with the Ascanian fine-wool breed, therefore this crossbreeding option has the highest genetic potential for meat productivity. In contrast to purebred Merino peers in the early post-embryonic period, they are characterized by probably higher parameters of live weight gain, growth intensity, growth tension, as well as better characteristics of meat qualities of young lamb. That is, due to their adaptive abilities, these animals are quite suitable for breeding in the conditions of southern Ukraine when creating new highly productive genotypes of the meat sector of productivity.

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Характеристика росту, розвитку та м'ясних якостей молодняку овець різних генотипів

Василь Іовенко

Доктор сільськогосподарських наук, професор
Інститут тваринництва степових районів імені М.Ф. Іванова «Асканія-Нова»
75230, вул. Соборна, 1, смт Асканія-Нова, Херсонська область, Україна
https://orcid.org/0000-0002-0829-7844

Ілона Гладій

Аспірант
Інститут тваринництва степових районів імені М.Ф. Іванова «Асканія-Нова»
75230, вул. Соборна, 1, смт Асканія-Нова, Херсонська область, Україна
https://orcid.org/0000-0003-3078-1103

Анотація. Дослідження розвитку організму, враховуючи генотип тварин та умови середовища, дає можливість суттєво пришвидшити процес удосконалення існуючих порід. Інтенсивність росту і розвитку має вагоме значення, тому що скоростиглий молодняк швидше досягає строку господарського використання з меншими витратами корму на одиницю приросту. За динамікою живої маси з віком можна характеризувати інтенсивність росту, характер обміну речовин, скоростиглість і стан організму в цілому. Тому представляє науковий і практичний інтерес вивчення особливостей росту і розвитку чистопородних і помісних овець м'ясного напряму продуктивності. Скоростиглий молодняк швидше досягає строку господарського використання з меншими витратами корму на одиницю приросту. На інтенсивність росту, характер обміну речовин, скоростиглість і стан організму вказує динаміка живої маси. Метою статті було визначити варіант схрещування, який володіє найвищим генетичним потенціалом м'ясної продуктивності та інтенсивності росту. У ході дослідження автори використали метод лабораторного аналізу, порівняння, синтезу та прогнозування. Досліджено особливості росту та розвитку баранчиків трьох різних генотипів від народження до шестимісячного віку, зокрема: чистопородного молодняку асканійської тонкорунної породи (АТП); помісей цього генофонду з породами тексель (АТПхТ) та мериноландшаф (АТПхМ). Контроль за ростом і розвитком піддослідних тварин здійснювали методом зважування у різні вікові періоди. Оцінку м'ясних якостей проведено за результатами забою. Встановлено, що кращими параметрами розвитку характеризувалися помісі тексель з асканійською тонкорунною породою, тому цей варіант схрещування має найвищий генетичний потенціал м'ясної продуктивності. Практична цінність полягає в отриманні потенційно більшого приросту живої маси овець за коротший період часу і лабораторному вивченні властивостей потомства отриманої породи

Ключові слова: вівці, генотип, жива маса, лінійні параметри, інтенсивність росту

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The determining of the force for corn-cobs separation

Vasyl Hruban*

PhD in Technical Sciences, Associate Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0003-0753-565X

Valerii Havrysh

Full Doctor in Economics, Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0001-7055-1674

Antonina Kalinichenko

Doctor Habilitatus, Professor
University of Opole
45-040, Kopernik Sq., 11A, Opole, Poland
https://orcid.org/0000-0001-7342-3803

Abstract. There has been an increase in demand of corn in the world. This requires the use of high-performance agricultural machinery, including combine harvesters. However, corn harvesters have high grain losses and their apparatuses must be improved. The aim of the article was justification of corn picker operation by developing a mathematical model of the process of cobs separation in the complex combination several forces. To verify this model the results of the simulation were compared to experimental data. The wave theory has proved to be more accurate compared to the static model. The results of the theoretical researches of the methods of corn-cobs separation from stems are given and mathematical models are worked out. The technological process of corn-cobs separation fulfilled by the combination of different forces and the valuation of the resulting tension. The technological process of cobs separation is considered in combination of many forces, and making assessments of the resultant tension. Further research will be focused on the intensification of this process by the integration of stretching the stalk together with its twisting

Keywords: corn, cob, separation, cob separation system, mathematical model

INTRODUCTION

For the long time corn has ranked third among cereals in the world [1]. Corn is the world's largest crop and important feedstock for food, fodder and ethanol production. World ethanol production is expected to be doubled in the nearest future. Moreover, corn cobs are agricultural biomass and they can be feedstocks for renewable energy industries to abate the current energy and the greenhouse gas problems. Corn cobs can be used for producing variety of energy and fuels such as heat, electricity, gaseous, liquid and solid fuels, as well as a number of chemical products. It results in an increase of corn demand. The growth is expected to occur in Ukraine too, which currently is a large producer in Europe.

One of the important technological processes which regulate qualitative and quantitative indexes while harvesting corn for seeds is the separation of cobs from stems. The most widespread commercial method of separating is the cutting with a sharp blade. Unfortunately

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*Corresponding author

this cutting operation may sever the upper part of the cob. It results in reducing the harvest obtained. The losses are around 20%. However, installed on the majority of the world's corn-harvesting machines picker-strapping cob- separating apparatus are not on appropriate level of quantitative indexes of operation. The improper quality of this technological process fulfilling is explained mostly by the fact that their operation is based on the principle of separation at the expense of longitudinal stretching that leads to its rupture. But in some cases the resistance of the stem rupture may be less than in the stalk. This may lead to harvest losses by free cobs [2]. In addition, due to the considerable tension of the stalk and its violent destruction, we cannot exclude the possibility of throwing the cob outside the reaper after separation.

That's why the development of a new design of a cob separation apparatus is an important scientific problem. Its solving would give a possibility to increase general technical level of corn-harvesting machines.

Design engineers need reliable and simple mathematical apparatus to create effective corn harvesters and corresponding equipment. That is why the aim of this study is to develop the mathematical model for the cob-separating in the cases of static and dynamic loads with choosing of the best option.

LITERATURE REVIEW

Scientists of various research institutions carried out a significant amount of work to improve the cob-separating apparatus (particular elements of this question were solved in the design bureau of Kherson Combine Plant).

Classification of corn cob recovery systems are within the following domains: separation method, separation location, and storage location. The corn cobs can be separated by the following methods: mechanical, pneumatic, and combined. This process can be carried out on board the harvester and in stationary conditions. In Ukraine combine based methods of separation are used.

There are patents to solve this problem. They propose the following ways: removing intact whole kernels of corn from the cob [3]; a dual action corn cob separation [4]; the use of conveyer system [5].

On the basis of the research a common thought appeared that the most promising way to improve cob-separating apparatuses is stabilization of the parameters of the cob-separating process. That is, the transition from structures in which the separation of the cobs is random, chaotic in nature, to structures in which these processes are predicted on the basis of certain regularities [6].

Researchers have studied the mechanical properties of corn stalk. Threshing forces of corn stalk have been tested by X.P. Li & L.X. Gao [7], X.F. Li et al. [8], L.X. Gao et al. [9] and H.D.A. Dominguez et al. [10]. In the above publications the effects of a number of factors were considered.

To design agricultural and processing machines requires specific of knowledge, including mechanical properties of biological materials. They are necessary to develop agricultural machines that operate in aggressive and severe conditions. Therefore, mechanical properties of biological materials produced by agriculture have been the object of studies. The above knowledge is useful for the development of technological processes [11].

C.D. Akritidis has revealed the mechanical factors affecting the cut of corn stalks [12]. He analyzed the stalk cutting taking into account the mechanical properties of the corn stalk and the cutting blade. A. Esehaghbeygi [13] carried out the measurement of the shear stress of stalk for the following conditions: different moisture content; different cutting heights of stalk. The optimal knife oblique for the lowest shearing pressure has been found. Its value was determined at 30 degree. Prasad & Gupta [14] studied the shearing force for cutting corn stalks. They found that the maximum shearing force depends on the shearing velocity.

P. Miu [15] found the impact of a number of factors (mechanical and physical properties of stalks, the mechanical forces exerted through the harvester combine, plant curvature, and pick up cobs) on the cutting process.

To design agriculture machines it is necessary to know the physical and mechanical properties of the plants. The geometrical dimensions, ultimate tensile strength, angle of friction of corn cob, etc. are essential for the designing of harvester units.

RESULTS

The conventional cob-separating apparatus operation process was considered. They use the principle of the stretching of a stalk. The corn stalk was considered as a tensile elastic constant section thread of permanent intersection. It has area of S_0. This physical model was selected to develop the mathematical model.

This thread is stretched by pull rollers. The stretching process continues until the cob meets the stripper plates. The process from the moment of contact with the stripper plates to the moment of separation of the cob was considered. The moment of contact was accepted as the origin of time (t=0). The pulling force of the rollers is replaced with the applied force No to the free end of the cob (z=l). The left side of the cob is clamped with stripper plates and could be considered to be fixed between the stripper plates. The length of the cob is equal to l.

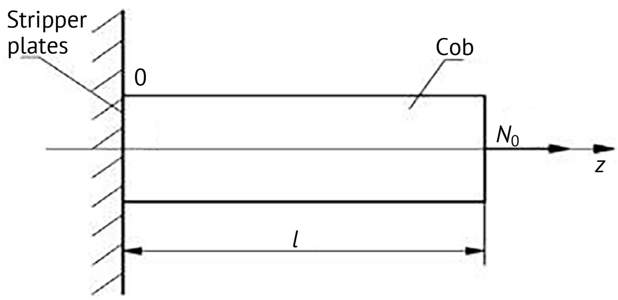

Figure 1. *The calculation scheme*

In the case of the stalk static load, a tension of the same length appears in the pattern thread [16]:

$$\sigma = \frac{N_0}{S_0}, Pa, \tag{1}$$

where S_0 is the section of the stalk, m^2.

Initial conditions are considered to be zero, and at the initial time (t=0) they are described by expression:

$$t = 0; u(0, z) = 0; \frac{du(0,z)}{dt} = 0, \tag{2}$$

where t is the time, sec; u is the function of longitudinal deformations, m; z is the longitudinal coordinate, m.

The boundary conditions are the following: z=0, u=(0, t). In this point the stalk is clamped. No force is applied to the other end of the cob. Its longitudinal coordinate is z=l. The maximum value of the stalk deformation u (t, z) is reached at the moment of time:

$$t_1 = \frac{2l}{a_0}, sec, \tag{3}$$

where a_0 is the speed of sound into the plant, m/s.

The maximum value of the stalk deformation is determined by the equation:

$$u_{max} = \frac{16N_0 l}{ES\pi^2} \sum\nolimits_n \frac{1}{n^2}, (n = 1{,}3{,}5 \dots), m \tag{4}$$

where l is the cob length, m; E is the modulus of elasticity (Young's module) of the corn cob, Pa.

Loay Al-Zube et al. studied the modulus of elasticity values of the dry maize stalks obtained using different mechanical loading modes. All methods showed that the modulus of elasticity ranges from 6 to 16 GPa [17]. In the case of the dynamic load, the longitudinal function is equal to:

$$u_{max} = \frac{2N_0 l}{ES_0}, m\ . \tag{5}$$

In the case of the static load, the longitudinal function is halved:

$$u_{max} = \frac{N_0 l}{ES_0}, m. \tag{6}$$

The maximum force in the thread can be found by the following expression:

$$T_{max} = \frac{8N_0 ES_0}{\pi q_0 a_0^2} \sum\nolimits_n \frac{-1^{\frac{n-1}{2}}}{n}, N, \tag{7}$$

where q_0 is the weight per unit length of the thread (cob), kg/m.

Thus, the dynamic destruction of the thread by force N_0 will give an effort at the point of fastening the stalk and the cob [16]:

$$T_{max}=2N_0, N \tag{8}$$

Thus the dynamic force is twice the force under static load. The tension in the thread when it is destroyed is:

$$\sigma_{max} = \frac{T_{max}}{S} = \frac{2N_0}{S}, Pa. \tag{9}$$

The separating of cobs in the in the piker-strapping apparatus is accompanied by an impact to the stripper plates. Therefore, the next stage of this study is the investigation of this phenomenon.

The interaction of a cob and the stripper plates was considered as a strike of an elastic rod (the moving speed is equal to V_0) on a stationary plate (Fig. 2). The weight of the stationary plate exceeds the weight of the rod. We accept the following interaction conditions:

- the stripper plates do not deform;
- the stripper plates remain stationary.

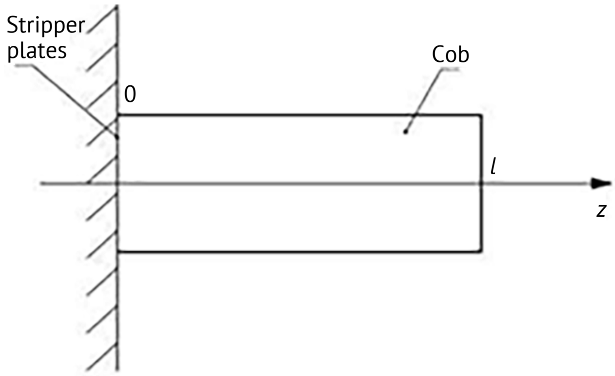

***Figure 2**. Scheme of the interaction of the cob and the stripper plates*

Two models of strike were considered. In the first case, the wave processes in the cob is neglected. We believe that the cob deforms along the whole length at the same time. The distribution of the tension in the cob can be determined by the equation:

$$\sigma(z) = \sigma_0 \frac{z}{l}, Pa. \tag{10}$$

where z is the coordinate whose size differs from the free end of the stalk; σ_0 is the tension at the base of the cob, Pa; l is the length of the cob, m; $\sigma(z)$ is the tension in the point with the coordinate z, Pa.

The force in the cob is determined as:

$$T(z)=S_0\sigma(z), N \tag{11}$$

The full work of cob deformation is:

$$A = \frac{\sigma_0^2 S_0 l}{6E}, J. \tag{12}$$

Having equated the work of deformation (11) to kinetic energy, we obtain the tension [6]:

$$\sigma_0 = \sqrt{3}\frac{V_0}{a_0} E, Pa. \tag{13}$$

where V_0 is the velocity, m/s.

Then, substituting (12) in (10), we obtain the expression for determining the force in the cob during the impact:

$$T = \sqrt{3}\frac{V_0}{a_0}ES_o, Pa. \qquad (14)$$

We can see from formula (13) that in order to perform the technological process of separation of cobs more effectively, it is necessary to strive in increasing the speed of rotation of the stretching rollers. However, rather high dragging speeds and significant separation efforts lead to the cobs throwing beyond the reaper, thereby reducing the harvest.

In the second case, we solve the same problem using the wave model of the rod. The maximum value of the movement of the right end of the cob (z=l) is reached by t=l/a_0 [18]:

$$u_{max} = -\frac{8V_0 l}{\pi^2 a_0}\left(1+\frac{1}{9}+\frac{1}{25}+\cdots\right) = \frac{V_0 l}{a_0}, m. \qquad (15)$$

The maximum force at the point z=0 is achieved at the moment of time t_1=l/a_0 is calculated by the expression:

$$T_{max} = -\frac{4V_0ES_0}{\pi a_0}\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{2n-1} = \frac{V_0}{a_0}ES_0 =$$
$$= -V_0S_0\sqrt{\rho E}\ (n = 1,3,5\ \ldots), N. \qquad (16)$$

Thus, the exact solution of the problem differs from the approximate one by the multiplier √3. The approximate solution gives a higher force.

To analyse the deformation of cob, its physical properties were used. Such data as length, diameter, porosity and angle of friction are necessary for our study. The selected physical properties of corn cobs are shown in Table 1. The length of cob varies from 20.17 to 23.2 cm. And the average length of 21.68 cm is assumed [11]. The diameters of a corn cob are within the range from 3.78 to 5.69 cm [11]. The average diameter is 4.94 cm. The porosity of cob ranges from 42.81 to 52.78%. The average repose of angle of corn cobs was 26.76 degrees, and the angle of friction was 32.90 degrees.

Table 1. *Physical properties of corn cobs*

Parameter	Unit	Minimum	Maximum	Average
Length of corn cob	cm	20.17	23.2	21.68
Diameter of corn cob	cm	3.78	5.69	4.94
Porosity	%	42.81	52.78	46.74
Repose angle of corn cobs	degree	19.1	37	26.76
Angle of friction of corn cobs	degree	28	38	32.9

The bulk density of whole corn cobs are within the range from 163 to 316 kg/m3 [20]. This value depends on species of corn and moisture content. The true density is a function of the bulk density and porosity:

$$\rho_t = \frac{100}{100-\varepsilon}\rho_b, kg/m^3, \qquad (17)$$

where ρ_b is the bulk density, kg/m^3; ε is the porosity, %.

The deformation chart of the cob and the time dependent force is of significant scientific interest. To find the above, new variables have been introduced:

$$n=2k-1. \qquad (18)$$

And the dimensionless time $\tau = \frac{a_0 t}{l}$. Moreover, to make the equation more compact new abbreviations are applied u_0 =$V_0 l/a_0$, and To=$ES_0 \cdot V_0/a_0$.

Then equation for the longitudinal deformation can be represented in the following form:

$$u(l,\tau) = 2u_0\sum_{k=1}^{\infty}\frac{(-1)^{k-1}}{\left[\frac{\pi(2k-1)}{2}\right]^2}\sin\left[\frac{\pi(2k-1)\tau}{2}\right], m. \qquad (19)$$

And the equation for the force is:

$$T(o,\tau) = -2T_0\sum_{k=1}^{\infty}\frac{sin\left[\frac{\pi(2k-1)\tau}{2}\right]}{\left[\frac{\pi(2k-1)}{2}\right]}, N. \qquad (20)$$

For the graphic interpretation of the results of calculating the longitudinal deformation, the dimensionless function was used:

$$\bar{u}(l,\tau) = \frac{u(l,\tau)}{2u_0}. \qquad (21)$$

We introduce a dimensionless function to determine the force:

$$\bar{T}(0,\tau) = \frac{T(0,\tau)}{2T_0}. \qquad (22)$$

The calculation results are shown in Figure 3 and Figure 4.

To verify the mathematical model, the pulling force for the separation of a corn cob was calculated and compared to the experimental results. Initial data have been taken from research conducted by Al-Mitewty et al. [21]. The following data were assumed for computation:

- The diameter of stalk is 2.21 cm;
- The weight of a corn cob is 0.42 kg;
- The length of corn cob is 21.68 cm;
- The diameter of corn cob is 4.94 cm.

Al-Mitewty et al. reported that the pulling force ranged from 307.9 to 330.18 N. Our computations had the following results. In the case of the static load, the pulling force was 355-396 N. The use of the wave theory resulted in a less separating force. This force varies from 290.9 to 324.6 N. The developed mathematical model has good correspondence to experimental data and, therefore, it can be used for the corn harvester design.

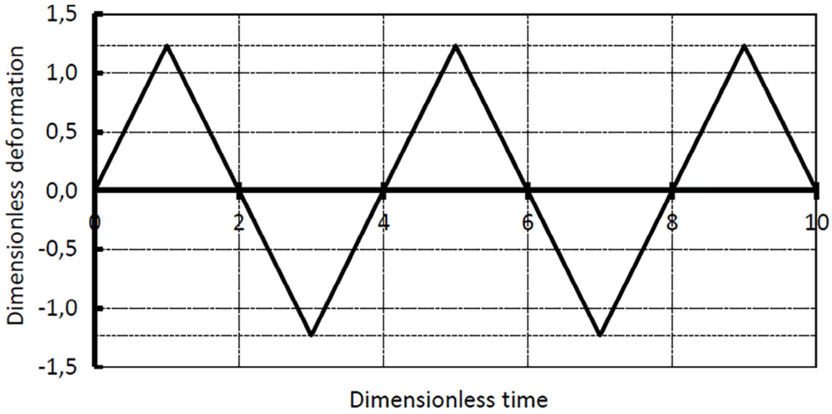

Figure 3*. Graph of the deformation in the end of the cob*

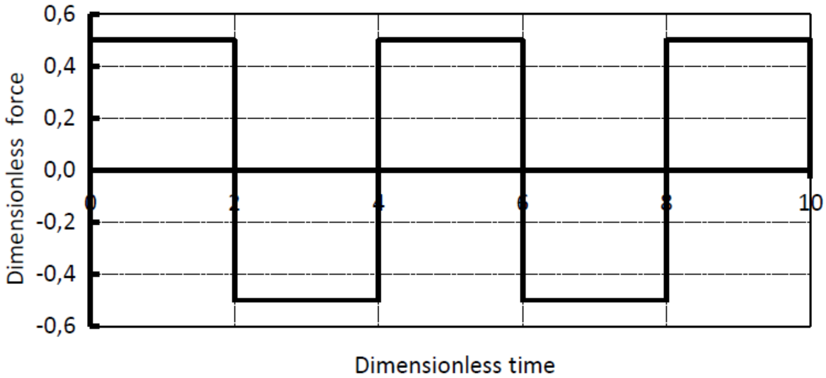

Figure 4*. Force in the point of interaction of the cob and the stripper plates*

Based on the above, we can conclude that the use of wave theory will give more accurate results. This theory more accurately describes the processes that take place in the cob during its separation due to the impact on the stripper plates. However, the impact in the process of cob separation remains undesirable, because as a result of such interaction of the cob with stripper plates there is a high probability of destruction of the cob base. It can result in partial and complete dropping-out of grain during its transportation by corn harvesting machines, thereby increasing the overall yield loss.

CONCLUSIONS

To analyze the separating force, the threshing properties were tested. The mathematical model has been developed under quasi-static loading. As the result of the research conducted the mathematical model of major methods of cob separation has been developed, which makes it possible to establish the regularities of the change of the main kinematic parameters of the cob-separating apparatus of the multifactorial action.

If we consider the combination of several forces in the process of cob separation, then one of the promising ways to intensify this process is the integrated use of stretching the stalk together with its twisting. In this case, the torsion will be an additional destructive force.

Further research after checking the received results at a laboratory will focus on the practical implementation of them in the design and manufacture of corn-harvesting machines.

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Визначення сили для відділення качанів кукурудзи

Василь Грубань

Кандидат технічних наук, доцент
Миколаївський національний аграрний університет
54008, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0003-0753-565X

Валерій Гавриш

Доктор економічних наук, професор
Миколаївський національний аграрний університет
54008, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0001-7055-1674

Антоніна Калініченко

Доктор габілітований, професор
Опольський університет
45-040, площа Коперника, 11А, м. Ополе, Польща
https://orcid.org/0000-0001-7342-3803

Анотація. У світі спостерігається зростання попиту на кукурудзу. Це вимагає використання високопродуктивної сільськогосподарської техніки, в тому числі зернозбиральних комбайнів. Проте кукурудзозбиральні комбайни мають високі втрати зерна, а їх обладнання потребує вдосконалення. Метою статті було обґрунтування роботи кукурудзозбирального комбайна шляхом розробки математичної моделі процесу відділення качанів у комплексному поєднанні кількох сил. Для перевірки цієї моделі результати моделювання порівнювалися з експериментальними даними. Хвильова теорія виявилася точнішою порівняно зі статичною моделлю. Наведено результати теоретичних досліджень способів відокремлення качанів кукурудзи від стебла та розроблено математичні моделі. Технологічний процес сепарації качанів кукурудзи виконується шляхом поєднання різних зусиль і оцінки результуючого напруження. Розглянуто технологічний процес сепарації качанів у поєднанні багатьох сил і оцінці результуючого напруження. Подальші дослідження будуть зосереджені на інтенсифікації цього процесу шляхом інтеграції розтягування стебла разом із його скручуванням

Ключові слова: кукурудза, качан, система сепарації качанів, математична модель

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Quality of pellets produced from agricultural wood residues specific to the Prut River basin

Grigore Marian*
Doctor Habilitat, Professor
State Agrarian University of Moldova
2049, 42 Mircesti Str., Chisinau, Moldova
https://orcid.org/0000-0002-9975-2522

Ianus Gelu
PhD, Associate Professor
Gh. Asachi Technical University of Iasi
700050, 67 Professor Dimitrie Mangeron Blvd., Iași, Romania
https://orcid.org/0000-0002-2998-0992

Bogdan Istrate
PhD, Associate Professor
Gh. Asachi Technical University of Iasi
700050, 67 Professor Dimitrie Mangeron Blvd., Iași, Romania
https://orcid.org/0000-0003-0817-3523

Andrei Gudîma
PhD, Associate Professor
State Agrarian University of Moldova
2049, 42 Mircesti Str., Chisinau, Moldova
https://orcid.org/0000-0002-7250-8423

Boris Nazar
PhD, Associate Professor
State Agrarian University of Moldova
2049, 42 Mircesti Str., Chisinau, Moldova
https://orcid.org/0000-0002-9262-5061

Andrei Pavlenco
PhD, Senior Researcher
State Agrarian University of Moldova
2049, 42 Mircesti Str., Chisinau, Moldova
https://orcid.org/0000-0002-3320-2907

Alexandru Banari
Researcher
State Agrarian University of Moldova
2049, 42 Mircesti Str., Chisinau, Moldova
https://orcid.org/0000-0001-9132-610X

Nicolae Daraduda
Researcher
State Agrarian University of Moldova
2049, 42 Mircesti Str., Chisinau, Moldova
https://orcid.org/0000-0001-5683-0431

Abstract. This paper presents an overview of the prospects for the use of agricultural wood residues, specific to the climatic zone adjacent to the Prut River and the qualitative characteristics of densified solid biofuels in the form of pellets produced from the main types of the agricultural wood biomass, taken from agricultural plantations in the Republic of Moldova and Botosani, Iasi, Vaslui and Galați counties in Romania. The aim of the paper is to establish the energy potential of the main indigenous agricultural wood residues and to analyze the quality of the pellets produced from these residues. The research results showed that the pellets produced from the studied agricultural residues mainly meet ENPlus 3 requirements for most qualitative parameters, except for those produced from blackberry and currant residues. Residues from the prunning of some types of fruit shrubs can be used to produce pellets by creating mixtures of different proportions, and their qualitative characteristics can be significantly improved by thermo-chemical pre- treatment of the raw material

Keywords: plant biomass, densified solid biofuels, pellets, biofuel, energy potential, agricultural wood residues

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*Corresponding author

INTRODUCTION

The sustainable development of energy systems in the Republic of Moldova and Romania cannot be conceived without a continuous development of energy production based on renewable resources. Biomass energy presents the most viable and promising prospects for the conditions of the Republic of Moldova and the related regions of Romania (Botosani, Iasi, Vaslui and Galati counties) [1-3].

For the areas metioned above, the main sources suitable to be used as raw material for the production of densified solid biofuels (DSBF) are agricultural wood residues, in particular those of apple, plum, cherry, sweet cherry and pear trees, walnut bushes, as well as vines [4; 5].

During the last decade there has been a growing interest of economic agents for the cultivation of different species of shrubs, in particular sea buckthorn [6], blackberry, raspberry, blackcurrant, etc. [7]. in these areas. These crops also generate large volumes of plant residues, suitable to be used as raw material for the production of DSBF [8].

The use of agricultural waste as a raw material is argued, both because it helps to reduce dependence on fossil fuels and emissions of harmful gases into the atmosphere, and because it is a stimulus to establish some new small and medium-sized enterprises in rural areas.

DSBF are produced in the form of briquettes and pellets. This paper focuses on the study of DSBF produced from pellet-shaped agricultural residues, although some results can be adopted for all types of DSBF.

Pellets are prepared from shredded biomass, with or without additives, by dehydration and compression to double energy density of green wood. It is an environmentally friendly fuel, which, when beeing burnt, eliminates the same amount of CO_2 that is absorbed during the plant growth [9, pp. 96-98]. Moreover, the use of pellets significantly reduces the generation of dust, allows the use of various mixtures and mixtures of raw materials – the process that allows to manage certain qualitative characteristics of the finished product [10].

The management of agricultural residues for the pellet production involves several specific technological operations, the realization of which is influenced by a number of factors with a significant share of ensuring the quality of the finished product.

Although, the analysis of the factors that influence the DSBF quality is quite complete in the literature [11-14], the problem of influencing factors that occur during the production of pellets from indigenous agricultural residues, requires a specific approach for each type of biomass used as raw material. In addition, there is practically no data on the use of residues derived from different species of shrubs for energy purposes in the literature.

Thus, the study of the quality of pellets produced from indigenous agricultural residues is relevant and requires a detailed analysis of the factors that influence it. The research problem has been structured based on the findings and it consists in ensuring the quality of fire pellets, produced from various agricultural wood residues, by identifying and studying the influencing factors distributed throughout the production process.

Agricultural wood residues collected on both banks of the Prut River served as the object of research.

LITERATURE REVIEW

Topics related to the quality of fire pellets have always been an important study topic. The EN ISO 17225 standard specifies two classes of pellets: the first one is for residential and household uses, and the second one is fors industrial uses. Quality requirements for pellets differ from class to class, however, there are mandatory quality characteristics for both groups of pellets that give them the ability to satisfy consumer requirements to a greater or lesser extent.

The SE ISO 17225 standard regulates several qualitative characteristics of fire pellets, the most important of which are: moisture content, ash content, bulk density, fine fraction content, durability, lower calorific value at reception, S, N and Cl content.

The quality of pellets is influenced by several factors that can be grouped as follows: raw material variables and manufacturing process variables [9, p. 39-46; 155-162; 15; 16].

The raw material variables, which show the maximum influence on the quality of pellets, refer to the origin of the biomass, moisture content, impurity content, storage time and particle sizes [17-19].

According to the classification of solid biofuels by origin, the research object of this paper is classified in group 1.1.7 "Sorted wood from gardens, parks, road maintenance, vineyards, orchards and floating wood material from fresh water", and according to the classification of biomass for energy purposes it can be found in the category – residues, wastes and agricultural plant by-products [9, p. 35].

Our earlier research has shown that the quantity of the plant wood biomass derived from agricultural wastes makes up approximately 9% of the total amount of agricultural residues [4], and this is exactly the type of the plant biomass that can ensure the production of the above-mentioned quality characteristics in accordance with the requirements of EN Plus 3 international standards [17].

The data presented by several researchers [20; 21] show the influence that the moisture content of the undensified raw material has on the quality of DSBF densification. For example, Tumularu experimentally demonstrated that the best conditions for the formation of adhesion and cohesion bonds between biomass particles are formed when the moisture content initiates optimal conditions for the growth of contact surfaces due to van der Waals forces that occur under certain densification conditions [22; 23]. Other authors provide similar explanations [11; 24; 17; 25], they consider that optimum conditions of particle agglomeration upon pelletizing shall be ensured by the moisture content equal to 10±2%.

Several researchers have shown that the mechanism of forming cohesion bonds when densifying pellets produced from the biomass of different origin differs from case to case. Thus, Stelte and others explain the peculiarities of cohesion and adhesion bonds formation between biomass particles by the amount of extractives present in the biomass and lignin diffusion, which depends on the processing temperature and moisture content in the biomass before it is pressed. They concluded this, having studied the adhesion mechanism between biomass particles and the evolution of structural failures in pellets produced from hard, soft and straw biomass types (Beech, spruce and wheat straw) [26-28; 22].

Production variables also demonstrate an important influence on the structure and properties of pellets. Thus, they include: technological regimes (compression pressure, grain formation temperature; roller speed); constructive parameters of the mold (diameter and length of the channels, the gap between the roller and the mold), etc.

Some of the most important properties influenced by the production variables of pellets include: mechanical durability, bulk density and fine fraction content.

It is obvious that production variables influence the mechanism of bond formation between biomass particles. However, up to now there is no single theory of this mechanism. The existing data are in most cases limited to experimental treatments for certain biomass types [29; 30; 12].

There are some proposals regarding the calculation of the pelletizing pressure depending on the sample plasticity, the Poisson ratio, the friction coefficient and the compression ratio [31], though the values calculated according to these recommendations are approximate and need to be specified for certain conditions [17].

Dependence of the pellet mechanical properties and energy consumption on the temperature and moisture content, fiber orientation [30], extractive substance content and storage time [32] – also refers to certain types of biomass.

Therefore, raw material and production variables are provided in the literature largely enough, which is why the analysis of SDBF qualitative parameters produced from indigenous agricultural residues is argued.

The aim of the work is to establish the energy potential of the main indigenous agricultural wood residues and to analyze the quality of pellets produced from these residues.

To achieve the proposed aim, the following objectives have been put forward:

- quantitative and qualitative analysis of agricultural wood residues specific to the climatic zone of the Prut River;
- analysis of the influence of production factors on the quality of SDBF produced in the form of pellets from indigenous agricultural residues;
- qualitative analysis of pellets produced from agricultural wood residues collected in the Republic of Moldova and Botosani, Iasi, Vaslui and Galati counties of Romania.

MATERIALS AND METHODS

The research implied several distinct stages.
At the first stage, plant biomass was collected from different development areas of the Republic of Moldova and from the counties adjacent to the Prut River in Romania. All residues were coarsely shredded right on the field and transported to the Laboratory of Solid Biofuels, SAUM. Before processing, the biomass was dried by the natural conversion method in the dryer provided by the laboratory to M=10±2%, then grinded at the SV 7 hammer mill with a 6 mm mesh size of the sieve.

At the second stage, there was carried out a quantitative analysis of wood residues collected on the territory of the Republic of Moldova that can be used as raw material. There was determined the energy potential of the agricultural wood residues generated from one hectare of plantations. Thus, there were identified the theoretical energy potential (PTRM=10%) and the sustainable one (PSIM=10%). The calculation was made for the moisture content of the biomass equal to 10%, which corresponds on average, to the moisture content of the finished product at reception.

The theoretical potential is the maximum amount of energy that can be obtained from the residues generated from one hectare with the condition it is fully used for energy purposes. It is determined by means of the following relationship:

$$PTR_M = 10\% = m_{p.b.rec.}\left(1-\frac{M_{rec}-10}{100}\right)\cdot \cdot K_{rez.rec}\cdot q_{p,net.M=10\%}, \frac{MJ}{an}, \quad (1)$$

where $m_{p.b.rec.}$ represents the basic production mass at harvest from one hectare, kg/ha; $K_{rez.rec.}$ – unit conversion factor for that crop at harvest; M – moisture content of the biomass at harvest, %; $q_{p.net.\cdot M=10\%}$ – lower calorific value of the biomass with moisture content equal to 10%.

The sustainable implementation potential represents the amount of energy calculated considering the technical, economic and sustainability availability of the residues generated by the corresponding crop and was calculated by means of the following relationship:

$$PSI_{M=10\%} = PTR_{M-10\%}k_{d.t-e}\cdot\left(1-k_{per}\right), \frac{MJ}{an}, \quad (2)$$

where $k_{d.t-e}$ is the factor of sustainable technical and economic availability for energy purposes of the residues with reference to the corresponding crop, k_{per} is the coefficient of unavoidable residue losses.

At the third stage there were produced pellets at the mini semi-automatic pellet production line MGL 200 within the Laboratory of solid biofuels, SAUM. A horizontal mold with two rotating rollers and the mesh size of the sieve of 6 mm was used as a working body. The fourth stage was devoted to determining the properties of pellets made from the studied agricultural residues.

The higher calorific value was obtained using the LEGO is operibolic calorimetric pump (model MC 10) in accordance with the procedures described in the EN ISO 18125 standard. The lower calorific value was determined for humidity equal to 10% using the following relationship:

$$q_{p,net,M=10}=\{q_{v,gr,d})-212{,}2w(H)_d-0.8[w(0)_d+w(N)_d]\}(1-0.01M)-24.43M, \quad (3)$$

where: $q_{p,net,M}$ is the lower calorific value in the dry base at constant pressure, J/g; $q_{v,gr,d}$ is the higher calorific value at constant volume, J/g; $w(H)_d$ – the mass content of hydrogen, %; $w(0)_d$ – the mass content of oxygen in the dry base, %; $w(N)_d$ – the mass content of nitrogen in the dry base, %; M – the moisture content at which the lower calorific value was determined (M=10%).

The ash content was determined for samples of crushed pellets in advance at a German mill SM 100 by passing through the sieve with the mesh screen of 1 mm. The samples were calcined according to the EN ISO 18122 standard by keeping them for 6 hours at a temperature of 550°C in the LH 05/13 chamber furnace.

The content of N, S and Cl was established as the result of the chemical analysis performed at the elemental analyzer Vario MACRO cube CHNS & Cl. The bulk density was determined in accordance with the EN ISO 17828 standard for pellets with a moisture content of (10±2)%.

The mechanical durability was established by determining the ability of the pellets to resist shocks and wear being subjected to controlled blows in accordance with the EN ISO 17831 standard. The test was carried out for pre-screened pellet samples with a mass of 500±10 g. The samples were taken and sampled in accordance with the requirements of the EN ISO 14780 and EN ISO 18135:2017 standards.

The samples were rotated in the plant to determine durability with a frequency of 50±2 m for 10 min-1. The durability value was calculated with the ratio of the pellet mass before and after the test and sifted through a sieve with a 3.15 mm mesh screen.

The content of the fine fraction was determined as the ratio percentage of the mass of the particle fraction, formed after sifting a certain amount of pellets through a vibrating sieve with mesh screen dimensions of 3.15 mm and the initial amount of the tested pellet sample.

The energy density was determined as the amount of energy stored per unit of volume as follows:

$$E_{density}=BDq_{p,net,M=10}. \quad (4)$$

RESULTS AND DISCUSSION

The raw material analysis. In order to justify the use of different types of residues as raw material for the production of SDBF, it is necessary to know the potential available for different types of residues and their quality. Table 1 shows the estimate of the theoretical and sustainable energy potential of agricultural wood residues calculated on the basis of the average harvest obtained during the years 2017-2019.

Table 1. *The energy potential of plant biomass generated by agricultural wood residues in the Republic of Moldova*

Crops	$m_{p.b.i}$, kg/ha				$Kr_{ez.rec.max.}$	$k_{d.t-e}$	k_{per}	$q_{p,net}$, MJ/kg		PTR_M=10% in MJ/ha	PSI_M=10%, in MJ/ha
	2017	2018	2019	Average				In the dry base	Moisture content 10%		
Seed fruit, and namely:											
Apples	10710.0	14760.0	16030.0	13833.3	0.29	0.80	0.10	19.0	16.8	57.1	41.1
Pears	2060.0	2060.0	320.0	1480.0	0.22	0.80	0.10	19.6	17.4	3.9	2.8
Stone fruit, and namely:											
Cherries	3010.0	5910.0	5960.0	4960.0	0.16	0.80	0.10	19.4	17.2	11.5	8.3
Sweet cherries	4640.0	5320.0	3930.0	4630.0	0.24	0.80	0.10	20.8	18.5	16.9	12.2
Apricots	2850.0	2330.0	5510.0	3563.3	0.31	0.80	0.10	19.5	17.3	16.4	11.8
Peaches and nectarines	1950.0	1870.0	1340.0	1720.0	0.26	0.80	0.10	20.0	17.8	6.7	4.8
Plums	5640.0	8170.0	8390.0	7400.0	0.30	0.80	0.10	20.1	17.8	29.7	21.4
Nuts, almonds, etc.	340.0	610.0	540.0	496.7	0.10	0.80	0.10	16.9	14.4	0.5	0.4
Fruit shrubs	850.0	3320.0	3910.0	2693.3	0.70	0.80	0.10	19.9	16.8	23.5	16.9
Vines, and namely:											
Table varieties	7190.0	7480.0	7640.0	7436.7	0.6	0.7	0.1	19.0	16.9	54.8	34.5
Technical variables	4480.0	5490.0	4370.0	4780.0	0.4	0.7	0.1	18.3	16.3	20.5	12.9

Note: *conventional ratings are provided according to formulas 1 and 2*

The results presented in Table 1 show that practically all the studied agricultural residues, as calorific value, can be used as raw material for the production of pellets for residential and similar uses having a calorific value at 10% humidity greater than 16.5 MJ/kg, with the exception of nuts and residues of vines, technical varieties.

The highest energy potential can be obtained from the emondation of apple trees (41.1 GJ/ha), followed by that of vines, table varieties (34.5 GJ/ha) and the one received from the emondation of plums (21.4 GJ/kg). Thus, it can be concluded that the studied residues are an important source of raw material for SDBF production, in particular pellets. The influence of production factors on the quality of pellets. The properties of pellets, regulated by the EN ISO 17225-2 standard, are grouped into physical and chemical properties. Physical properties influence the combustion efficiency and logistics of pellets; chemical properties are responsible for the environmental impact, durability and smooth operation of thermal power plants [17].

The quality analysis results of the pellets produced from different types of agricultural wood biomass are presented in Table 2.

The first thing that interests the beneficiary is the amount of heat obtained from the combustion of a unit mass of pellets that is expressed in the upper (gross) calorific value, the lower (net) calorific value and the energy density.

Table 2. *Qualitative parameters of pellets produced from agricultural wood residues*

Name of residues	$q_{p.net.r}$, MJ/kg	A, %	DU, %	DB, kg/m^3	FF, %	E, GJ/m^3	N, %	S, %	Cl, %
Apples	17.72	0.9	98.25	680	0.42	12.05	0.25	0.03	0.02
Pears	17.31	1.47	97.9	674	0.44	11.67	0.26	0.03	0.03
Cherries	17.10	1.11	98.1	682	0.51	11.66	0.27	0.03	0.03
Sweet cherries	18.00	1.42	98	680	0.52	12.24	0.3	0.03	0.03
Apricots	17.04	1.08	98.3	654	0.48	11.14	0.3	0.03	0.03
Peaches and nectarines	17.07	1.38	97.9	658	0.54	11.23	0.28	0.03	0.03
Plums	17.70	0.74	98.2	684	0.41	12.11	0.3	0.03	0.03
Sea buckthorn	17.05	1.3	98.1	685	0.38	11.68	0.98	0.05	0.04
Blackberries	15.7	1.62	97.4	656	0.66	10.30	0.88	0.06	0.04
Black currants	15.3	2.53	97.2	654	0.72	10.01	0.87	0.05	0.03
Vines, table variables	16.8	2.6	98.10	702	0.66	11.79			
Vines, technical varieties	16.5	2.5	97.9	696	0.67	11.48			

The lower calorific value, calculated for moisture equal to 10% for all pellet samples, except those of blackberries and black currants, falls within the limits stipulated by the ENPlus 3 norms, i.e. exceeds 16.5 Mj/kg.

Energy density, derived from the lower calorific value and bulk density, is important for transporting and storing pellets.

The obtained results show that the energy density of pellets, produced from agricultural wood residues is quite high. The lowest energy density was reported in black currant and blackberry pellets with the following values of 10.01 GJ/m^3 and 10.30 GJ/m^3 respectively; the highest energy density was noticed in sweet cherry pellets (12.24 GJ/m^3) followed by those produced from plums (12.11 GJ/m^3) and apples (12.05 GJ/m^3).

The lower density of blackberry and black currant pellets can be explained by their lower calorific value as well as by their low bulk density in relation to the other pellet samples.

The bulk density of the studied pellets does not vary greatly from one biomass type to another, ranging from 654 kg/m^3 for the black currant pellet sample to 702 kg/m^3 for the pellet sample produced from vine residues.

The indicative limits for wood pellets are specified by En Plus 3 with the range of 600≤BD≥750 kg/m^3. Thus, all the studied pellets fall under the ENPlus 3 regulations.

The ash content is one of the most important qualitative characteristics of pellets, which influences, above all, the calorific value; the combustion process and the corrosion degree of boilers. It is for these reasons that the ENPlus rules have become more demanding, reducing the allowed amount of ash from 1.5 to 1.2% for Class ENPlus A2 and from 3 to 2% for Class En-B (9 p. 171).

The obtained results demonstrate that the ash content of pellets produced from black currant and vine plant residues exceeds the allowed norms for residential pellets, however, this qualitative parameter allows their application for industrial uses. The least amount of ash results from burning plum and apple pellets.

The content of *N*, *S* and Cl have a negative impact on the environment and the functioning of thermal power plants. Thus, nitrogen, when being burnt, forms nitrogen oxides, which leads to the formation of acid rain and smog.

The ENPlus 3 rules limit the nitrogen content for residential pellets up to 0.3% for Class A1 pellets, up to 0.5% for Class A2 and up to 1% for Class EN- B.

The requirements for nitrogen content in the pellets for industrial uses are more severe, having the following restrictions: 0.3% – for classes I1 and I2 and 0.6% – for Class I3.

Looking at the data, provided in Table 2, we can state that all pellet samples scored a percentage of N less than 1% and can be classified into different classes of pellets for residential uses. At the same time, blackberry, sea buckthorn and black currant pellets cannot be used for industrial uses.

The sulphur content for residential pellets is limited by ENPlus 3 up to 0.04% for Class A2 and up to 0.05% for classes A2 and EN-B. The sulphur content must not exceed 0.05% in the case of all classes of pellets for industrial uses.

All analyzed samples had an S content of less than or equal to 0.05%, with the exception of those of blackberries which exceeded the maximum allowed limit insignificantly.

Chlorine content participates in the formation of various compounds, in particular HCl and dionines/furans. CL compounds strengthened by condensation processes cause intense corrosive effects of metal components of heating systems; such effects significantly reduce their reliability. Therefore, the ENPlus 3 regulations limit the CL content in pellets up to 0.02% for classes A1 and A2 and up to 0.03% for Class EN-B.

The CL content allowed by ENPlus 3 is higher for industrial pellets: Class I1≤0.03%; I2≤0.05% and I3≤1%. Thus, all pellet samples analyzed at this parameter correspond to the requirements of ENPlus3 for different quality classes.

Improving the quality of pellets by creating biomass mixtures from agricultural residues. The following research refers to the quality assessment of pellets produced from mixtures that consist of vegetable agricultural residues, have lower calorific value and are less studied. Since the energy potential of agricultural residues from shrubs is the highest and the quality properties are lower than those of other agricultural residues from trees (Table 1), one has studied the pellets produced from mixtures of blackberry and sea buckthorn residues.

Table 2 shows that murine residues have registered the following parameters: the calorific value ($q_{p,net,M=10\%}$=15.7 MJ/kg), ash 1.62%, nitrogen 0.88% and sulfur content 0.06%, and pellets from sea buckthorn residues have a calorific value ($q_{p,net,M}$=10%=17.05 MJ/kg), ash content 1.3%, nitrogen 0,98% and sulphur 0,05%. These indicators prove the possibility to use these two types of biomass in the mixture.

Ten samples of mixtures with a different content and a step of 5% were studied. The results are presented in Table 3.

Table 3. *Quality parameters of pellets produced from mixtures of murine residues (RM) and sea buckthorn residues (RCA)*

Nr. of sample	BBR, w%	SBR, w%	$q_{p, net, M=10\%}$, MJ/kg	A, %	DU, %	DB, kg/m^3	FF, %	N, %	S, %	Cl, %
1	0	100	17.05	1.3(±0.021)	98.03(±0.15)	685(±2.5)	0.42(±0.022)	0.98	0.05	0.04
2	10	90	17.64	1.3(±0.015)	98.03 (±0.1)	682(±1.5)	0.42(±0.018)	0.98	0.05	0.04
3	15	85	17.214	1.35(±0.01)	98(±0.21)	680(±3)	0.42(±0.01)	0.96	0.05	0.04
4	20	80	16.84	1.36(±0.016)	97.98(±0.14)	680(±2.8)	0.44(±0.019)	0.96	0.05	0.04
5	25	75	16.54	1.4(±0.012)	97.93(±0.17)	677(±3.2)	0.45(±0.009)	0.97	0.05	0.04
6	30	70	16.52	1.39(±0.01)	97.9(±0.21)	676(±1.8)	0.44(±0.02)	0.95	0.4	0.04
7	35	65	16.52	1.41(±0.011)	97.86(±0.18)	674(±1.5)	0.46(±0.01)	0.94	0.05	0.04
8	40	60	16.5	1.43(±0.01)	97.82(±0.14)	674(±2.1)	0.48(±0.017)	0.94	0.04	0.04
9	45	55	16.5	1.45(±0.018)	97.75(±0.21)	673(±2.1)	0.52(±0.022)	0.93	0.04	0.04
10	50	50	16.1	1.46(±0.012)	97.75(±0.22)	670(±1.5)	0.52(±0.016)	0.93	0.04	0.04

The obtained results demonstrate the efficiency of biomass mixtures produced from bush prunning. All qualitative parameters of samples 1…9 fall within the limits stated by MS EN ISO 17225- 3:2016 standard.

Improving the quality of pellets produced from agricultural residues by torrefaction. The research results presented in Table 3 show that as to the calorific value, a part of the studied biomass samples has a net calorific value of less than 16.5 MJ/kg or is close to this value.

One of the effective methods to improve the quality of SDBF produced from the biomass with lower characteristics, is the heat pre-treatment of the raw material with the absence of oxygen. The process, called torrefaction, consists of slowly heating the biomass or the finished product in an inert environment at relatively low temperatures (200…300)°C under the atmospheric pressure and at the speed that does not exceed 50°C/min.

The torified biomass is more easily ground, so the bulk density of the biomass before densification is low, therefore the densification expenditure is reduced and the particle density of the finished product is changed. At the same time, the chemical composition of the biomass changes too because a significant amount of moisture and volatile matter is removed, which leads to dehydration, dehydrooxylation and decarboxylation reactions.

Due to the degradation of hemicellulosis during torrefaction, caused by the interaction of the drying phenomenon with incomplete pyrolysis, the content of lignin that has more carbon is increased, which leads to an increase in the calorific value of the product.

Obviously, since it is a thermochemical process, torrefaction is influenced by several factors, in particular torrefaction temperature and time. In order to estimate the effect of torrefaction, one studied the biomass mixture, which consisted of 50% of the sea buckthorn and 50% of the blackberry shrubs.

The torrefaction experiment was carried out according to a polyfactor program with two influence factors (Table 4). A laboratory facility was used to simulate the torrefaction process in an oxygen-free environment by creating a vacuum atmosphere in a closed space (Fig. 1).

Table 4. *Experimental plan to study the effect of torrefaction*

Coded coordinates		Natural coordinates	
T_t, °C	σ_t, min	T_t, °C	σ_t, min
1	1	1	1
-1	-1	-1	-1
0	0	0	0
0	0	0	0
1	1	1	1
-1	-1	-1	-1
0	0	0	0
1	1	1	1
-1	-1	-1	-1

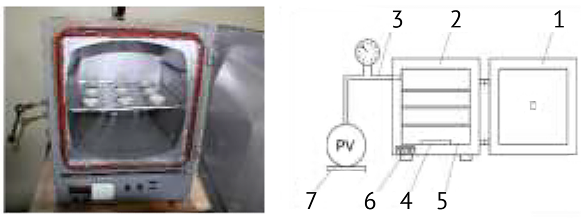

***Figure 1**. The laboratory installation used to torrefact biomass samples in vacuum*

Note: *1 – the sealed furnace door; 2 – the furnace frame; 3 – the air outlet with a vacuum meter; 4 – the thermostat support; 5 – shelves; 6 – the control panel and the control of thermal regimes; 7 – the vacuum pump.*

A vacuum drying furnace was used as a reactor to torrefact biomass samples under laboratory conditions (Fig. 1). The air from the furnace is discharged by a vacuum pump that provides a depression of 0.08 MPa. The temperature inside the furnace was monitored and controlled with a thermocouple at the predetermined temperature within the range of +35 – +350°C with a sensitivity of ±2°C.

The obtained results are shown in Figure 2. Exemplified by the contours of the response surfaces, the Pareto diagram and dominated effects. The torrefaction temperature influences the calorific value most of all. Basically, the maximum point is outside the aim of the experiment, but this area is limited by the maximum temperature that can be used at torrefaction, and namely 300°C. The duration of torrefaction also has an increasing trend of influence, though it is slower in the case of temperature.

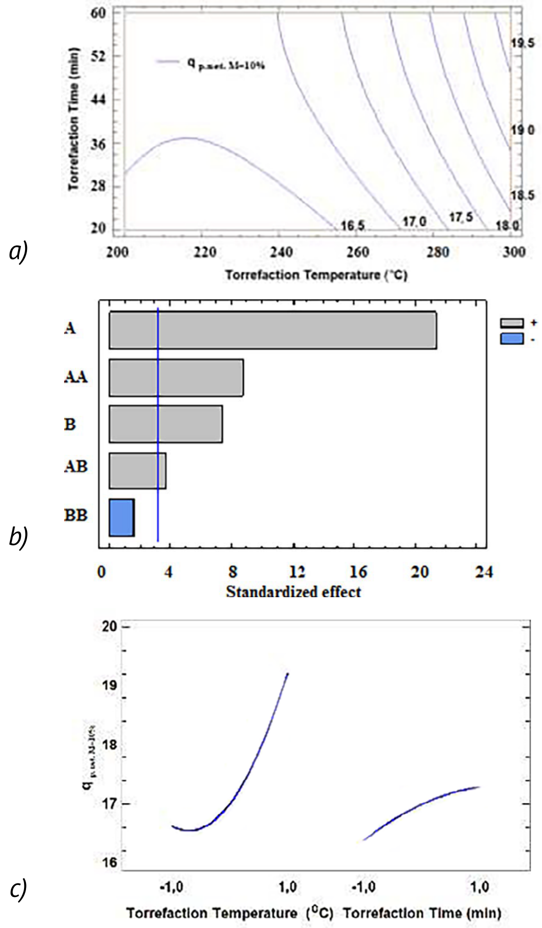

***Figure 2**. Calorific value of the biomass mixture that includes 50% of blackberry, 50% of sea buckthorn according to torrefaction temperature and time:*
a) Contours of Estimated Response Surface;
b) Standardized Pareto Chart for $q_{p,net,M=10\%}$ (A – Torrefaction temperature, °C; B – Torrefaction Time, min); c) Main Effect Plot for $q_{p,net,M=10\%}$ of thermal regimes; 7 – the vacuum pump.

The obtained results demonstrate that the calorific value of the mixtures consisting of 50% of blackberry residues and 50% of sea buckthorn residues can be increased by up to about 20% using heat treatment and torrefaction. In order to get this performance it is necessary to re-establish torrefaction at a temperature, which is as close to 300°C as possible and maintain this temperature for at least 40 minutes. The longer the torrefaction time, the better the expected result.

CONCLUSIONS

As to the quality and the possibility of the use of agricultural wood residues for the production of solid biofuels in the form of pellets, it has been found out that the existing data in the literature refer to particular types of plant biomass, and does not sufficiently reflect the integrity of the situation with regard to the quality of solid biofuels in the form of pellets made from agricultural wood residues, collected in the specific climate of the Prut River. This conclusion is based on the knowledge accumulated at both national and international levels.

The results of the quantitative study of the agricultural wood residues, suitable to be used as raw material for the production of solid biofuels in the form of pellets under the conditions of the Republic of Moldova and the counties of Botosani, Iasi, Vaslui and Galati, Romania, have shown that the potential energy that is sustainable for the implementation of agricultural residues, which is estimated from a hectare of plantation, is an important source of raw material for the production of solid biofuels. It has been stated that plantations of apples (41.1 GJ/ha), vines (34.5 GJ/ha), plums (21.4 GJ/ha), sweet cherries (12.2 GJ/ha) and apricots (11.8 GJ/kg) show higher energy potentials.

The estimation of the qualitative parameters of pellets produced from agricultural wood residues collected in the areas adjacent to the Prut River have shown that they largely correspond to ENPlus 3 requirements for most qualitative parameters except for those produced from blackberry and black currant residues.

The highest net calorific value is recorded in the case of sweet cherry (11.8 MJ/kg), plum (17.7 MJ/kg), apple (17.72 MJ/kg) and pear (17.31 MJ/kg) pellets.

The obtained results can be applied by pellet producers to argue the use of different types of agricultural wood residues in the production of pellets. At the same time the results of this study can be used for further research in the field of quality management of the finished product by forming mixtures of different types of plant biomass and by improving the technological process of processing pellets and other types of densified solid biofuels. It is also interesting to study the way the moisture content, processing temperature, origin and particle size affect the flow properties of polymers in agricultural wood biomass during pelletizing.

Experimentally it has been shown that the arboreal residues, received from prunning some types of fruit shrubs, can be used to produce pellets by creating mixtures with different proportions, and their qualitative characteristics can be significantly improved by thermo-chemical pre-treatment of the raw material.

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Якість пелет, виготовлених з сільськогосподарських деревних відходів, характерних для басейна річки Прут

Григорій Мар'ян

Доктор габілітований, професор
Державний аграрний університет Молдови
2049, вул. Мірчешті, 42, м. Кишинів, Молдова
https://orcid.org/0000-0002-9975-2522

Янус Гелу

Кандидат, доцент
Ясський технічний університет ім. Георге Асакі
700050, бульв. професора Дімітріє Мангерона, 67, м. Яси, Румунія
https://orcid.org/0000-0002-2998-0992

Богдан Істрате

Кандидат, доцент
Ясський технічний університет ім. Георге Асакі
700050, бульв. професора Дімітріє Мангерона, 67, м. Яси, Румунія
https://orcid.org/0000-0003-0817-3523

Андрій Гудима

Кандидат, старший науковий дослідник
Державний аграрний університет Молдови
2049, вул. Мірчешті, 42, м. Кишинів, Молдова
https://orcid.org/0000-0002-7250-8423

Борис Назар

Кандидат, доцент
Державний аграрний університет Молдови
2049, вул. Мірчешті, 42, м. Кишинів, Молдова
https://orcid.org/0000-0002-9262-5061

Андрій Павленко

Кандидат, старший науковий дослідник
Державний аграрний університет Молдови
2049, вул. Мірчешті, 42, м. Кишинів, Молдова
https://orcid.org/0000-0002-3320-2907

Александру Банарі

Науковий дослідник
Державний аграрний університет Молдови
2049, вул. Мірчешті, 42, м. Кишинів, Молдова
https://orcid.org/0000-0001-9132-610X

Ніколає Дарадуда

Науковий дослідник
Державний аграрний університет Молдови
2049, вул. Мірчешті, 42, м. Кишинів, Молдова
https://orcid.org/0000-0001-5683-0431

Анотація. У статті представлено перспективи використання деревних сільськогосподарських відходів, характерних для кліматичної зони, прилеглої до річки Прут, а також якісні характеристики ущільненого твердого біопалива у вигляді пелет, отриманих з основних видів деревної сільськогосподарської біомаси, характерної для Республіки Молдова і повітів Ботошани, Ясси, Васлуй і Галац з Румунії. Метою статті є визначення енергетичного потенціалу основних місцевих сільськогосподарських деревних відходів і аналіз якості пелет, вироблених з цих відходів. Результати дослідження показали, що пелети, отримані з вивчених сільськогосподарських відходів, значною мірою відповідають вимогам ENPlus 3 за більшістю якісних показників, за винятком пелет, отриманих з відходів ожини та смородини. Відходи, отримані від обрізки певних типів плодових чагарників, можуть бути використані для виробництва пелет шляхом формування сумішей різних пропорцій, а їх якісні характеристики можуть бути значно поліпшені шляхом попередньої термохімічної обробки сировини

Ключові слова: рослинна біомаса, ущільнене тверде біопаливо, пелети, біопаливо, енергетичний потенціал, деревні сільськогосподарські відходи

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Generalized indicator of the quality of qualimetry objects of various nature

Natalia Kim*

PhD in Technical Sciences
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0002-1110-8522

Abstract. The production of high-quality products stimulates Ukrainian manufacturers to enter the European and international markets, which at the same time stimulates domestic manufacturers to produce competitive products on a par with high-quality foreign alternative products. The promotion of competitive high-quality products to the European and world markets will make it possible to strengthen the national currency, which will actively contribute to the improvement of the economy of Ukraine, will create appropriate conditions for the development of entrepreneurial activity, fair competition, and improvement of the level of well-being of the population. The only approach to evaluating the quality of products is designed to quickly monitor indicators throughout the entire cycle of its production. In order to most economically and quickly achieve the goal in the field of qualimetry without violating the current restrictions, there is a need to optimize the requirements for product quality indicators. There are a number of methods that have their own advantages and disadvantages for each object of quality measurement. The purpose of the work is to analyze the mechanisms of quality metrics and to combine their advantages into a joint assessment model. The research was conducted using the methods of analysis, synthesis, comparison, generalization and induction. The article presents the methodology for determining the generalized quality indicator of quality measurement objects of various nature, including: products, technological processes, systems, or anything that requires a step-by-step assessment. Based on the analysis of existing non-linear relationships between the measured quality indicator and its assessment on a dimensionless scale, a method based on the use of generalized quality indicators is proposed. The application of the proposed method will provide a high-precision assessment of a wide range of objects with the fixation of changes over time

Keywords: technological process, shape parameter, production cycle, use of statistical information, mathematical dependence

INTRODUCTION

Production of high-quality products enables Ukrainian manufacturers to enter European and international markets, which in turn stimulates national manufacturers to produce competitive products alongside high-quality foreign counterparts. Promotion of competitive high-quality products to European and world markets will strengthen the national currency, which will contribute to the growth of the economy of Ukraine, will create favorable conditions for the development of entrepreneurial activity, fair competition, improvement of life and health of the population.

Leaders of the world economy have proven that in order to achieve high results in the field of quality, a constant process of their evaluation, research and management is necessary. Qualimetry objects have a different nature, and it is not always possible to measure their quality indicators, so they have to be evaluated by various existing methods [1]. Objects of various nature can include products, services, products, processes, systems or anything that is subject to evaluation for the purpose of quality management.

To maintain a high level of product quality, there should be a single approach to evaluation that will be applied at all stages of the product production cycle. A typical product production cycle includes the stages of its creation from raw materials to finished products. Each

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*Corresponding author

of these stages has its own quality indicators, established in regulatory documents of different levels and periods of publication with different units of measurement.

It is not always advisable to increase all indicators of product quality. Products must be competitive, that is, the ratio of quality and price must meet the requirements of consumers. Therefore, it is necessary to optimize the requirements for product quality indicators. Optimization consists in determining and establishing such values of quality indicators, at which the set goal in the field of quality is most economically and quickly achieved without violating existing restrictions, that is, laws or regulatory documents.

As an optimization method, a method based on the use of generalized quality indicators is proposed. With this approach, a number of advantages are achieved, which include increasing the methodological reliability of quality assessment, reducing the list of controlled indicators, the possibility of unifying diagnostics, etc. However, there are certain difficulties associated with the definition of a generalized quality indicator.

A number of scientific works by domestic scientists are devoted to the problems of assessing the quality of quality measurement objects. B.I. Stadnyk [2] in his works considered the main problems of the development of qualimetry, namely, the use in the theory and practice of qualimetry of the conceptual concept "qualimetric measurements" as one of the types of measurements, which in turn made it possible to combine the methodology of qualimetry and metrology and significantly to expand the capabilities of qualimetry regarding the reliability and accuracy of the obtained product quality assessments. R.I. Baitsar [3; 4] proposed a method of harmonizing the quality management system of an industrial enterprise according to the new ISO 9001:2015 standard, this method makes it possible to more efficiently organize the passage of information flows, decentralize responsibility for product quality, and improve interaction with the customer. In the works of P.G. Stolyarchuk [5], the essence of methods and means of determining product quality indicators is revealed, the peculiarities of classification and application of quality indicators for various types of products are indicated, and the basic provisions of qualimetry are also outlined. Considerable attention is paid to the applied aspects of determining the quality indicators of objects of various nature and their application. M.I. Novytskyi [6] described a systematic approach to product quality management and considered the organizational and methodological foundations of product certification and metrological activity. H.G. Azgaldov [7] is generally the initiator of the creation of the scientific discipline of qualimetry, which studies the methodology and problems of quantitative assessment of the quality of objects of any nature: objects or processes, products of labor or products of nature that have a material or spiritual nature.

In the scientific works of foreign scientists: C. Fletcher [8], L.C. Struckenbruck [9], P.G. Tzamalis, D.B. Panagiotakos, E.H. Drosinos [10], M.F. Rebelo, G. Santos, R. Silva [11], topical issues of quality assessment of of quality metrics, namely how to manage quality and projects.

The analysis of the scientific literature of domestic and foreign authors showed that the existing methods are mainly aimed at evaluating the quality of products and consist in the averaging of single quality indicators when determining a complex or integral quality indicator [12]. This approach should not be used to assess the quality of such quality metrics as processes or systems.

The purpose of the article is to study the method of determining the generalized indicator of the quality of quality measurement objects of various nature, including products, technological processes, systems, or anything that is subject to evaluation. Therefore, the task was set to develop and scientifically substantiate new quality assessment methods that would take into account the heterogeneity of indicators of objects of different nature.

RESEARCHING THE MECHANISMS OF QUALITY METRICS AND COMBINING THEIR ADVANTAGES INTO A COMMON ASSESSMENT MODEL

In qualimetry, when assessing the quality of objects of various nature, an important place is occupied by the type of dependence between the measured quality indicator and its assessment on a dimensionless scale. After all, quality indicators are not always evenly distributed and do not always have a linear mathematical relationship with their assessment. The development of objective mathematical dependencies is a time-consuming and urgent task that requires a deep and comprehensive study of the object, which can be explained by the fact that in most existing methods of quality assessment fairly approximate formulas are used, which poorly reflect the main ideological principles of the quality assessment process [12].

To ensure and maintain a high level of product quality, there should be a single approach to evaluation, that is, there should be a single metric that will be used at all stages of the product life cycle. One of these approaches is to consider the production of products at all stages of the life cycle as a single technological system aimed at obtaining high-quality products. A typical production life cycle includes the stages of its creation from raw materials to finished products. Each of these stages has its own quality indicators, established in regulatory documents of different levels and periods of publication with different units of measurement.

A technological system is understood as a set of interconnected technological processes, equipment, equipment, devices for measurement, analysis and control, as well as a management process intended for the manufacture of products. The basis of such a technological system is information integration of all stages of product creation.It involves the use of information models that describe products and their production technologies, which allows having the same methods of managing processes. In such conditions, some quality indicators may be underestimated, which may lead to a decrease in the quality of finished products or an increase in the price of subsequent operations, while others may be overestimated, which will increase their cost [13].

For the effective use of information models operating within the technological system, it is desirable to have a unified system for evaluating the quality of products and technological processes at all stages of the life cycle of its creation. This will improve the efficiency of using statistical information.

To optimize quality indicators, it is necessary to carry out a number of works in order to obtain additional information or reduce its uncertainty. There is always uncertainty, so there is a problem of finding a compromise, for example, between the cost and the quality of the product [14].

To optimize quality indicators, it is proposed to use a method based on the use of generalized quality indicators. With this approach, a number of advantages are achieved, which include increasing the methodological reliability of quality assessment, reducing the list of controlled indicators, the possibility of unifying diagnostics, etc. However, there are certain difficulties associated with the definition of a generalized quality indicator.

Determining the generalized indicator of product quality is related to the creation of a single assessment that quantifies quality through its indicators. The task can be solved by introducing a single artificial metric for all indicators of product quality and processes. The set of values of each quality indicator needs to be matched with a certain standard analogue, with a single quality rating scale from zero to one. This scale should be the same for all indicator values. The construction of this scale is related to the distribution of quality indicators as random variables. This task can be solved by combining single evaluations of product quality indicators with a generalized quality indicator.

Any quantitative assessment of quality defined by a single number is a point estimate and is subject to error. Therefore, the task was set - in addition to the point generalized assessment of product quality, to find a generalized interval assessment of quality, which allows optimizing quality indicators at all stages of the product life cycle and creating a unified system of assessing the quality of technological systems.The definition of a generalized indicator of product quality is related to the creation of a single assessment that quantifies quality through its indicators. The task can be solved by introducing a single, artificial metric for all quality indicators of products and processes.

To solve the set goal, an analysis of the existing non-linear dependencies between the measured quality indicator and its assessment on a dimensionless scale was carried out and, taking into account their shortcomings, a new type of dependencies is proposed:

$$f(q) = \frac{1}{1+ab^{-kq}}, \qquad (1)$$

where a, b – coefficients of process quality indicators; q – quality indicator; k is a shape parameter that affects the function, it is used to evaluate processes of different importance with different quality requirements [15].

The coefficients a and b are found as:

$$b = b_1^{\frac{1}{(q\,min - q\,max)}}, \qquad (2)$$

$$b_1 = \frac{(1-q_{max})q_{min}}{(1-q_{min})q_{max}}, \qquad (3)$$

q_{min} and q_{max} – are the minimum and maximum permissible value of a single quality indicator.

After normalization, the coefficient a is found as:

$$a = \frac{(1-q_{min})}{q_{min}}\, b^{kq_{min}}. \qquad (4)$$

Function (1) has an inflection point at $q_{inf} = \frac{ln\, a}{k\, ln\, b}$.

The shape parameter k affects the steepness of the function along the OX axis. By changing k, it is possible to control the curvature of the function (1) and thus obtain different estimates with the same results of the quality indicator measurements.

In graphic form, dependence (1) at k=1 is shown in Figure 1. On Figure 1 quality indicator is conditionally selected, which varies from S_{min}=0.1 до S_{max}=0.2 with a step of 0.01 to visually show the type of dependence (1). Regardless of the units of measurement and the digits of the value of the quality indicator on the OX axis, the type and form of the dependence will not change. A change in the shape parameter – k will lead to a change in shape. How to choose this parameter is the goal of further research.

Figure 2 shows a series of five dependences, with k varying from 1.2 to 0.8 in steps of 0.1 from left to right. On the OX axis, the scale corresponds to the scale of measurement units and can be changed for each individual quality indicator. The leftmost value on this scale "0" corresponds to Q_{min} – the minimum permissible value of the quality indicator. The extreme right value on this scale "1" corresponds to Q_{max} – the maximum permissible value of the quality indicator. They correspond to the respective values of each individual quality indicator. So, if the object of qualimetry has n quality indicators, then for each of them it is necessary to determine the coefficients a and b according to formulas (4) and (2), respectively.

Figure 2 shows that with a quality indicator of 0.6, measured in units of measurement, its assessment on a dimensionless scale varies from 0.95 at k =1.2 to 0.43 at k=0.8. So, having one measured value of the quality indicator of any object of qualimetry, we can obtain a range of values of its estimates on a dimensionless scale. Such a situation allows you to choose one of the power indicators in function (1) and change the estimate of the measured quality indicator q on a dimensionless scale. The size of the interval of quality indicators estimates on a dimensionless scale with different parameters of the form k is shown in Figure 3.

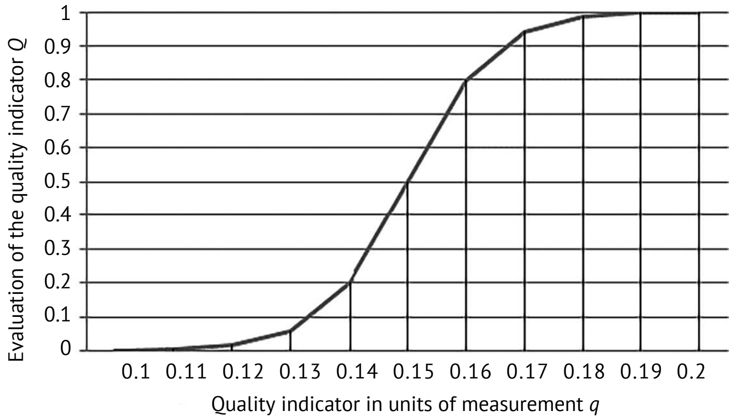

***Figure 1**. Type of dependence (1) at k=1.0*

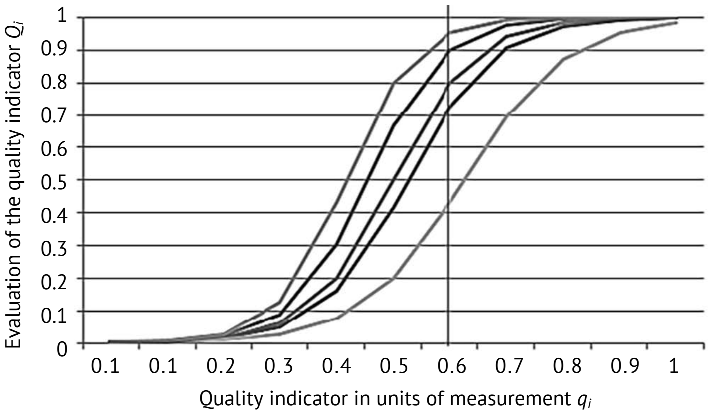

***Figure 2**. Series of dependencies (1) at k=1.2–0.8 with a step of 0.1 from left to right*

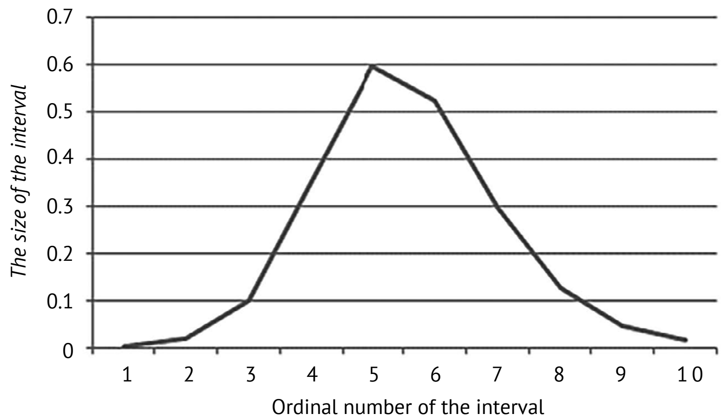

***Figure 3**. The value of the interval of quality indicators estimates on a dimensionless scale with different shape parameters k*

To obtain the values of the intervals, the value of the tolerance field $T=q_{max}-q_{min}$ was divided into ten parts, and the values of the intervals in each of them were determined. As shown in Figure 3, the largest interval of quality indicators on the dimensionless scale is in the middle of the tolerance field and is 0.6. Approaching the extreme values, the interval of estimates practically does not change. Therefore, it can be concluded that in the middle of the tolerance field, the shape parameter k has the greatest influence on the quality assessment.

In order to effectively apply the proposed mathematical relationship between the measured quality indicators and their assessment on a dimensionless scale in practice, when assessing the quality of qualimetry objects, it is necessary to know their numerical characteristics. This will make it possible to create a standardized methodology that will be universal and can be applied in the assessment of any objects of quality measurement, regardless of their complexity, etc.

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Let's consider a number of practical problems that may arise when evaluating objects of quality measurement [16]. For example, if we take the desirability function (1) and set by a fixed parameter of the form k, then it is possible to find the limits within which the quality indicator q must fall, provided that the value of its assessment Q_i is in the given interval [Q_{min}-Q_{max}]. Since the quality assessment interval on the dimensionless scale varies from "0" to "1", the condition must be fulfilled:

$$0<Q_{min}<Q_i<Q_{max}<1, \quad (5)$$

where Q_{min} and Q_{max} are the lower and upper limits of the given interval of assessment of Q_i on the dimensionless scale OY. Therefore:

$$Q_{min} = f(q_{min})\frac{1}{1+ab^{-kq_{min}}}, \quad (6)$$

where q_{min} – the value of the quality indicator on the OX axis, which corresponds to its Q_{min} rating on the OY scale at the given shape parameter k. After performing the transformation, we will obtain the minimum value of the quality indicator q_{min} – on the OX axis, which corresponds to its estimate Q_{min} on the OY scale with the given shape parameter k:

$$q_{min} = \frac{1}{-k\ln b}\ln\frac{1-Q_{min}}{aQ_{min}}. \quad (7)$$

Accordingly, in the same way we can obtain the maximum value of the quality indicator q_{max} – on the OX axis, which corresponds to its estimate Q_{max} on the OY scale at the given shape parameter k:

$$q_{max} = \frac{1}{-k\ln b}\ln\frac{1-Q_{max}}{aQ_{max}}. \quad (8)$$

Note that the length of the interval in which the measured indicator of the quality of the object of qualimetry should be located will be:

$$L = q_{min} + q_{max}\left(\frac{1}{-k\ln b}\ln\frac{1-Q_{max}}{aQ_{max}}\right) - \\ -\left(\frac{1}{-k\ln b}\ln\frac{1-Q_{min}}{aQ_{min}}\right). \quad (9)$$

Let the limits of estimates of the quality indicator of the object of quality measurement Qi be specified in the given interval [Qmin-Qmax] as follows:

$$0<Q_{min}<Q_i<Q_{max}<1, \quad (5)$$

and the measured value of the quality indicator qi is known, then it is possible to find the interval for the measured quality indicator q, at which the fulfillment of the condition (5) will be guaranteed. In other words, let's define all the functions that, at a given (measured) value of q, will provide a given quality assessment on a dimensionless scale.

As a result of algebraic transformations, we get an interval:

$$\frac{1}{-k\ln b}\ln\frac{1-Q_{max}}{aQ_{max}} > q >> \frac{1}{-k\ln b}\ln\frac{1-Q_{min}}{aQ_{min}}. \quad (10)$$

So, in this way, it is found the interval in which the measured quality indicator q should be at the given evaluations on the dimensionless scale OY.

Let's set one more possible condition. Let a fixed estimate of the indicator $Q_i=x$ be given, while the measured value of the quality indicator q is in the interval [q_{min}-q_{max}], then it is possible to determine the range of values of the shape parameter k, at which the given conditions will be fulfilled [17]. In other words, let's define all the functions that, given the range of given (measured) values of q, will provide a given quality estimate Q_i=x on a dimensionless scale. To solve this problem, it is solved equation (1):

$$f(q) = \frac{1}{1+ab^{-kq}}. \quad (1)$$

According to condition (5):

$$0<Q_{min}<f(q)<Q_{max}<1. \quad (11)$$

So:

$$Q_{min} < \frac{1}{1+ab^{-kq}} < Q_{max}. \quad (12)$$

As a result of mathematical transformations, we will obtain an interval for parameters of the form k of function (1), in which condition (11) will be fulfilled:

$$\frac{1}{-q\ln b}ln\frac{1-Q_{max}}{aQ_{max}} < k < \frac{1}{-q\ln b}ln\frac{1-Q_{min}}{aQ_{min}}. \quad (13)$$

So, with the help of desirability functions, it is possible to determine a number of useful numerical characteristics of process quality indicators, using which you can manage quality estimates, reduce or increase them, which will allow you to effectively manage the quality of qualitative objects of various nature.

As a result of the given formulas, we can get an estimate of a single quality indicator on a dimensionless scale. But, as a rule, it is necessary to know the estimate of the generalized dimensionless quality indicator, which consists of n indicators. As a generalized indicator of quality, it is suggested to find one of the averages: arithmetic average; medium harmonic; geometric mean.

Taking into account the ideology of quality assessment, it is proposed to use the geometric mean value of individual quality indicators as a generalized indicator, since the geometric mean is less than the arithmetic mean value and, most importantly, if at least one of the quality indicators Q_i is zero, then the generalized value of the quality indicator W will also be zero. Also, W=1 if and only if all single quality indicators Q_i=1. In addition, note that the generalized value of the quality indicator W is very sensitive to small values of the single quality indicators Q_i. That is, if one of the individual quality indicators is close to zero, it will significantly affect the generalized quality indicator.

So, the generalized quality assessment can be found using the formula:

$$W = \sqrt[n]{\prod_{i=1}^{n} Q_i}, \quad (14)$$

where Q_i – value of the i-th quality indicator on a dimensionless scale. Also, to determine the generalized quality indicator, it is possible to recommend an assessment in a different form, for example, determine W by the formula of the harmonic mean, since the geometric mean of positive values is greater than or equal to their harmonic mean

$$\frac{1}{W} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{Q_i}, \quad (15)$$

where Q_i is a unit estimate of the i-th quality indicator, calculated according to formula (1).

Another generalized quality estimate W can be proposed as the arithmetic mean of the single values Q_i determined by formula (1), since the arithmetic mean is greater than the geometric mean and the harmonic mean:

$$W = \frac{1}{n}\sum_{i=1}^{n} Q_i. \quad (16)$$

By choosing a method for obtaining a generalized quality indicator, you can lower or raise the requirements for object quality assessment.

We offer a step-by-step method for determining the generalized indicator of the quality of the object of qualimetry:

1. Determination of single indicators of the quality of the object of qualimetry. As a rule, those quality indicators that are decisive for this object, established by regulatory documents, determined by the consumer (customer) and managed are defined. They can be identified by a group of experts.

2. For each of the unit quality indicators, their maximum permissible, minimum permissible and optimal (best) values are determined.

3. These quality indicators are measured, and the results are recorded in a specially prepared table.

4. Formula (1) determines the assessment of a single quality indicator on a dimensionless scale. For this, it is necessary to use formulas (2-4) and assign the shape parameter *k*. The form parameter is determined depending on the level of the quality indicator: high, medium, low or general, and depending on the importance and responsibility of the indicator. The form parameter is assigned either by a group of experts or by the customer (consumer).

5. The level of the generalized quality indicator is determined: high, medium or low, depending on the importance and responsibility of the object. It is recommended to use formula (14) at a high quality level, (15) at an average level, and (16) at a low level. In any case, determining the method of obtaining a generalized quality indicator is a debatable task and is decided in each individual case.

CONCLUSIONS

To maintain a high level of product quality, there should be a single approach to evaluation that will be applied at all stages of the product production cycle. A typical product production cycle includes the stages of its creation from raw materials to finished products. Each of these stages has its own quality indicators, established in regulatory documents of different levels and periods of publication with different units of measurement.

Based on the analysis of scientific sources and existing non-linear relationships between the measured quality indicator and its assessment on a dimensionless scale, a technique based on the use of generalized quality indicators is proposed.

The proposed methodology can be used to evaluate the quality of objects of various nature, including products, technological processes, systems, or anything that is subject to evaluation. If you evaluate objects in a certain order, you can build a time series of changes in quality indicators over time and get additional generalized information for making management decisions. When using this technique, a number of advantages are achieved, which include increasing the methodical reliability of quality assessment, reducing the list of controlled indicators, the possibility of unifying diagnostics, etc.

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Узагальнений показник якості об'єктів кваліметрії різної природи

Наталія Кім

Кандидат технічних наук
Миколаївський національний аграрний університет
54008, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0002-1110-8522

Анотація. Виготовлення якісної продукції стимулює українських виробників до здійснення виходу на європейські та міжнародні ринки, що водночас стимулює внутрішніх виробників до випуску конкурентоспроможної продукції на рівні з високоякісними закордонними альтернативними товарами. Просування конкурентноспроможної високоякісної продукції на європейські та світові ринки дасть змогу укріпити національну валюту, що активно сприятиме покращенню економіки України, створюватиме належні умови для розвитку підприємницької діяльності, справедливої конкуренції, покращення рівня благополуччя населення. Єдиний підхід до оцінювання якості продукції покликаний оперативно відстежувати показники впродовж усього циклу її виготовлення. Для найбільш економічного і швидкого досягнення мети у сфері кваліметрії без порушення діючих обмежень постає необхідність оптимізації вимог до показників якості продукції. Існує низка методів, що мають для кожного об'єкта кваліметрії свої переваги та недоліки. Метою роботи є аналіз механізмів кваліметрії та поєднання їх переваг у спільну модель оцінювання. Дослідження проводилося із використанням методів аналізу, синтезу, порівняння, узагальнення та індукції. У статті представлено методику визначення узагальненого показника якості об'єктів кваліметрії різної природи, серед яких: продукція, технологічний процес, система, чи будь-що, що потребує поетапного оцінювання. На основі проведеного аналізу існуючих нелінійних залежностей між вимірюваним показником якості та його оцінкою на безрозмірній шкалі пропонується метод, заснований на використанні узагальнених показників якості. Застосування запропонованого методу дозволить надати високоточну оцінку широкого спектру об'єктів з фіксацією змін у часі

Ключові слова: технологічний процес, параметр форми, цикл виробництва, використання статистичної інформації, математична залежність

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тел.: +38(0512) 70-93-54
E-mail: info@bsagriculture.com.ua
www: https://bsagriculture.com.ua/uk

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