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Article

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Specifics in Modelling of Energy Efficient Production in Agribusiness

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ABSTRACT

A resource potential in agribusiness is a roundup indicator of resource availability. Its assessment and efficiently used resources govern a level of competitiveness of farm products among enterprises that have various operating practices. Power industry is a significant component of the resource potential. Greenhouses that operate in unfavourable natural and climatic conditions are an indicative example in this field. The study of practices that Russian agribusiness has will make it possible to identify strong component dependencies and challenges that businesspeople face when they introduce energy-saving solutions. Having reviewed corresponding sources, authors conclude that robust control aims at corrections to be made to the rule of uncertainty of conditions that govern the high energy/output ratio in greenhouse facilities. Based on the correlation/regression and index analysis they have established that the return rate in production of vegetables grown under cover depends on following three components: The specific gravity of costs for natural gas and other heat supply sources, the share of costs for electricity and capital-labour ratio. Findings imply that energy efficiency in national agribusiness was insufficient. Authors justify a need for a substantial increase in a use of alternate energy sources with mostly decentralized distribution.

Keywords: Agribusiness, Energy Efficiency, Greenhouse Industry, Resource Potential, Energy Supply, Cost Factor Analysis
JEL Classifications: O13, Q42, Q47

1. INTRODUCTION

The energy development in agribusiness is a priority direction in economy modernization. Importance of energy saving in agribusiness is clearly visible when experts review costs of enterprises. Costs for fuel and energy resources in the cost structure in Russian agribusiness are 15-20%, while in some producing unites, they are 30-40% (Tikhomirov, 2016). Note that a demand for energy resources significantly differs among various branches of farming. At the same time, consistency in energy supply significantly influences quantitative and qualitative indicators in agribusiness.

A search for solutions to the problem of efficiency in agribusiness is among central issues in the strategy of social and economic development. An inefficient use of technical and energy resources is getting a key factor for lower competitiveness of agribusiness products. Empirical estimates made by researchers convincingly indicate that today's Russian agribusiness is highly energy-consuming (Lisjutchenko and Polukhin, 2012. p. 20-26). That is why the problem of the improved energy saving business mechanism has recently become particularly relevant.

More intensive methods of operation in greenhouses and resource saving in production of vegetable grown under cover (protected ground) have become an important direction in efforts to decrease the energy/output ratio. It is noteworthy that a share of energy resources in the production cost of vegetable grown under cover has increased by 50-60% over the past few years (Chazova and Dolgovykh, 2012. p. 72-76; Gonova et al., 2016. p. 111-118). As a consequence, to achieve reasonable consumption of energy resources and, accordingly, decrease the production cost, activities in agribusiness should focus on introduction of technical, technological, and administrative procedures. Numerous researches on food and economic security focus on the price factor as a source of the market equilibrium (Kuzmin, 2016. p. 37-44). At the same time, researchers mention that the national food market is more susceptible to volatility of prices for agricultural resources and foods than the global market. These circumstances once again highlight applied significance of a review of energy-saving measures in agribusiness, an ultimate goal of which is a lower production cost.

A search for reserves that allow production cost reduction centres on estimations of costs and a factor impact on dynamics of indicators. A separate scientific mission is energy efficiency modeling for various operating practices. An indicative example of a greenhouse will make it possible to follow up explicit regularities available in the production cost structure and gives a complete sense of those costs that might be minimized. In a design of energy supply systems, justification and a choice of the most effective option opens doors to the most reasonable use of resources and lower energy consumption and energy/output ratio of agribusiness products.

2. REVIEW OF LITERATURE

Greenhouse agribusiness is usually an industry with a high energy/output ratio. In this connection, the introduction of energy-saving solutions has been recently highly pressing and scientists have been faced quite an acute problem of how to make an energy/output ratio less than it is now. Calculations made by Soloshenko and Kurasova (2011), Minakov (2015) and Gushcha (2016) generally imply that farming of vegetables grown under cover is one of the most complex and labour-consuming branches in agribusiness.

Secure and efficient energy supplies to rural consumers, the value of costs and, consequently, production energy/output ratio largely depends on an adopted energy supply system, energy products used and an amount of energy losses. As a result, a rationale and choice of a rational energy supply system in design of rural facilities is by far the most important task in deployment of energy supply systems. Therefore, it makes sense to consider robust design and correlation-regression analysis among the other tools leading to solutions to this problem. This approach implies a choice of operating practices for a facility with the least troubled state, when a small change in parameters of the controlled facility results in a small change in an "output" of the control system.

A search for methods and means of energy cost reduction is the main task in robust design in agribusiness production planning (De Goede, 2014; Napel et al., 2006). It is obvious that the applied methodology for modeling of energy consumption and production resource cost planning is a promising area of research focused on applications of robust control as their main topic. Thus, Guiver et al. (2016) believe that in robust design, it is reasonable to pay special attention to environmental positions of production processes. Urruty et al. (2016: 15) believe that robust design is an opportunity to make a sustainable system that operates under conditions of higher uncertainty. De Goede et al. (2013) adhere to the similar position. In their paper, they observe that in agribusiness robust control is extremely necessary as cropping generally goes under uncertainty. If we say that it is possible to apply such systems as part of more complex designs, then forecasting of their operation is quite a controversial point. Bojariu et al. (2014) adhere to the stand that one of the tasks in robust control in agribusiness is consideration of all the dangerous region-specific meteorological phenomena. It is obvious that a quality of a natural environment determines sustainability in the development of eco-systems and productive efficiency of crops (Naylor, 2008) that finally results in economic indicators that give or do not give evidence of efficiency in agribusiness (Clay et al., 2003).

Li (2014) focuses on process improvements in existing greenhouse production facilities applying intelligence control systems. Li believes that efficiency of such enterprises largely depends on introduction of breakthrough solutions and energy saving management. Main components in energy consumption management are the energy audit of an enterprise (Turhan et al., 2008; Redick, 2014), continuous monitoring and arrangements for accounting of energy resource consumption (Zisopoulos et al., 2017), as well as limited resource consumption.

The review of the energy consumption structure based on empirical studies shows that greenhouses have a high potential for resource saving (for example, in irrigation and energy consumption (Buttaro et al., 2015; Ahmad et al., 2017). Measurements of their energy saving potential relate to an in-detail review of a factor influence of energy costs on financial and economic indicators of activities carried out by a greenhouse facility.

It seems difficult to disagree with Chazova (2009) saying that there are extremely small opportunities for making under-cover environments with controlled processes for cropping are small. Therefore, it is only worth talking about a search for a way to minimize a negative impact from the main factor in the process of crop growing by making the best strategy for energy saving.

3. METHODS

One should say that a use of productive resources is efficient if there is the highest increase in the efficiency factor owing to the use of consumable resources in contrast to prevailing multi criteria methods for sustainability score in agribusiness (Bockstaller et al., 2009). This approach, firstly, makes it possible to compare an actually achieved result with a possible one, thus making an assessment of business in an agricultural enterprise. Secondly, it allows us to identify an amount of missed opportunities, comprehensively examine a cause of them and, based on that, develop measures for a better use of production resources. Third, implementation of this approach creates conditions for an objective rating of activities in an enterprise, regardless of its size, profile, and location.

To achieve high efficiency in agribusiness, it is necessary to monitor processes aimed at reducing costs of resources per unit of output. This encourages a search for reserves to reduce costs of energy and other resources that make a core of the production cost.

This includes, in particular, calculations of an 'energy' received from an entire yield of crops grown. The total energy accumulated in the yield of a crop is calculated by formula:

$$A_{oi} = \frac{\varepsilon_0 \times O_i}{A} \quad (1)$$

where ε_0 is a total energy, accumulated per unit of the main crop, MJ/kg; O_i is a yield of core products, kg/ha; A is a conversion factor with considered humidity and other characteristics of the yield.

Make a multifactor model for a dependence of a level of specific energy consumption per product unit Y on values of integral criterion OTRP (organizational and technical rate of production). Having assumed that a connection between all the exposures and the resultant is of a rectilinear character, it is possible to use the linear function for these dependencies to be recorded:

$$Y_{k1\_OTRP=}b_0+b_1k_{1\_OTRP} \quad (2)$$

Where Y_{k1_OTRP} is a function of dependence of specific energy consumption on integral criterion OTRP (specific energy consumption per production of a ton of finished products, kW/year/t); K_{1_OTRP} is an integral criterion of OTRP.

The energy return index depends on a quantitative content of energy in a final product unit. At the same time, the greater is a specific gravity of energy in a final product, the higher its energy return is. The energy return of a product of the i-th type is calculated as follows:

$$\Delta^1 E_i = P_i(U,V) \quad (3)$$

where P is a function of an energy content per mass unit in a products of the i-th kind.

Taking into account the formula (3), the energy return is calculated as follows:

$$\Delta^1 E_i = \frac{\sum_{i=1}^{m} P_i(U,V) q_i}{Q} \quad (4)$$

Where q_i is gross output of goods of the i-th kind, kg; Q is gross output of final products, modified to the same kind, kg.

In that case, the bioenergetic transformation ratio of energy looks like:

$$r = \frac{\Delta^1 E}{\Delta E} \quad (5)$$

While for a good of the i-th kind:

$$r_i = \frac{\Delta^1 E_i}{\Delta E_i} \quad (6)$$

Where ΔE_i is process energy/output ratio in production of a good of the i-th kind, KJ/kg.

Measurements of energy efficiency centre on a measurement of its absolute level, i.e., energy products required to produce a unit of output and a measurement of a change to this level for a certain period. The energy efficiency growth index (I_{ee}) is calculated by formula:

$$I_{ee} = \frac{I_{GP}}{I_e}, \quad (7)$$

$$I_{ee} = \frac{e_1}{e_0}, \quad (8)$$

$$I_{B\Pi} = \frac{GP_1}{GP_0}, \quad (9)$$

Where GP_0, GP_1 refer to a value of gross output in agribusiness in coherence in reference and accounting periods; e_0, e_1 are production unit costs, respectively, in reference and accounting periods.

4. RESULTS AND DISCUSSION

In the production cost structure, a share of costs for heating, energy, and production facility capital-labour ratio are the most important indicators for an assessment of general energy efficiency of an enterprise. A rise in prices for energy products has in recent years had a negative influence on dynamics of the specific gravity of energy products in the production cost structure of an enterprise involved in production of vegetables grown under cover.

In order to find whether energy-saving solutions are efficiently introduced, we compared efficiency between several production units. In the research, we compared efficiency indicators in production of vegetables grown under cover between various alternative solutions. We mean typical greenhouses as a basic technology, low-capacity hydroponics as the Dutch technology, and customised greenhouses as an improved basic technology.

Estimates from an aggregated sample with n = 36 as a total number of observations across production units in the Teplichny farm imply a close relationship between profit and costs for energy products, as well as semi-constant costs, 0.59 and 0.52 respectively. We considered additional factors (Figure 1) where 1 is a share of costs for wages, 2 is a share of costs for energy products, 3 is a share of costs for reproductive material, 4 is a share of costs for protective equipment, 5 is a share of costs for preparatory works, and 6 is a share of semi-constant costs.

The evaluation of energy efficiency in production of vegetables grown under cover requires a detailed review of production costs considering their rate of return. Having completed the multi-factor correlation, we established a dependence of the rate of return (Y) for vegetables grown under cover (evidence from tomatoes) on three components. There are the specific gravity of costs for natural gas and other heat supply sources (X_1), the share of costs for electricity (X_2) and the capital-labour ratio (X_3). The general regression equation is:

$$Y = k_1X_1 + k_2X_2 + k_3X_3 + C \quad (10)$$

where C is absolute term in an equation regression and k_1, k_2, k_3 are beta coefficients.

Obtained regression coefficients are statistically significant. Calculated parameters of the correlation-regression analysis are given in Table 1.

Our calculations have resulted in the following model:

$$Y = (-0.538 * X_1) + (3.643 * X_2) + (0.208 * X_3) - 28.058$$

Findings imply that the production return rate is in a direct relationship to the specific gravity of costs for power supply in the production cost structure. An inverse relationship was found between specific costs for greenhouse heating (natural gas, etc.) and the return rate. The production return rate and enterprise profit depend on costs for energy products (gas, power supply), reproductive material, as well as reconstruction and operation of greenhouses (depreciation, maintenance), etc. In view of the fact that significant costs are required for greenhouse reconstruction, a high share of costs is associated with depreciation and greenhouse scheduled maintenance (in calculations, they are treated as semi-constant costs). Calculations showed a low level of correlation between these costs and the enterprise return rate (<0.3). The revealed dependence is largely explained with technical equipment that a production unit has.

The high correlation ratio (>0.7) was found between profit and energy products, as well as profit and costs for reproductive material (0.776-0.854). Findings from calculation are given in Table 2.

Measurements of energy efficiency include making a flow of resources and their analysis. Then it is necessary to define energy characteristics and indicators, review processes, choose necessary options in accordance with specified criteria and constraints. For this purpose, we reviewed the system of energy indexes.

Note that in part the company covered its costs for power supply at the expense of own generation of electricity with a lower production cost compared to a market level.

The reviewed dynamics of basic indicators for energy efficiency showed positive results and confirmed that it had been efficient to

Figure 1: Paired correlation coefficients for profit/cost factors dependence

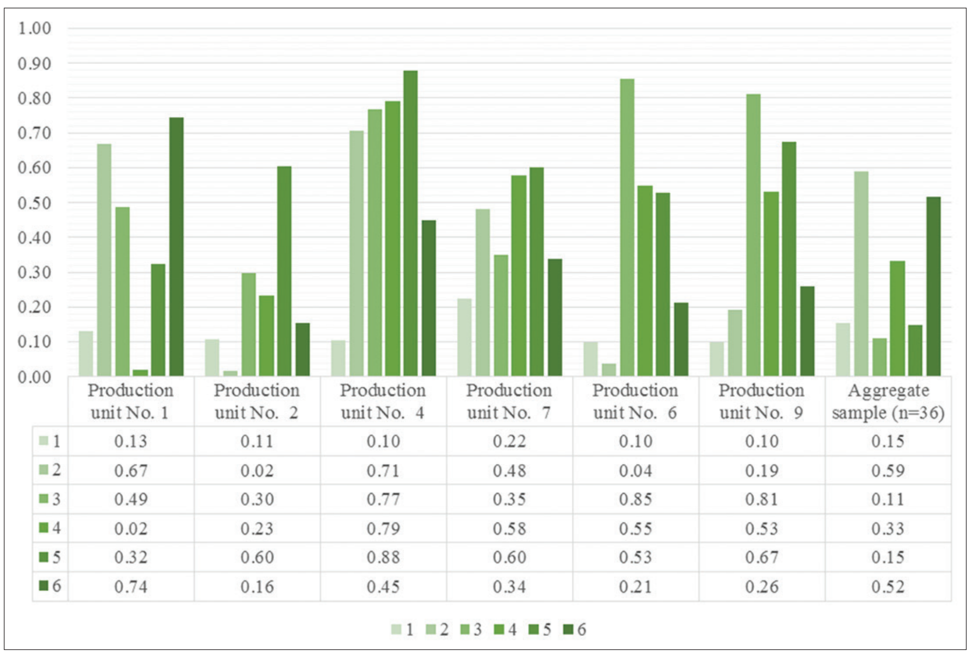

Table 1: Correlation/regression analysis

Analysis of variance					
Indicators	**df**	**SS**	**MS**	**F**	**Value of F**
Regression	3	3341.762	1113.921	15.81084	1.32E-05
Excess	21	1479.513	70.45299		
Total	24	4821.275			
Beta coefficients					
	Coefficients	**Standard error**	**t-statistics**	**Upper value P=95%**	**Lower value P=95%**
Y-Indicator	−28.058	5.498	−5.103	−39.4927	−16.6231
	−0.538	0.182	−2.964	−0.91616	−0.16059
	3.643	0.634	5.741	2.323486	4.96222
	0.208	0.039	5.388	0.127468	0.28770

introduce energy-saving solutions. The most significant decrease was −60.6 and −60.5% for production heat and energy/output ratio respectively (Table 3).

In the research, measurements were done for the growth index of energy efficiency, as well as gross output production rates and the growth index for the energy/output ratio. The analysis made for a number of years showed that efficiency in a use of energy resources was strongly variable depending on prices for energy resources and an aggregate output (Table 4). The positive index (more than 1) was only observed once in the period under review. This, other things being equal, might be considered a statistical error instead of a convincing argument for justification of a tendency. Negative indices (<1) for other years are a result of higher energy prices, especially in 2015, when the minimum value of the energy efficiency index (0.76) was recorded. There was quite a different situation in modeling of a use of other solutions in agribusiness.

To evaluate energy efficiency and production return rate for various operating practices, regression dependence indicators were applied obtained earlier in the research. Findings show that the introduction of the so-called Dutch solution (Dutch light houses) makes it possible to increase the production return rate by 4.5-7% (Table 5).

Thus, the analysis of energy cost dynamics using the econometric model in an agribusiness enterprise with various operating practices made it possible to identify in-house production reserves to improve the use of the resource potential. Note that in the production cost structure there is a tangible increase in the specific gravity of energy products (gas, electricity). This encourages a search for business measures for an efficient use of resources. A positive aspect is that the growth in energy efficiency leads to higher company's income, but this trend is not sustainable.

Based on the energy supply analysis, it is possible to declare that promising directions in the development of the resource base in agribusiness are new ways for the supply of power and heat energy, the development of decentralized gas-fired, electricity-fired and bio fuel-fired energy-supply systems, more efficient than centralized heat supply, and creation of autonomous local networks of distributed energy with a primary use of renewable and local energy resources.

5. CONCLUSION

The production cost is one of the main indicators of production efficiency in agribusiness. This production cost changes under an influence of dynamics of resource prices. This is particularly visual for enterprises that consume large amounts of energy. Vegetable and fruit greenhouses are exactly such enterprises

Table 2: Return/production cost structure dependence

Indicator	Return per 1 ha	Specific production costs, %				Facility
		Wage	Energy resources	Reproductive material	Semi-fixed costs	
	Y	Xa	Xb	Xc	Xd	
X	323.0	22.73	38.79	2.27	29.98	Production unit No. 1
±x	148.7	1.97	5.86	0.64	6.41	
σ		19.37	171.7	2.04	205.2	
Cv		3.22	28.61	0.34	34.19	
R x/y		0.132	0.667	0.487	0.743	
X	335.0	25.73	38.52	2.17	27.42	Production unit No. 4
±x	102.7	1.37	3.21	0.46	2.00	
σ		16.9	76.04	1.75	29.5	
Cv		3.38	15.21	0.35	5.90	
R x/y		0.103	0.705	0.767	0.450	
X	860.8	24.82	28.51	2.17	36.95	Production unit No. 7
±x	63.44	2.28	4.70	0.17	5.33	
σ		44.53	188.5	0.25	286.3	
Cv		8.91	37.70	0.05	57.26	
R x/y		0.223	0.480	0.351	0.338	
X	641.3	24.07	36.25	2.07	31.04	Production unit No. 6
±x	94.75	0.93	3.02	0.15	2.52	
σ		4.70	51.04	0.13	32.96	
Cv		1.57	17.01	0.04	10.99	
R x/y		0.099	0.037	0.854	0.211	

BT is basic technology, DLH is Dutch light house technology; IBT is improved basic technology, ±x is mean statistical error, Σ is standard deviation, Cv is indicator's coefficient of variation and R x/y is correlation ratio

Table 3: Core indicators of energy efficiency

Indicator	Year					
	2011	2012	2013	2014	2015	2016
Product heat capacity	8.10	5.58	4.82	4.77	4.51	3.19
Product energy/output ratio	8.30	5.76	4.98	4.94	4.63	3.28
Energy/output ratio of fixed capital assets	6.27	4.39	4.27	5.25	5.42	3.27

Table 4: Economic evaluation of energy resource consumption efficiency

Indicator	Year				
	2011	2012	2013	2014	2015
$I_e = e_1/e_0$	1.32	1.48	1.04	1.25	1.56
$I_{вп} = ВП_1/ВП_0$	1.24	1.21	1.1	1.24	1.19
$I_{ee} = I_{вп}/I_e$	0.94	0.81	1.06	0.99	0.76

Table 5: Prospective production return rate, %

Indicator	Technology			
	Dutch light house	Standard indicator	Basic production units	DLH (±) to BT
Aggregate	9.52	6.29	4.85	+ 4.67
Maximum	14.78	8.92	7.85	+ 6.93

The research on dynamics of energy costs in an agribusiness enterprise applying various operating practices led us to the conclusion that efficiency in the use of energy resources varies and varies strongly depending on energy prices and a total output. Having completed the multifactor correlation analysis, we established the dependence of the return rate of vegetables grown under cover on three components. There are the specific gravity of costs for natural gas and other heat supply sources, the share of electricity costs and capital-labour ratio. Resulting regression coefficients are statistically significant. The high correlation coefficient (>0.70) was obtained for profit and energy products, as well as for profit and costs for reproductive material (>0.75). Based on the found regularities, it is possible to identify with confidence an area for improvements at an enterprise, which will make it possible to use in-house production reserves of the resource potential with the highest efficiency.

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