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CONSERVATION LAW OF PLANTS' ENERGY VALUE DEPENDENCE OF PLANTS' NEED IN NUTRIENTS ON BIOCHEMICAL COMPOSITION

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ABSTRACT

The plants differences in biochemical composition are analyzed, and the conservation law of energy value in plants is obtained. The link between the need for the nutrients and the plants biochemical composition is examined, Liebig's law is specified.

Keywords: plant's biochemical composition, biochemistry, energy value in plants, plants' nutrition.

INTRODUCTION

"Global population growth and the increase in the number of starving and malnourished people, changes in dietary habits, and thus the demand increase for food require the significant intensification of the agricultural output. Therefore, the majority of the civilized countries of the world pays special attention to the development of the high-yield farming, the soil fertility recovery and the provision of the high-quality food for the population. Mineral and organic plants fertilizers are one of the boosting factor in farming and plant growing intensification" (Nechaeva and Bykova, 2014)

The increase of crops yield capacity is one of the key challenges faced by a mankind. Efficient use of mineral fertilizers is the most crucial factor for the agriculture intensification. It has widely been known that every crop requires its own individual amount of nutrients.

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There is a rationale to identify the underlying determinants for the nutrients necessary for the appropriate growth of plants provided the other factors (humidity, temperature, light, etc.) are adequate for the specified yield capacity of the crops. If we refer to the principle from Liebig's law of the minimum and Shelford's law of tolerance which states that with any yield capacity the factors are within the tolerance range, i.e. not higher and not lower the critical levels, then the element content in the plants given further matches the optimal level for the specified yield capacity.

Generally, all annual plants contain the same substances: carbohydrates, protein, fats and water, but they are different in the substances' proportions. For a person, the energy value of a plant is of importance, and this value, in its turn, is characterized by the amount of protein, fats and carbohydrates. It is obvious that the plant nutrition depends on its chemical composition, and the solution for the problem is interdisciplinary - biochemistry and agrochemistry.

Research

First, it is necessary to gather the information and to categorize all plants by their biochemical composition. It is not possible to find the data on the biochemical composition of the plants, that is why certain work was carried out to find the information about the biochemical composition of fruits and the plants' need in nutrients.

As the paper describes a wide variety of crops, the fruits are the edible part of a plant (corn, beans, roots, tuberous roots, etc.)

Latter calculations show that the average need of soybean in nitrogen leads to the negative result for protein in fruit-free plant weight, that is why for the further calculations, soybean need in nitrogen is supposed to equal the maximum need of 326 gr per 5 kg of yield by the source (Adamenko and Kostyushko, n.d.), which is 62.5 gr per 1 kg of yield.

In the initial data the carbohydrate content is supposed to be the person-consumed carbohydrates, therefore for the further calculations it is necessary to know the overall amount of carbohydrates including the undigested fiber.

Fiber share of digested carbohydrate weight for all plants is on average 25 %. Keeping it in mind the overall amount of carbohydrates is taken to be 1.25 time more than the amount of digested carbohydrates.

To identify the link between the biochemical composition of a plant and the nutrient consumption, it is important to know both the biochemical composition of fruits and the biochemical composition of all fruit-free plant weight.

All nitrogen consumed by a plant is spent on protein and nonprotein compounds formation. Average content of nitrogen in protein and nonprotein compounds is 16% (Smirnov and Muravin, 1977). With the need of a plant in nitrogen, one can accurately calculate the overall protein content.

* We take the maximum need of soybean in nitrogen as the average values of soybean need in nitrogen give the negative value of protein in fruit-free plant weight.

It may be assumed that the biochemical composition of fruit-free plant weight and biochemical composition of herbaceous plants can be similar. Let us consider the biochemical composition of feedstuff herbage (Table 14) and check the stability of biochemical composition, i.e. the preservation of the proportions between the protein, fats and carbohydrates with no regard to the type of feedstuff herbage.

Biochemical composition of feedstuff herbage is stable, but, first, let us check the biochemical composition of fruits without jumping to conclusion (Table 15).

Biochemical composition of fruits is also stable - the proportions between protein, fats and carbohydrates do not change regardless of fruit type (Figure 2). Let us compare the compositions in Table 16.

The content of protein and fats in herbage is a bit higher than in the fruits. This is likely to be explained by the seeds in feedstuff herbage. With this, for our further calculations of overall weight of a plant we use the biochemical composition of fruits (Figure 2).

Energy value (EV) of food is the amount of energy released from food in a person's body during the digestion provided the food is completely digested, and EV numerically equals the sum of energy values of protein, fats and carbohydrates in the food.

Energy value (EV) of a plant is the overall amount of energy accumulated in protein, fats and carbohydrates in the whole vegetative system of a plant, including all fibers. And the energy accumulated in fiber weight quantitatively equals the energy value of the same weight of digested carbohydrates as the same amount of energy is released when the same weight of carbohydrates and fibers is burnt.

From the source (Tablitsa kaloriynosti…, n.d.) the energy value of protein is 4.1 kcal/gr, that of fats is 9.3 kcal/gr, that of carbohydrates is 4.1 kcal/gr. The energy value (EV) of fats is 2.268 times higher than carbohydrate and protein EVs.

Photosynthesis is the only source of carbohydrates for all living organisms. Part of the carbohydrates from the photosynthesis under the impact from the enzymes is spent to form protein and fats.

To simplify the information understanding, let us introduce the concept of energy value equivalent (EVE) which equals the weight of all carbohydrates formed under photosynthesis during vegetation and is calculated by a formula:

EVE=P+2,268*F+C, where P, F, C are the protein, fats and carbohydrate weight respectively, and 2.268 is the coefficient of carbohydrate energy conversion into energy of fats.

With EVE we can find the energy value of plants by a formula:

EV=EVE (energy value equivalent) * 4.1 kcal

Let us graphically present the weight of protein, fats and carbohydrates of all plants in their dependence on EVE and add an interpolation line of dependence of protein, fats and carbohydrate weight with EVE lower than 400 (Figure 3).

The graph (Figure 3) shows that the wheat with EVE higher than 400 is also within this regularity. It can clearly been seen that such crops as colza and soybean significantly deviate from the interpolation line. We can see that colza has increased amount of proteins and fats but its carbohydrate content is greatly lower than the interpolation line illustrating the carbohydrate dependence on the energy value. The same is true for soybean with the increased protein content.

Let us find the energy value equivalent of deviations (Table 19).

EVE deviations tend to zero, that is why we may say that biochemical composition in colza and soybean is redistributed, and carbohydrate energy quantitatively transforms into the protein and fat energy.

With due regard to said above, it is necessary to introduce the concepts of the relative weights of protein (Pg), fats (Fg) and carbohydrates (Cg) which are directly proportionate to the energy value equivalent, are on the interpolation lines (Figure 3) and are calculated by a formula:

Pg(EVE)=0.1018*EVE

Fg(EVE)=0.0132*EVE

Cg(EVE)=0.8683*EVE

Let us also introduce the concept of relative dry weight of plants (Wg), which is the sum of relative weights of protein (Pg), fats (Fg) and carbohydrates (Cg) at a particular energy value equivalent.

Wg(EVE) = Pg(EVE) + Fg(EVE) + Cg(EVE)

RESULTS

With deviation EVE approaching zero (Table 19), the relative weights of protein, fats and carbohydrates for colza and soybean can be found, and they appear on the interpolation line. The analysis of the graph (Figure 3) clearly shows that the proportion of energy value equivalent to the relative dry weight is a constant figure that equals 1.017. It means that the conservation law of energy is true for the plant world. *In other words, the proportion of energy value to the relative dry weight of a plant is a constant figure that is approximately 4,169.79 kcal/kg of relative dry weight or 17.5 MJ/kg of the given dry weight, with the energy value of plants calculated by the relative protein, fat and carbohydrate weights being the same as the actual amount of protein, fats and carbohydrates.*

Since the conservation law of energy unites all plants into one rigid mathematical system, it is time to find the link between the biochemical composition and the need in mineral nutrients.

Photosynthesis is the only process for the plants to accumulate energy. Photosynthesis product is the carbohydrates, which are then transformed into fats or protein depending on the intrinsic genetic information under the enzymes influence.

The main weight of plants consists of macroelements: carbon, oxygen, hydrogen, nitrogen, phosphorous, potassium. Carbon, oxygen and hydrogen get into a plant from the atmosphere in the form of carbon dioxide or from the soil and atmosphere in the form of moisture. Nitrogen, phosphorous, potassium gets mainly from the soil. However, the sufficient amount of macroelements in the soil does not provide the adequate plant growth, there is a need in mesoelements (sulfur, calcium, magnesium) and microelements (iron, copper, manganese, boracium, zinc, molybdenum, cobalt, etc.). Microelements are minor in plants, but they are very important as they involved in biochemical processes. About a quarter of all known enzymes need the microelements to show their full catalytic effect, without these microelements many enzymes are non-active. Mesoelements are intermediary between the micro- and macroelements in their content in plants and are the parts of both the main weight of a plant and the enzyme composition.

To explore all those biochemical processes it is necessary to analyze and to identify the links between the protein, fats and carbohydrates, and macro-, meso- and microelements.

Macroelement - Nitrogen

It has already been said above that the content of nitrogen in plants is 16% of weight of protein and nonprotein compounds (Smirnov and Muravin, 1977)..

Macroelement - Phosphorous

Phosphorous is one of the main macroelements. The graph (Figure 4) clearly shows that despite the deviations the need in phosphorous among the presented crops is linearly dependent on the energy value of a plant. The deviations are determined by the difficulty to accurately identify the plant’s need in P2O5.

Macroelement - Potassium

The need in potassium as the need in phosphorous is linearly dependent on energy value, as it is seen at the graph (Figure 5). Linear dependences of need in potassium and phosphorous on energy value of plant make us assume that these elements directly involved in photosynthesis.

The need in nitrogen, phosphorous and potassium is given for all crops per all plants' weight but if one wants to find the content of macro- and microelements in all plants' weight, one needs to carry out a large-scale expensive research, while the data in the Internet is very controversial. The initial data has the content of microelements in fruits, therefore we will find the link with the biochemical composition of fruits.

Mesoelement - Sulfur

The content of sulfur as the content of potassium and phosphorous is linearly dependent on energy value (Figure 6). This dependence of sulfur content also indicates that the sulfur is very active in participating in photosynthesis.

Mesoelement - Calcium

The graph (Figure 7) shows that the calcium content depends on the fat weight in fruits. Calcium plays an important role in metabolism regulation in a plant cell.

As the calcium is transported very slowly along the plant, this element tends to be accumulated in the older parts of plants. This explains the deviations we see in the graph.

Mesoelement - Magnesium

The content of magnesium is linearly connected with the sum of protein and fat weight. Magnesium is a cofactor for nearly all enzymes, it is a part of chlorophyll, the protein being its ancestor.

Microelements - Copper, Manganese, Zinc, Boracium, Ferrum, Molybdenum, Cobalt

The graphs (figures 9-15) illustrate that all microelements are linearly dependent on either protein weight, or fat weight, or the sum of protein and fat weight. This means that being a part of enzymes they directly involved in protein and fat synthesis.

CONCLUSIONS

The results of this work can be checked only with a large-scale and expensive research but if we assume that for all plants the dependence between the biochemical composition and nutrients is preserved, then their accuracy is quite enough to describe the link between nearly all substances formed in a plant and all range of nutrients. The obtained formulas can help to specify Liebig's law of limiting factor for each nutrient and to quantify it. This fact is as important for agrochemistry as Mendeleev's periodic law for chemistry. When we know the whole need in mineral substances, we can obtain the yield limited by an amount of carbon dioxide in atmosphere and sun energy, and it is difficult to guess the limit of the maximum yield.

Vasilii Grigorevich MINEEV, the Head of the Agrochemistry and Biochemistry Department in M.V. Lomonosov Moscow State University, gave the following answer to the question "What role does agrochemistry play in modern agriculture?" from a journalist:

"*... I believe that agrochemistry is the core of the modern agriculture. The civilized and industry-developed countries rely on it in developing their performance and quality, while here our country thinks that the fertilizers are unreasonably expensive and we can do without them. West European countries use about 300, 400 and sometimes up to 500 kilos of nutrients per a hectare. In China this figure is up to 500. This country annually produces up to 50 million tons of fertilizers, which are used in agriculture, they even buy from foreign countries. Russia produces about 20 million tons of fertilizers but only two millions are used. The rest goes abroad. Our agriculture is kept on short rations*".

To change the belief about the fertilizer usage in Russia, it is necessary to understand that their effective use increases the yield capacity, reduces the overall expenditures (farming, etc.), results in increase of production profitability and contributes into the problem solution to provide the growing number of population with food.

Since the dependences of plants' needs in nutrients on biochemical composition have been identified, then the agrochemistry can be considered to be both a quantitative, and descriptive, and qualitative science.

The accurate knowledge about the plants' needs in mineral nutrients comes close to the solution but does not answer all the questions about the increase of yield capacity. It is important both to know the amount of the necessary elements and to provide these elements to plants in an appropriate way.

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Tables

Table 1. Cabbage. Biochemical composition of fruits, yield capacity and need in nutrients.

#	Indicator	Source						Average value of indicator, gr/kg of yield
		[1]	[1]	[2]	[3]	[4]	[5]	
1	Protein, gr			1.8		1.2	1.28	14.27
2	Fats, gr			0.1		0.2		1.50
3	Carbohydrates, gr			4.7		5.4	5.8	53.00
4	Dietary fibers, gr					2.3		23.00
5	Yield capacity, kg	70	70	0.1	10	0.1	0.1	1.00
6	N, gr	250	230		40.8			3.65
7	P2O5, gr	39.6	38.7	0.071	11.2	0.526	0.06	1.47
8	K2O, gr	249	253	0.361	41.9	0.296	0.204	3.33
9	S, gr			0.037				0.370
10	Ca, gr	248	298	0.048		0.047	0.04	1.83
11	Mg, gr			0.016		0.015	0.012	0.14
12	Cu, gr			0.000075			0.000019	0.00047
13	Mn, gr			0.00017		0.0002	0.00016	0.0018
14	Zn, gr			0.0004		0.0002	0.00018	0.0026
15	B, gr			0.0002				0.0020
16	Fe, gr			0.0006		0.0006	0.00047	0.0056
17	Mo, gr			0.00001				0.00010
18	Co, gr			0.000003				0.000030

Note for Tables 1-10.

Value for "Average value of indicator, gr/kg of yield" is an average value of an indicator preliminary divided by the yield capacity (column 5), for all sources.

The columns numbered [1], [2], [3], [4], [5] refer to (Vyraschivanie rasteniy…, 2015), (Chto soderzhitsya v kapuste…, 2011), (Stepuro, 2012), (Dieta Online, 2009), (Tablitsa soderzhaniya…, 2015) respectively.

Table 2. Potato. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source								Average value of indicator, gr/kg of yield
		[1]	[1]	[6]	[7]	[8]	[9]	[10]	[11]	
1	Protein, gr			2			2		1.9	19.67
2	Fats, gr			0.4			0.4		0.1	3.00
3	Carbohydrates, gr			16.3			16		16.6	163.00
4	Dietary fibers, gr			1.4					1.8	16.00
5	Yield capacity, kg	30.6	15	0.1	22.5	0.1	0.1	10	0.1	1.00
6	N, gr	125	84		112.5	0.62		47.5		5.13
7	P2O5, gr	14	18	0.132	45	0.3	0.132	16.5	0.135	1.54
8	K2O, gr	133.6	153	0.684	170	1.45	0.684	65	0.513	7.74
9	S, gr			0.032			0.032			0.32
10	Ca, gr		74	0.01			0.01		0.011	1.31
11	Mg, gr			0.023			0.023	9	0.022	0.40
12	Cu, gr			0.00014			0.00014			0.0014
13	Mn, gr			0.00017			0.00017			0.0017
14	Zn, gr			0.00036			0.00036			0.0036
15	B, gr			0.000115			0.000115			0.0012
16	Fe, gr			0.0009			0.0009		0.0007	0.0083
17	Mo, gr			0.000008			0.000008			0.00008
18	Co, gr			0.0000005			0.000005			0.000028

The columns numbered [1], [6], [7], [8], [9], [10], [11] refer to (Vyraschivanie rasteniy…, 2015), (Kartofel' – kaloriynost'…, 2015), (Potrebnost' kartofelya…, 2015), (Fyodorova, 2015), (Chto soderzhitsya v kartofele?, 2011), (Podkolzin and Burlazin, 1988), (Kartofel', n.d.) respectively.

Table 3. Bulb onion. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source					Average value of indicator, gr/kg of yield
		[12]	[13]	[4]	[14]	[5]	
1	Protein, gr		1.4	1.1	1.4	1.1	12.50
2	Fats, gr		0.2	0.1	0.2		1.67
3	Carbohydrates, gr		8.2	9.3	8.2	9.34	87.60
4	Dietary fibers, gr		3	1.7	3	1.7	23.50
5	Yield capacity, kg	10	0.1	0.1	0.1	0.1	1.00
6	N, gr	44					4.40
7	P2O5, gr	12	0.132	0.066	0.132	0.066	1.03
8	K2O, gr	21	0.21	0.176	0.21	0.175	1.96
9	S, gr		0.065		0.065		0.65
10	Ca, gr	5	0.031	0.023	0.031	0.023	0.32
11	Mg, gr	2.4	0.014	0.01	0.014	0.01	0.14
12	Cu, gr		0.000085			0.000039	0.00062
13	Mn, gr		0.00023	0.0001		0.000129	0.0015
14	Zn, gr		0.00085	0.0002		0.00017	0.0041
15	B, gr		0.0002				0.0020
16	Fe, gr		0.0008	0.0002		0.00021	0.0040
17	Mo, gr		0.000012				0.00012
18	Co, gr		0.000005				0.00005

The columns numbered [4], [5], [12], [13], [14] refer to (Dieta Online, 2009), (Tablitsa soderzhaniya…, 2015), (Zharkov and Kalashnikov, 2015), (Yadrov, 2009a), (Kakie vitanimy i mikroelementy…, 2013) respectively.

Table 4. Carrot. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source			Average value of indicator, gr/kg of yield
		[15]	[16]	[5]	
1	Protein, gr		1.3	0.93	11.15
2	Fats, gr		0.1		1.00
3	Carbohydrates, gr		7.2	9.58	83.90
4	Dietary fibers, gr		0.8	2.8	18.00
5	Yield capacity, kg	1	0.1	0.1	1.00
6	N, gr	3.2			3.20
7	P2O5, gr	1	0.137	0.08	1.06
8	K2O, gr	5	0.282	0.385	3.89
9	S, gr		0.006		0.06
10	Ca, gr		0.046	0.033	0.40
11	Mg, gr		0.036	0.012	0.24
12	Cu, gr		0.00008	0.000045	0.00063
13	Mn, gr		0.0002	0.000143	0.0017
14	Zn, gr		0.0004	0.00024	0.0032
15	B, gr		0.0002	0.0003	0.0025
16	Fe, gr		0.0014		0.014

17	Mo, gr		0.00002		0.00020
18	Co, gr		0.000002		0.000020

The columns numbered [5], [15], [16] refer to (Tablitsa soderzhaniya, 2015), (Vynos pitatel’nyh veschestv…, n.d.), (Yadrov, 2009b) respectively.

Table 5. Cucumber. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source					Average value of indicator, gr/kg of yield
		[1]	[1]	[1]	[17]	[18]	
1	Protein, gr	-			0.7		7.00
2	Fats, gr				0.1		1.00
3	Carbohydrates, gr				1.9		19.00
4	Dietary fibers, gr				0.7		7.00
5	Yield capacity, kg	20.9	20.9	20	0.1	1	1.00
6	N, gr	51	109	37		2.64	3.04
7	P2O5, gr	18	15.9	8.8	0.687	1.55	2.10
8	K2O, gr	64.7	85.5	78.8	0.236	6.6	4.02
9	S, gr						-
10	Ca, gr	19		26.2	0.017		0.80
11	Mg, gr				0.014		0.14
12	Cu, gr				0.0001		0.0010
13	Mn, gr				0.00018		0.0018
14	Zn, gr				0.000215		0.0022

15	B, gr						-
16	Fe, gr				0.0005		0.0050
17	Mo, gr				0.000001		0.000010
18	Co, gr				0.000001		0.000010

The columns numbered [1], [17], [18] refer to (Vyraschivanie rasteniy, 2015), (Yadrov, 2009c), (Vasyaev and Vasyaeva, n.d.) respectively.

Table 6. Wheat. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source					
		[19]	[19]	[20]	[21]	[21]	[22]
1	Protein, gr						
2	Fats, gr						
3	Carbohydrates, gr						
4	Dietary fibers, gr						
5	Yield capacity, kg	1	1	0.1	2.7	3.8	1
6	N, gr	28					
7	P2O5, gr	5.2		0.842			
8	K2O, gr	18		0.392			
9	S, gr	3.1	4.4	0.1			
10	Ca, gr		3	0.062			
11	Mg, gr	2.6	3	0.114			
12	Cu, gr		0.01	0.00053	0.02	0.02	0.015
13	Mn, gr		0.07	0.0037	0.161	0.292	0.14

14	Zn, gr		0.052	0.00281	0.148	0.158	0.07
15	B, gr		0.025				0.005
16	Fe, gr		0.137	0.0053			
17	Mo, gr			0.000042	0.0001	0.00054	0.0009
18	Co, gr			0.0000054			0.0004

The columns numbered [19], [20], [21], [22] refer to (Povyshenie urozhaynosti…, n.d.), (Chto soderzhitsya v pshenitse?, 2011), (Mineev, n.d), (Spitsyna et at., 2013) respectively.

Table 7. (continued). Wheat. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source					Average value of indicator, gr/kg of yield
		[23]	[23]	[24]	[4]	[25]	
1	Protein, gr				11.3	13	121.50
2	Fats, gr				1.7	2.5	6.53
3	Carbohydrates, gr				75.9	57.5	667.00
4	Dietary fibers, gr				11.2	11.3	112.50
5	Yield capacity, kg	1	1	1	0.1	0.1	1.00
6	N, gr	30	5	28.1			22.78
7	P2O5, gr	13	12	11.6	0.812	0.842	9.54
8	K2O, gr	25	25	22.8	0.52	0.391	14.83
9	S, gr					0.1	2.38
10	Ca, gr				0.032	0.062	1.14
11	Mg, gr					0.114	1.97

12	Cu, gr				0.0004	0.00053	0.0075
13	Mn, gr				0.0038	0.0037	0.065
14	Zn, gr				0.0033	0.00281	0.044
15	B, gr						5.00
16	Fe, gr				0.0046	0.0053	0.072
17	Mo, gr					0.000042	0.00038
18	Co, gr						0.00023

The columns numbered [4], [23], [24], [25], refer to (Dieta Online, 2009), (Metody rascheta norm…, 2001), (Makarov, 2014), (Yadrov, 2009f) respectively.

Table 8. Colza. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source			Average value of indicator, gr/kg of yield
		[26]	[27]	[28]	
1	Protein, gr		24.5		245.00
2	Fats, gr		42.5		425.00
3	Carbohydrates, gr		6		60.00
4	Dietary fibers, gr				-
5	Yield capacity, kg	1	0.1	1	1.00
6	N, gr	50		51	50.50
7	P2O5, gr	24		23.5	23.75
8	K2O, gr	60		37.5	48.75
9	S, gr	20			20.00
10	Ca, gr	60			60.00
11	Mg, gr	10			10.00

12	Cu, gr	0.04			0.04
13	Mn, gr	0.1		1.05	0.58
14	Zn, gr	0.15			0.15
15	B, gr	0.06		0.1	0.080
16	Fe, gr	0.36			0.36
17	Mo, gr	0.002		0.0105	0.0063
18	Co, gr				-

The columns numbered [26], [27], [28] refer to (Research and Production Enterprise "CEOLIT", 1990), (Kulakov, 2009), (Biologicheskie osobennosti rapsa, 2015) respectively.

Table 9. Beetroot. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source			Average value of indicator, gr/kg of yield
		[1]	[29]	[30]	
1	Protein, gr		1.5		15.00
2	Fats, gr		0.1		1.00
3	Carbohydrates, gr		8.8		88.00
4	Dietary fibers, gr		2.5		25.00
5	Yield capacity, kg	20	0.1	10	1.00
6	N, gr	80		27	3.35
7	P2O5, gr	15.4	0.098	15	1.08
8	K2O, gr	103.7	0.346	43	4.32
9	S, gr		0.007		0.070
10	Ca, gr	21.3	0.037		0.72

11	Mg, gr		0.022		0.22
12	Cu, gr		0.00014		0.0014
13	Mn, gr		0.00066		0.0066
14	Zn, gr		0.000425		0.0043
15	B, gr		0.00028		0.0028
16	Fe, gr		0.0014		0.014
17	Mo, gr		0.00001		0.00010
18	Co, gr		0.000002		0.000020

The columns numbered [11], [29], [30] refer to (Kartofel', n.d.), (Yadrov, 2009e), (Udobrenie ovoschnyh kul'tur, n.d.) respectively.

Table 10. Soybean. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source			Average value of indicator, gr/kg of yield
		[31]	[32]	[33]	
1	Protein, gr			35	350.00
2	Fats, gr			17	170.00
3	Carbohydrates, gr			17	170.00
4	Dietary fibers, gr				-
5	Yield capacity, kg	5	1.81	0.1	1.00
6	N, gr	326	39.1		43.40
7	P2O5, gr	30	21.1	1.379	10.48
8	K2O, gr	170	50.3	1.936	27.05
9	S, gr	20		0.244	3.22
10	Ca, gr	70		0.348	8.74
11	Mg, gr	39		0.226	5.03

12	Cu, gr	0.109		0.005	0.036
13	Mn, gr	0.653		0.0028	0.079
14	Zn, gr	0.261		0.00201	0.036
15	B, gr	0.109			0.022
16	Fe, gr	1.305		0.0097	0.18
17	Mo, gr	0.02		0.000099	0.0025
18	Co, gr			0.0000312	0.00031

The columns numbered [31], [32], [33] refer to (Adamenko and Kostyushko, n.d.), (Isupova, 2013), (Chto soderzhitsya v soe?, 2011) respectively.

Table 11. Tomatoes. Biochemical composition of fruits, yield capacity and need in nutrients

#	Indicator	Source					Average value of indicator, gr/kg of yield
		[34]	[35]	[1]	[1]	[36]	
1	Protein, gr	0.6					6.00
2	Fats, gr	0.2					2.00
3	Carbohydrates, gr	4.2					42.00
4	Dietary fibers, gr	0.8					8.00
5	Yield capacity, kg	0.1	10000	40	40	3250	1.00
6	N, gr		31500	110	103	11.5	2.12
7	P2O5, gr	0.059	10500	11	7	4	0.42
8	K2O, gr	0.349	42500	124.5	119.5	16	2.77
9	S, gr	0.012					0.12
10	Ca, gr	0.014		92.3	94.4		1.60
11	Mg, gr	0.02					0.20
12	Cu, gr	0.00011					0.0011
13	Mn, gr	0.00014					0.0014
14	Zn, gr	0.0002					0.0020
15	B, gr	0.000115					0.0012

16	Fe, gr	0.0009					0.0090
17	Mo, gr	0.000007					0.00007
18	Co, gr	0.000006					0.00006

The columns numbered [1], [34], [35], [36] refer to (Vyraschivanie rasteniy…, 2015), (Yadrov, 2009d), (Osnovnoe vnesenie udobreniy, n.d.), (Podkormka pomidorov, n.d.) respectively.

Table 12. Share of undigested fiber.

Crop	Carbohydrates, gr/kg	Fiber, gr/kg	Share of fiber of carbohydrate weight, %
Cabbage	53.00	23.00	43%
Potato	163.00	16.00	10%
Bulb onion	87.60	23.50	27%
Carrot	83.90	18.00	21%
Cucumber	19.00	7.00	37%
Wheat	667.00	117.50	18%
Beetroot	88.00	25.00	28%
Tomatoes	42.00	8.00	19%
Average value of fiber share			25%

Table 13. Biochemical composition of fruits with due regard to fiber

Crop	Biochemical composition of fruits			Dry weight (Protein+Fats+Carbohydrates), gr
	Protein, gr/kg	Fats, gr/kg	Carbohydrates (with 1.25 coefficient), gr/kg	
Cabbage	14.27	1.50	66.25	82.02
Potato	19.67	3.00	203.75	226.42
Bulb onion	12.50	1.67	109.50	123.67
Carrot	11.15	1.00	104.88	117.03
Cucumber	7.00	1.00	23.75	31.75
Wheat	121.50	21.00	833.75	976.25
Colza	245.00	425.00	75.00	745.00
Beetroot	15.00	1.00	110.00	126.00
Soybean	350.00	170.00	212.50	732.50
Tomatoes	6.00	2.00	52.50	60.50

Table 14. Overall protein content in plants

Crop	Need in nitrogen, gr/kg	Protein content in all plant weight, gr/kg of fruits	Protein content in fruits, gr/kg of fruits	Protein content in fruit-free plant weight, gr/kg
Cabbage	3.65	22.79	14.27	8.52
Potato	5.13	32.04	19.67	12.38
Bulb onion	4.40	27.50	12.50	15.00
Carrot	3.20	20.00	11.15	8.85
Cucumber	3.04	18.98	7.00	11.98
Wheat	30.28	189.22	121.50	67.72
Colza	50.50	315.63	245.00	70.63
Beetroot	3.35	20.94	15.00	5.94
Soybean	65.20*	407.50	350.00	57.50*
Tomatoes	2.12	13.25	6.00	7.25

Table 15. Chemical composition of feedstuff herbage (Himicheskiy sostav…, n.d.).

Indicator	Feedstuff			
	Forest pasture	Flood meadow	Grass pasture	Clover-timothy pasture
Protein:				
Crude protein, gr	33.00	39.00	50.00	42.00
Fats, gr	10.00	10.00	15.00	9.00
Carbohydrates:				
Crude fiber, gr	81.00	86.00	136.00	95.00
Starch, gr	5.70	6.30	8.60	4.80
Sugar, gr	19.00	24.00	20.00	24.00
Total, carbohydrates, gr	105.70	116.30	164.60	123.80
Sum of protein, fats and carbohydrates weight, gr	148.70	165.30	229.60	174.80

Table 16. Analysis of biochemical composition of fruits in given crops, except wheat, colza, soybean (biochemical composition of fruits)

Crop	Biochemical composition of fruits			Dry weight (Protein +Fats+ Carbohydrates), gr	Protein content in the initial weight	Dry weight composition		
	Protein, gr/kg	Fats, gr/kg	Carbohydrates (with 1.25 coefficient), gr/kg			Protein, %	Fats, %	Carbohydrates, %
Cabbage	14.27	1.50	66.25	82.02	1%	17.39%	1.83 %	80.78%
Potato	19.67	3.00	203.75	226.42	2%	8.69%	1.32 %	89.99%
Bulb onion	12.50	1.67	109.50	123.67	1%	10.11%	1.35 %	88.54%
Carrot	11.15	1.00	104.88	117.03	1%	9.53%	0.85 %	89.62%
Cucumber					1%	22.05%	3.15	74.80%

	7.00	1.00	23.75	31.75			%	
Beetroot	15.00	1.00	110.00	126.00	2%	11.90%	0.79 %	87.30%
Tomatoes	6.00	2.00	52.50	60.50	1%	9.92%	3.31 %	86.78%

Table 17. Comparison of biochemical composition of fruits and feedstuff herbage.

Indicator	Content, %	
	Fruits, figure 2	Feedstuff herbage, figure 1
Protein	10.18%	22.74%
Fats	1.31%	6.15%
Carbohydrates	88.51%	71.11%
	100.00%	100.00%

Table 18. Biochemical composition of fruit-free plant mass

#	Crop	Content in fruit-free plant weight		
		Protein, gr/kg of yield (Table 13)	Fats, gr/kg of yield	Carbohydrates, gr/kg of yield
1	Cabbage	8.52	1.10	74.07
2	Potato	12.38	1.59	107.61
3	Bulb onion	15.00	1.93	130.42
4	Carrot	8.85	1.14	76.95
5	Cucumber	11.98	1.54	104.14
6	Wheat	67.72	8.71	588.78
7	Colza	70.63	9.09	614.05
8	Beetroot			

		5.94	0.76	51.62
9	Soybean	57.50	7.40	499.93
10	Tomatoes	7.25	0.93	63.02

Table 19. General biochemical composition of plants based on Table 12 and Table 17. Energy value equivalent.

#	Crop	Content in all plant weight			Energy value equivalent, P + 2.268*F+C
		Protein, gr/kg of yield	Fats, gr/kg of yield	Carbohydrates, gr/kg of yield	
1	Cabbage	22.79	2.60	140.32	168.99
2	Potato	32.04	4.59	311.36	353.82
3	Bulb onion	27.50	3.60	239.92	275.58
4	Carrot	20.00	2.14	181.82	206.67
5	Cucumber	18.98	2.54	127.89	152.63
6	Wheat	189.22	29.71	1,422.53	1,679.14
7	Colza	315.63	434.09	689.05	1,989.19
8	Beetroot	20.94	1.76	161.62	186.56
9	Soybean	407.50	177.40	712.43	1,522.28
10	Tomatoes	13.25	2.93	115.52	135.41

Table 20. Deviations of colza and soybean from the dependence of protein, fat and carbohydrate relative weights on EVE

#	Crop	Plant EVE	Protein deviation, gr	Fat deviation, gr	Carbohydrate deviation, gr	Deviation EVE	% of deviation from plant EVE
1	Colza	1,989.19	113.13	407.83	- 1,038.16.	- 0.07.	-0.0038%
2	Soybean	1,522.28	252.53	157.31	- 609.36.	- 0.06.	-0.0038%

Table 21. Energy value of plants per 1 kg of relative dry weight with regard to the dependences in Figure 3.

Protein, gr	Fats, gr	Carbohydrates, gr	Dry weight, gr	EVE	Energy value	
					kcal/kg	kJ/kg
101.80	13.20	868.30	983.30	1,000.0	4,169.79	17,458.08

Table 22. Plant's need in P2O5

#	Crop	Energy value equivalent, P + 2.268*F+C	Average need in P2O5, gr/kg of yield
1	Cabbage	168.99	0.68
2	Potato	353.82	1.54
3	Bulb onion	275.58	1.03
4	Carrot	206.67	1.06
5	Cucumber	152.63	2.10
6	Wheat	1.679.14	9.54
7	Colza	1.989.19	23.75
8	Beetroot	186.56	1.08
9	Soybean	1.522.28	10.48
10	Tomatoes	135.41	0.42

Table 23. Plant's need in K2O.

#	Crop	Energy value equivalent, P + 2.268*F+C	Average need in K2O, gr/kg of yield
1	Cabbage	168.99	3.33
2	Potato	353.82	7.74
3	Bulb onion	275.58	1.96
4	Carrot	206.67	3.89
5	Cucumber	152.63	4.02
6	Wheat	1,679.14	14.83
7	Colza	1,989.19	48.75
8	Beetroot	186.56	4.32
9	Soybean	1,522.28	27.05
10	Tomatoes	135.41	2.77

Table 24. Content of sulfur (S) in fruits

#	Crop	Fats, gr/kg of yield	Average S content in fruits, gr/kg of yield
1	Cabbage	1.50	0.37
2	Potato	3.00	0.32
3	Bulb onion	1.67	0.65

4	Carrot	1.00	0.06
5	Cucumber	1.00	
6	Wheat	21.00	2.38
7	Colza	425.00	20.00
8	Beetroot	1.00	0.07
9	Soybean	170.00	3.22
10	Tomatoes	2.00	0.12

Table 25. Content of calcium (Ca) in fruits

#	Crop	Fats, gr/kg of yield	Average Ca content in fruits, gr/kg of yield
1	Cabbage	1.50	1.83
2	Potato	3.00	1.31
3	Bulb onion	1.67	0.32
4	Carrot	1.00	0.40
5	Cucumber	1.00	1.14
6	Wheat	21.00	1.14
7	Colza	425.00	60.00
8	Beetroot	1.00	0.72
9	Soybean	170.00	8.74
10	Tomatoes	2.00	1.60

Table 26. Content of magnesium (Mg) in fruits

#	Crop	Biochemical composition of fruits		Sum of protein and fat weight, gr/kg of yield	Average Mg content in fruits, gr/kg of yield
		Protein, gr/kg of yield	Fats, gr/kg of yield		
1	Cabbage	14.27	1.50	15.77	0.143
2	Potato	19.67	3.00	22.67	0.395
3	Bulb onion	12.50	1.67	14.17	0.144
4	Carrot	11.15	1.00	12.15	0.240
5	Cucumber	7.00	1.00	8.00	0.355
6	Wheat	121.50	21.00	142.50	1.97

7	Colza	245.00	425.00	670.00	10.00
8	Beetroot	15.00	1.00	16.00	0.220
9	Soybean	350.00	170.00	520.00	5.03
10	Tomatoes	6.00	2.00	8.00	0.200

Table 27. Content of copper (Cu) in fruits

#	Crop	Biochemical composition of fruits		Sum of protein and fat weight, gr/kg of yield	Average Cu content in fruits, gr/kg of yield
		Protein, gr/kg of yield	Fats, gr/kg of yield		
1	Cabbage	14.27	1.50	15.77	0.00047
2	Potato	19.67	3.00	22.67	0.00140
3	Bulb onion	12.50	1.67	14.17	0.00062
4	Carrot	11.15	1.00	12.15	0.00063
5	Cucumber	7.00	1.00	8.00	0.00100
6	Wheat	121.50	21.00	142.50	0.00747
7	Colza	245.00	425.00	670.00	0.04000
8	Beetroot	15.00	1.00	16.00	0.00140
9	Soybean	350.00	170.00	520.00	0.03590
10	Tomatoes	6.00	2.00	8.00	0.00110

Table 28. Content of manganese (Mn) in fruits

#	Crop	Fats, gr/kg of yield	Average Mn content in fruits, gr/kg of yield
1	Cabbage	1.50	0.00177
2	Potato	3.00	0.00170
3	Bulb onion	1.67	0.00153
4	Carrot	1.00	0.00172
5	Cucumber	1.00	0.00180
6	Wheat	21.00	0.06550
7	Colza	425.00	0.57500
8	Beetroot	1.00	0.00660

9	Soybean	170.00	0.07930
10	Tomatoes	2.00	0.00140

Table 29. Content of zinc (Zn) in fruits

#	Crop	Fats, gr/kg of yield	Average Zn content in fruits, gr/kg of yield
1	Cabbage	1.50	0.00260
2	Potato	3.00	0.00360
3	Bulb onion	1.67	0.00407
4	Carrot	1.00	0.00320
5	Cucumber	1.00	0.00215
6	Wheat	21.00	0.04394
7	Colza	425.00	0.15000
8	Beetroot	1.00	0.00425
9	Soybean	170.00	0.03615
10	Tomatoes	2.00	0.00200

Table 30. Content of boracium (B) in fruits

#	Crop	Fats, gr/kg of yield	Average B content in fruits, gr/kg of yield
1	Cabbage	1.50	0.00200
2	Potato	3.00	0.00115
3	Bulb onion	1.67	0.00200
4	Carrot	1.00	0.00200
5	Cucumber	1.00	
6	Wheat	21.00	0.01500
7	Colza	425.00	0.08000
8	Beetroot	1.00	0.00280
9	Soybean	170.00	0.02180
10	Tomatoes	2.00	0.00115

Table 31. Content of ferrum (Fe) in fruits

#	Crop	Biochemical composition of fruits		Sum of protein and fat weight, gr/kg of yield	Average Fe content in fruits, gr/kg of yield
		Protein, gr/kg of yield	Fats, gr/kg of yield		
1	Cabbage	14.27	1.50	15.77	0.00557
2	Potato	19.67	3.00	22.67	0.00833
3	Bulb onion	12.50	1.67	14.17	0.00403
4	Carrot	11.15	1.00	12.15	0.00850
5	Cucumber	7.00	1.00	8.00	0.00500
6	Wheat	121.50	21.00	142.50	0.07225
7	Colza	245.00	425.00	670.00	0.36000
8	Beetroot	15.00	1.00	16.00	0.01400
9	Soybean	350.00	170.00	520.00	0.17900
10	Tomatoes	6.00	2.00	8.00	0.00900

Table 32. Content of molybdenum (Mo) in fruits

#	Crop	Fats, gr/kg of yield	Average Mo content in fruits, gr/kg of yield
1	Cabbage	1.50	0.00010
2	Potato	3.00	0.00008
3	Bulb onion	1.67	0.00012
4	Carrot	1.00	0.00020
5	Cucumber	1.00	0.00001
6	Wheat	21.00	0.00038
7	Colza	425.00	0.00625
8	Beetroot	1.00	0.00010
9	Soybean	170.00	0.00250
10	Tomatoes	2.00	0.00007

Table 33. Plants' need in cobalt (Co)

#	Crop	Protein, gr/kg of yield	Average Co content in fruits, gr/kg of yield
1	Cabbage	14.27	0.00003
2	Potato	19.67	0.00005
3	Bulb onion	12.50	0.00005
4	Carrot	11.15	0.00002
5	Cucumber	7.00	0.00001
6	Wheat	121.50	0.00023
7	Beetroot	15.00	0.00002
8	Soybean	350.00	0.00031
9	Tomatoes	6.00	0.00006

Figures

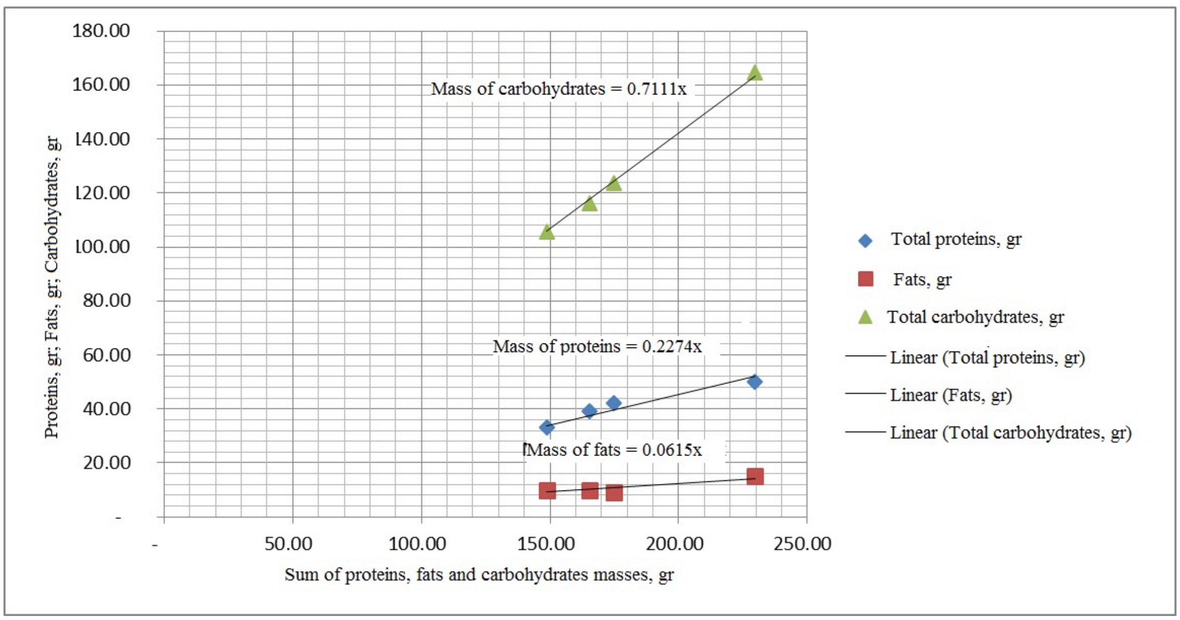

Fig.1. Dependence of protein, fats and carbohydrates weight in feedstuff herbage on their masses sum.

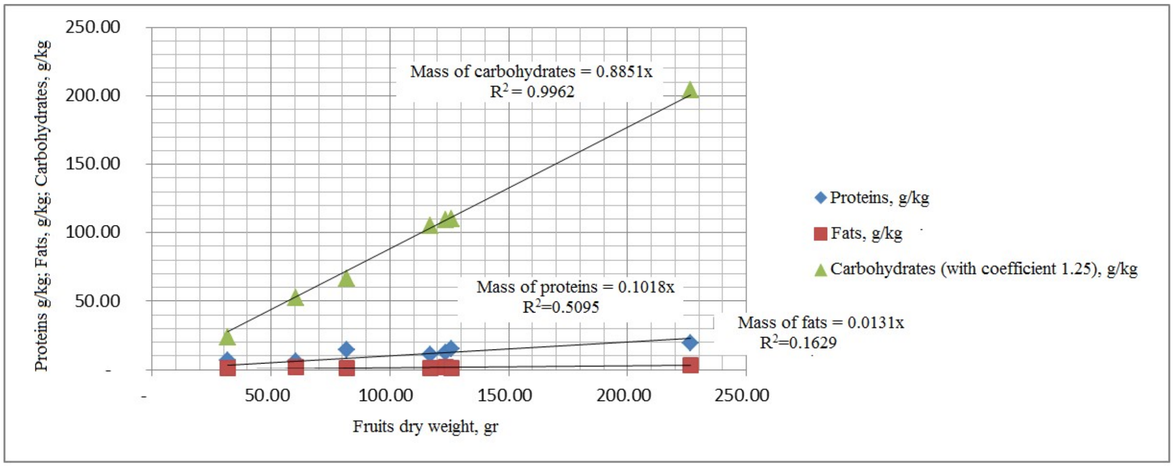

Fig.2. Dependence of protein, fat and carbohydrates weights in fruits on fruits dry masses.

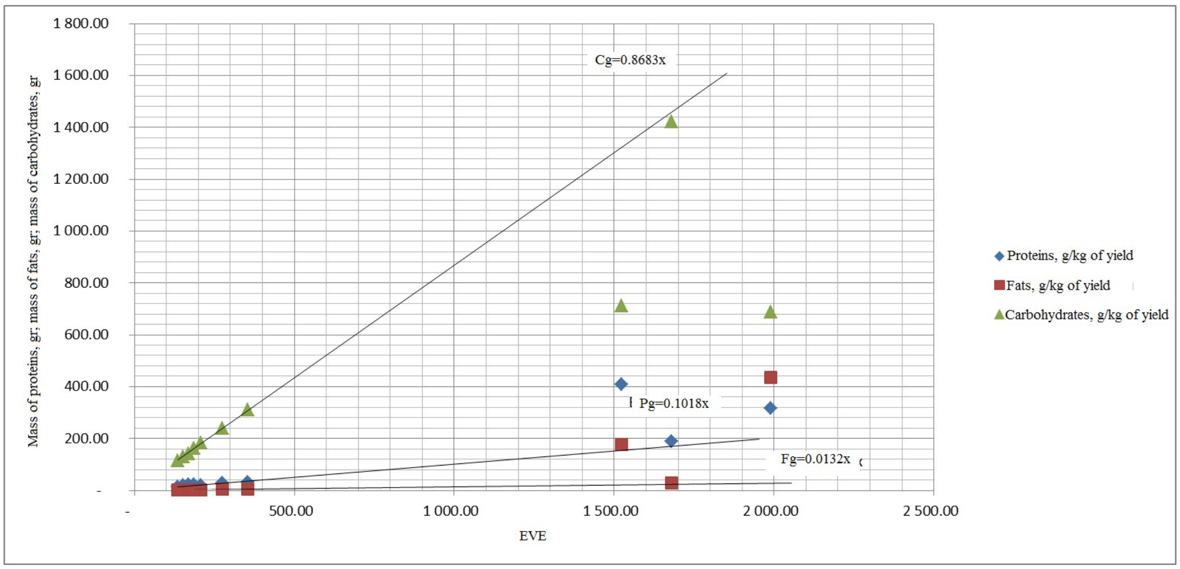

Fig.3. Dependence of protein, fats and carbohydrates weight on EVE.

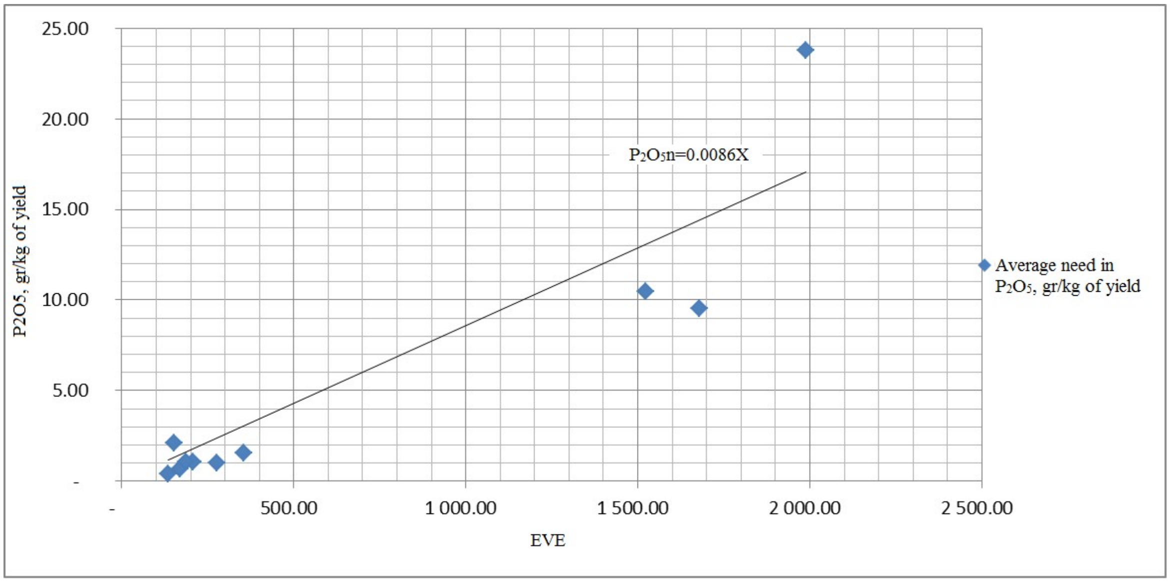

Fig.4. Dependence of need in P2O5 on energy value equivalent. R = 0.922, where R is the coefficient determining the correlation ratio and the reliability of the model.

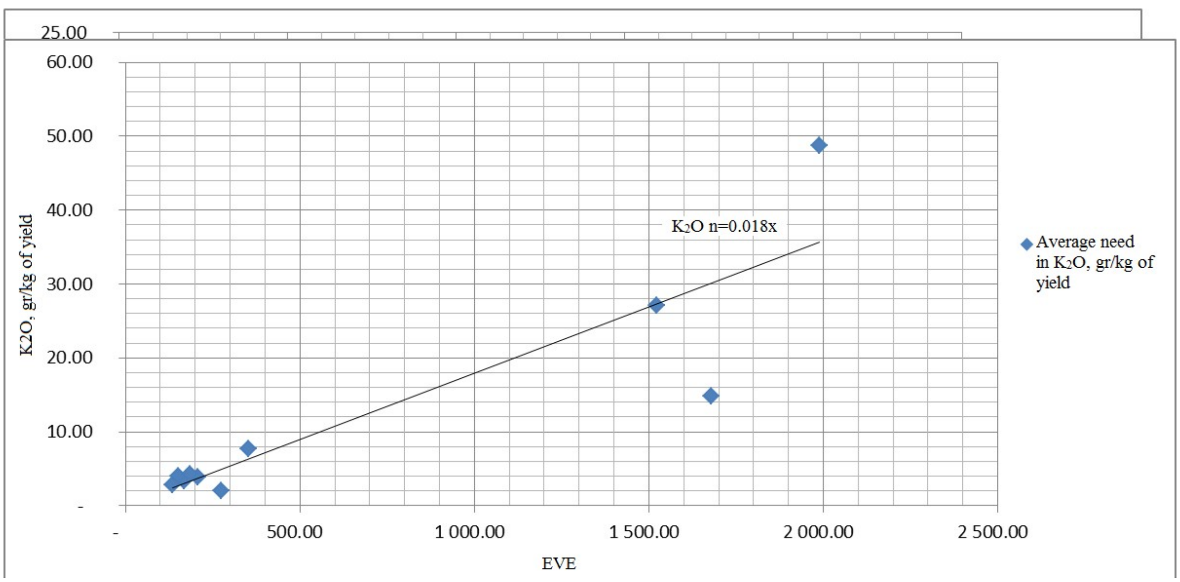

Fig.5. Dependence of need in K2O on energy value equivalent. R = 0.892, where R is the coefficient determining the correlation ratio and the reliability of the model.

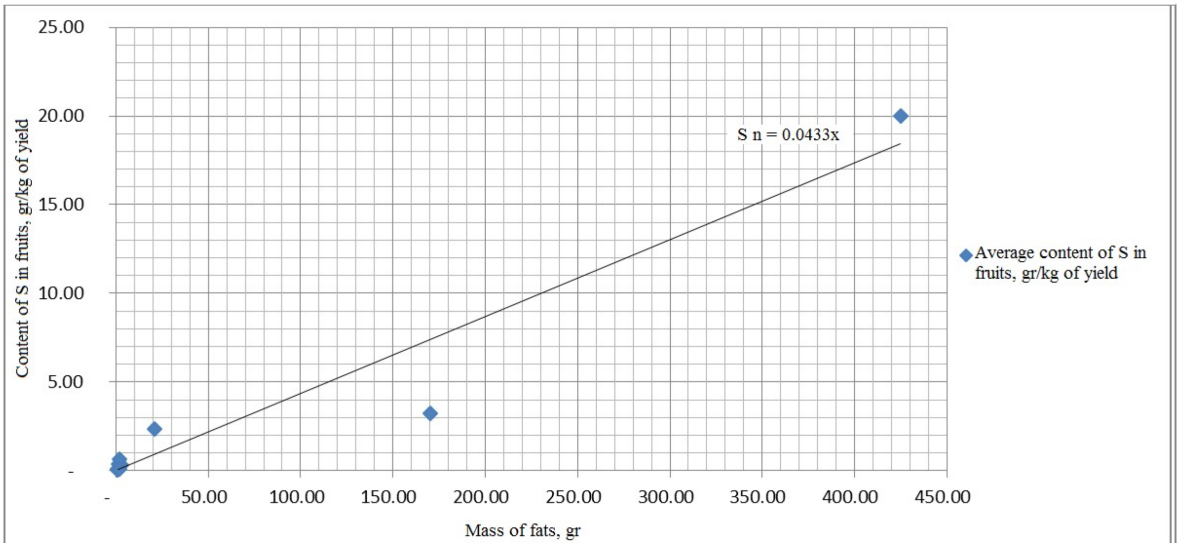

Fig.6. Dependence of sulfur (S) content in fruits on fat weight. R = 0.966, where R is the correlation determining the correlation ratio and the reliability of the model.

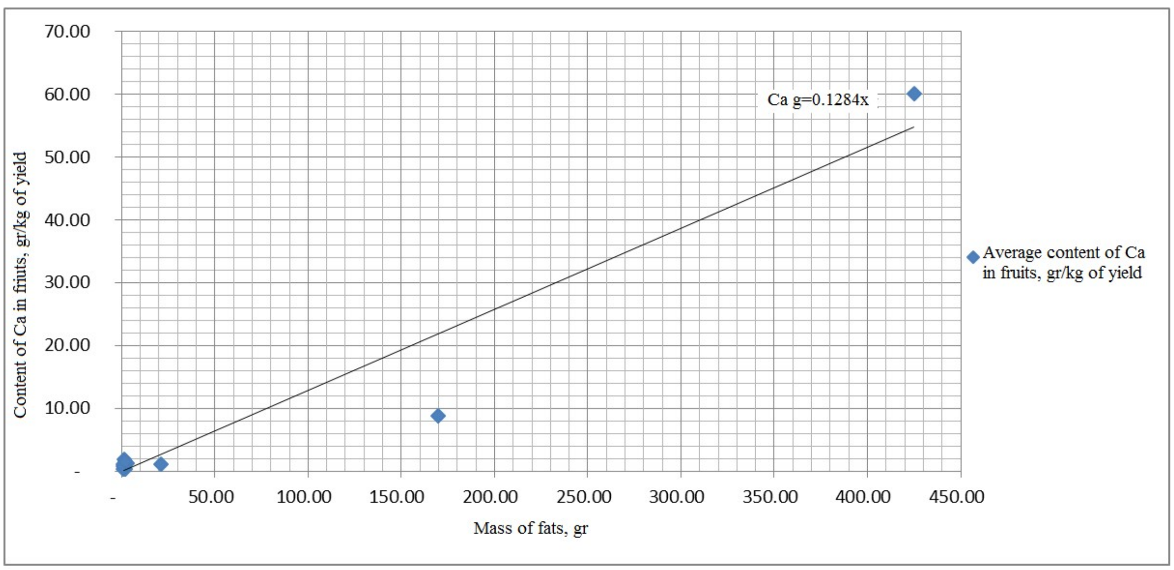

Fig.7. Dependence of calcium (Ca) content in fruits on fat weight. R = 0.966, where R is the coefficient determining the correlation ratio and the reliability of the model.

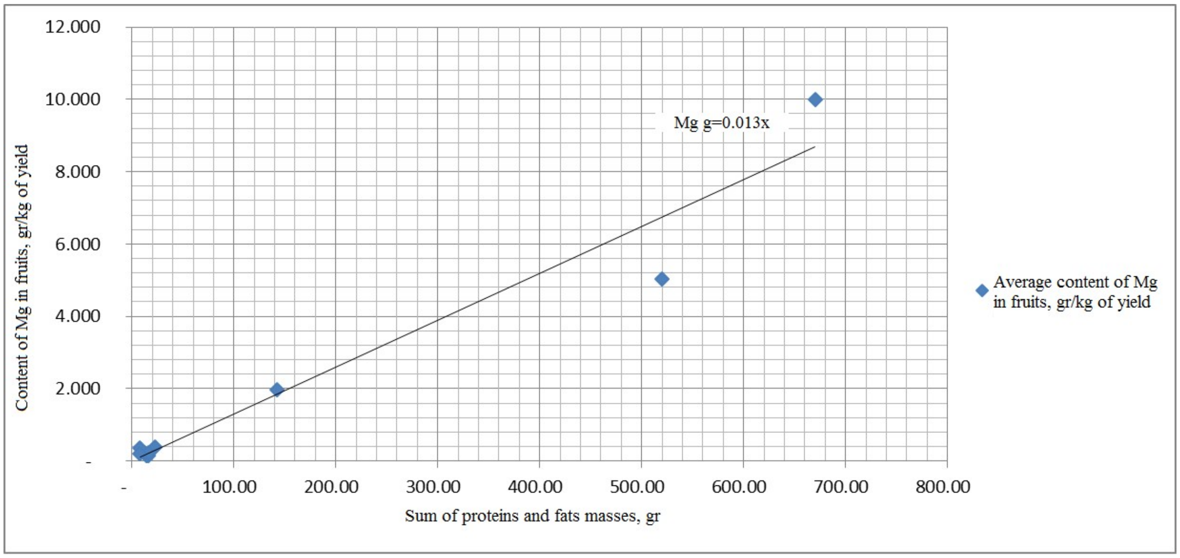

Fig.8. Dependence of magnesium (Mg) content in fruits on the sum of protein and fat weight. R = 0.975, where R is the coefficient determining the correlation ratio and the reliability of the model.

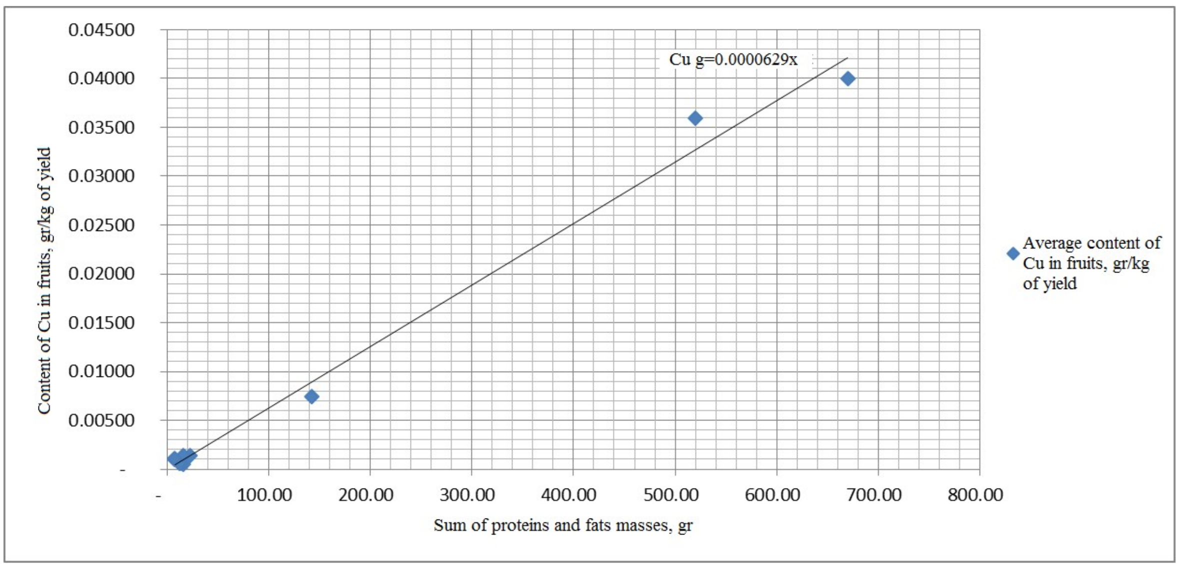

Fig.9. Dependence of copper (Cu) content in fruits on the sum of protein and fat weight. R = 0.996, where R is the coefficient determining the correlation ratio and the reliability of the model.

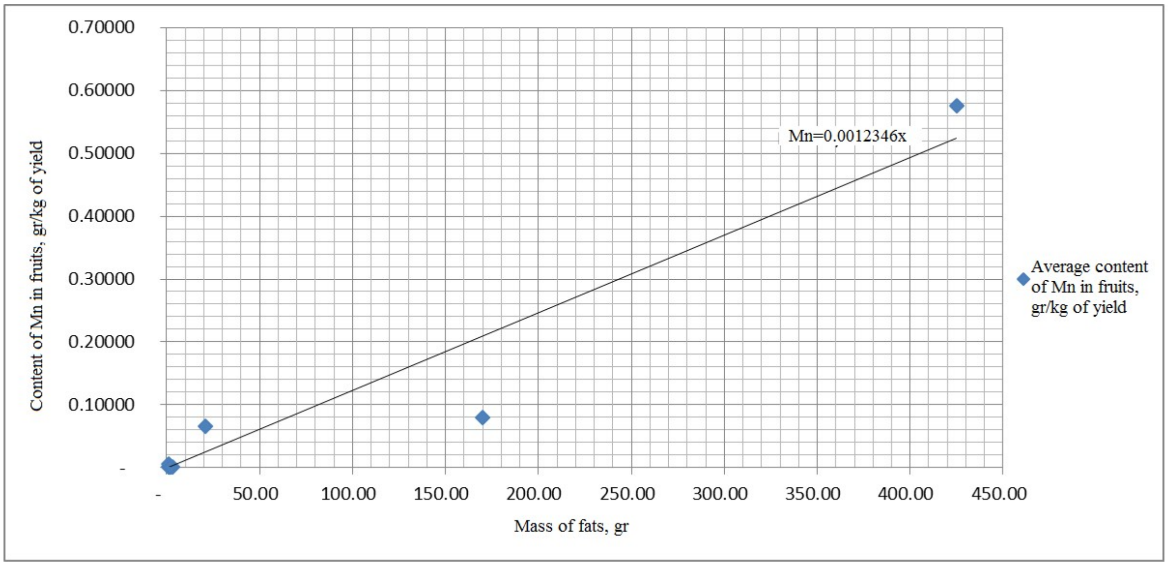

Fig.10. Dependence of manganese (Mn) content in fruits on fat weight. R = 0.963, where R is the coefficient determining the correlation ratio and the reliability of the model.

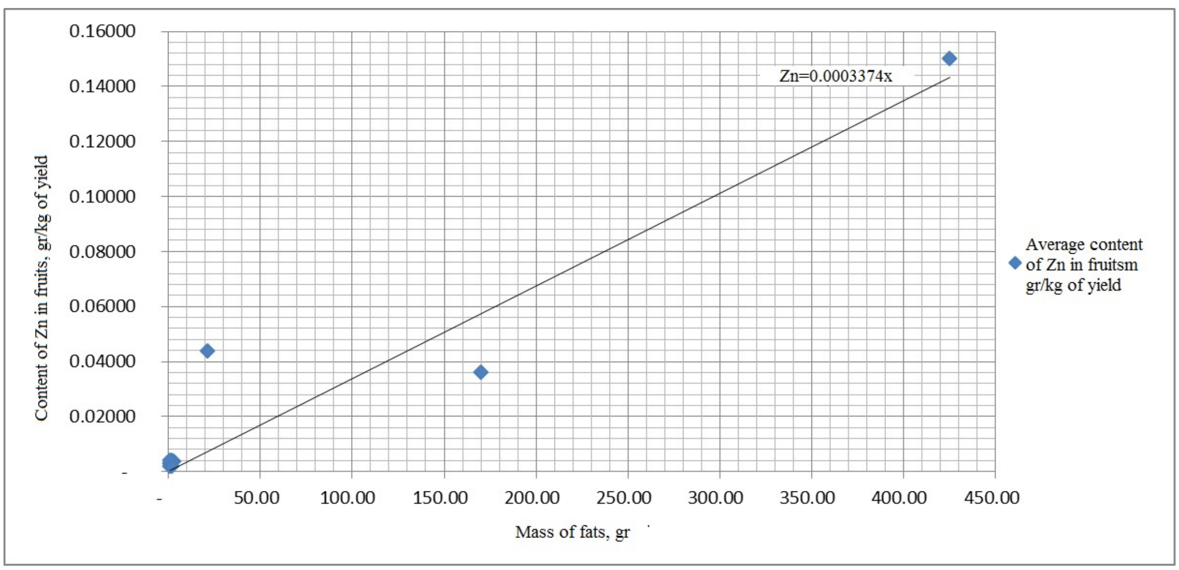

Fig.11. Dependence of zinc (Zn) content in fruits on fat weight. R = 0.955, where R is the coefficient determining the correlation ratio and the reliability of the model.

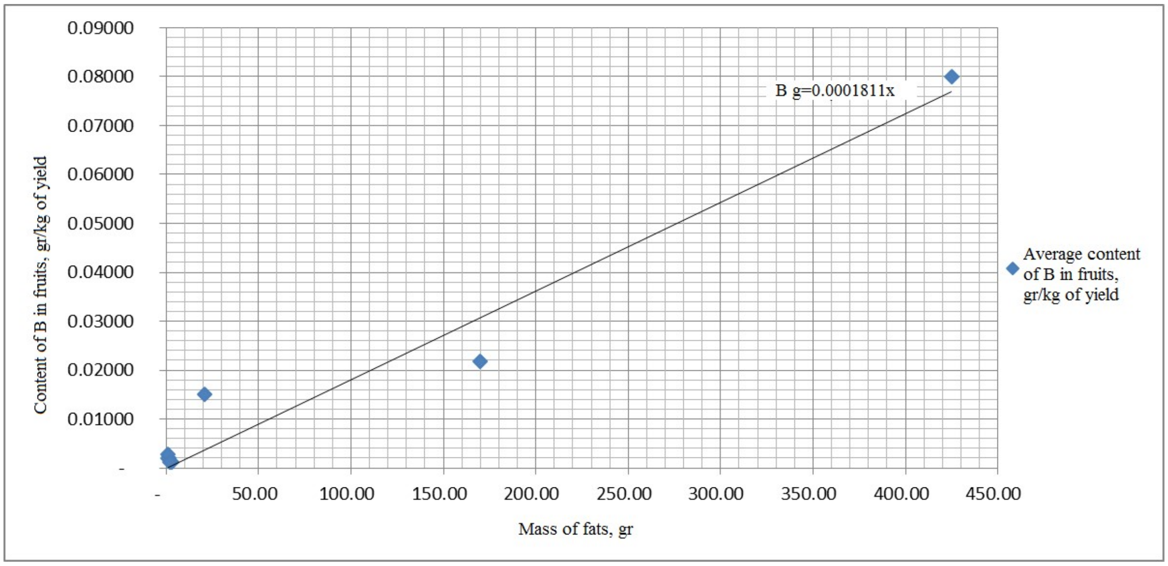

Fig.12. Dependence of boracium (B) content in fruits on fat weight. R = 0.981, where R is the coefficient determining the correlation ratio and the reliability of the model.

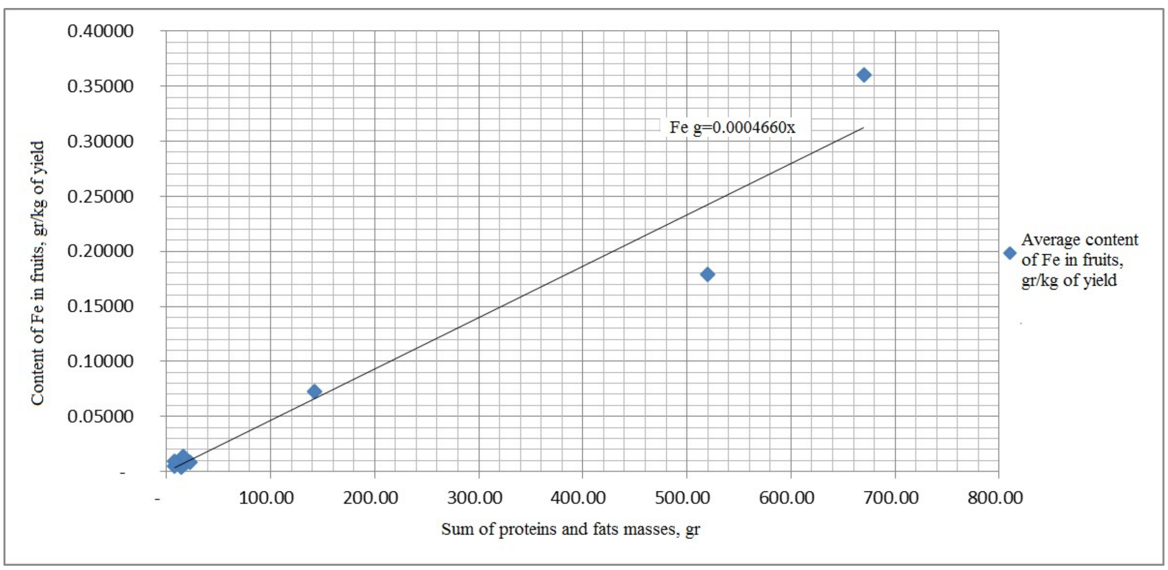

Fig.13. Dependence of ferrum (Fe) content in fruits on the sum of protein and fat weight. R = 0.974, where R is the coefficient determining the correlation ratio and the reliability of the model.

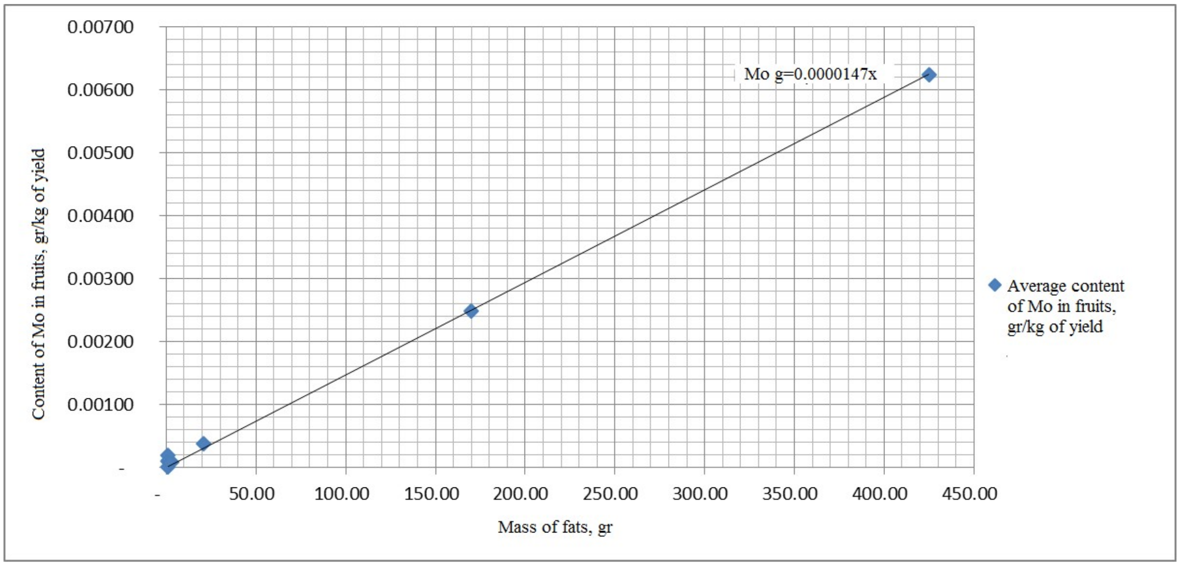

Fig.14. Dependence of molybdenum (Mo) content in fruits on fat weight. R = 1, where R is the coefficient determining the correlation ratio and the reliability of the model.

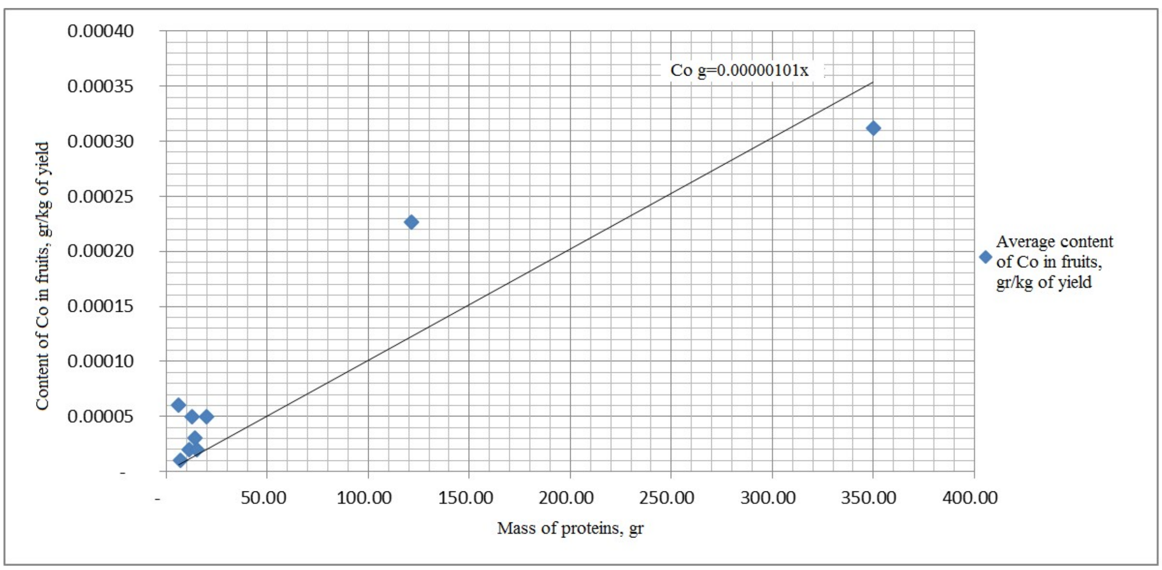

Fig.15. Dependence of cobalt (Co) content in fruits on protein weight. R = 0.937, where R is the coefficient determining the correlation ratio and the reliability of the model.

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