**CONTEÚDO DE SUBSTÂNCIAS BIOLÓGICAMENTE ATIVAS E METAIS PESADOS NAS
MAÇÃS DE UMA CADEIA DE VAREJO NA REGIÃO DE LIPETSK (RUSSIA),
DEPENDENDO DAS VARIEDADES DE MAÇÃS****THE CONTENT OF BIOLOGICALLY ACTIVE SUBSTANCES AND HEAVY METALS IN
THE APPLES OF A RETAIL CHAIN IN THE LIPETSK REGION DEPENDING ON THE
APPLE TREES VARIETIES****СОДЕРЖАНИЕ БИОЛОГИЧЕСКИ АКТИВНЫХ ВЕЩЕСТВ И ТЯЖЁЛЫХ МЕТАЛЛОВ В
ЯБЛОКАХ ТОРГОВОЙ СЕТИ ЛИПЕЦКОЙ ОБЛАСТИ В ЗАВИСИМОСТИ ОТ СОРТА
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RESUMO

A relevância baseia-se na necessidade de estudar a quantidade de substâncias biologicamente ativas e nutrientes-traço em variedades de maçã vendidas na cadeia de varejo da região de Lipetsk. O objetivo é analisar o conteúdo de substâncias biologicamente ativas e nutrientes-traço de todas as variedades de maçã vendidas na cadeia de varejo da região de Lipetsk. O artigo é o primeiro a estabelecer uma estreita relação entre o termo amadurecimento de maçãs e o teor de flavonóis, substâncias pécicas, antocianinas, Fe, Zn, Cu, Ni, Pb e Co. Ao mesmo tempo, os autores estabeleceram uma estreita correlação entre o teor de Fe e Zn nos frutos ($r = 0,8$). Foram utilizados métodos de arbitragem, titrimétrica, fotométrica, iodométrica, de cálcio-pectato de peso, de adsorção atômica, ionométrica e de correlação para resolver as tarefas. Na cadeia de varejo da região de Lipetsk, os autores identificaram variedades de maçãs com a maior massa de frutas e conteúdo de ácido ascórbico, ácidos orgânicos, substâncias secas, antocianinas, flavonóis, catequinas, pectinas, substâncias corantes e bronzeadores, incluindo tanino, carotenóides, incluindo β -caroteno, bem como elementos minerais: Fe, Mn, Zn, Cu, Ni, Pb, Cd e Co. Os autores também determinaram o teor de metais pesados em maçãs em relação à concentração máxima permitida (MAC). Variedades de outono contêm a maior quantidade de ácido ascórbico, carotenóides, caroteno, substâncias de bronzeamento e substâncias corantes e tanino. As variedades de inverno contêm menos catequinas, curtimento e substâncias corantes. O conteúdo de substâncias pécicas, antocianinas e flavonóis atinge seu máximo em frutos de variedades de inverno. O teor de flavonóis varia mais fortemente, e o menor - pH e conteúdo de ácidos orgânicos de todas as substâncias biologicamente ativas em frutos de maçã. O teor de ferro aumenta com o aumento do teor de zinco. O teor de elementos minerais nas variedades de verão é o mais baixo. O teor de elementos minerais e flavonóis nos frutos de maçã aumenta com a transição das variedades de verão para o outono e depois para o inverno. O conteúdo de ferro varia mais e menos do que tudo - cádmio dos elementos minerais nas frutas. O conteúdo de todos os elementos minerais varia mais fortemente nas variedades de maçã de inverno.

Palavras-chave: *substâncias biologicamente ativas, maçãs, variedade, nutrientes vestigiais.***ABSTRACT**

The relevance is based on the need to study the amount of biologically active substances and trace nutrients in apple varieties sold in the retail chain of the Lipetsk region. The purpose is to analyze the content of biologically active substances and trace nutrients of all apple varieties sold in the retail chain of the Lipetsk region. The article is the first to establish a close relationship between the term of apples ripening and the content of flavonols, pectic substances, anthocyanins, Fe, Zn, Cu, Ni, Pb, and Co in them. At the same time, the authors established a close correlation between the content of Fe and Zn in fruits ($r = 0.8$). Arbitration, titrimetric, photometric, iodometric, weight calcium-pectate, atomic-adsorption, ionometric, and correlation

analysis methods were used to solve the tasks. In the Lipetsk region retail chain, the authors identified varieties of apples with the most significant mass of fruit and content of ascorbic acid, organic acids, dry substances, anthocyanins, flavonols, catechins, pectins, tanning and coloring substances, including tannin, carotenoids, including β -carotene, as well as mineral elements: Fe, Mn, Zn, Cu, Ni, Pb, Cd, and Co. The authors also determined the content of heavy metals in apples relative to the maximum allowable concentration (MAC). Autumn varieties contain the highest amount of ascorbic acid, carotenoids, carotene, tanning substances and coloring substances, and tannin. Winter varieties contain the least catechins, tanning, and coloring substances. The content of pectic substances, anthocyanins, and flavonols, reaches its maximum in winter varieties fruits. The content of flavonols most strongly varies, and the least - pH and content of organic acids of all the biologically active substances in apple fruits. Iron content increases with the increase in zinc content. The content of mineral elements in the summer varieties is the lowest. The content of mineral elements and flavonols in apple fruits increases with the transition from summer varieties to autumn, and then to winter. The content of iron varies the most, and least of all - cadmium of the mineral elements in fruits. The content of all mineral elements varies most strongly in winter apple varieties.

Keywords: *biologically active substances, apples, variety, trace nutrients.*

АННОТАЦИЯ

Актуальность основана на необходимости изучения количества биологически активных веществ и микроэлементов в сортах яблок, продаваемых в розничной сети Липецкой области. Целью является анализ содержания биологически активных веществ и отслеживание питательных веществ всех сортов яблок, продаваемых в розничной сети Липецкой области. В статье впервые установлена тесная связь между сроком созревания яблок и содержанием в них флавонолов, пектиновых веществ, антоцианов, Fe, Zn, Cu, Ni, Pb и Co. В то же время авторы установили тесную корреляцию между содержанием Fe и Zn в плодах ($r = 0,8$). Для решения поставленных задач использовались методы арбитражного, титриметрического, фотометрического, йодометрического, весового кальция-пектата, атомно-адсорбционного, ионометрического и корреляционного анализа. В розничной сети Липецкой области авторы выявили сорта яблок с наибольшей массой фруктов и содержанием аскорбиновой кислоты, органических кислот, сухих веществ, антоцианов, флавонолов, катехинов, пектинов, дубильных и красящих веществ, в том числе дубильных веществ, каротиноидов, в том числе β -каротин, а также минеральные элементы: Fe, Mn, Zn, Cu, Ni, Pb, Cd и Co. Авторы также определили содержание тяжелых металлов в яблоках относительно предельно допустимой концентрации (ПДК). Осенние сорта содержат наибольшее количество аскорбиновой кислоты, каротиноидов, каротина, дубильных и красящих веществ, а также танинов. Зимние сорта содержат наименьшее количество катехинов, дубильных и красящих веществ. Содержание пектиновых веществ, антоцианов и флавонолов достигает максимума у зимних сортов плодов. Содержание флавонолов наиболее сильно варьирует, а наименьшее - pH и содержание органических кислот всех биологически активных веществ в яблонях. Содержание железа увеличивается с увеличением содержания цинка. Содержание минеральных элементов в летних сортах самое низкое. Содержание минеральных элементов и флавонолов в яблонях увеличивается с переходом от летних сортов к осени, а затем к зиме. Содержание железа колеблется больше всего, а меньше всего - кадмия из минеральных элементов в плодах. Содержание всех минеральных элементов наиболее сильно варьирует у зимних сортов яблок.

Ключевые слова: *биологически активные вещества, яблоки, сорт, микроэлементы.*

1. INTRODUCTION

A human being daily needs trace nutrients and biologically active substances (BAS) to maintain normal health (Nieder *et al.*, 2018; Estibaliz and Martinez, 2010). Apples are the fourth most important fruit in the world (Musacchi and Serra, 2018; Karasawa and Mohan, 2018), having a relatively long shelf life compared to other fruit crops (Gyul'ko *et al.*, 2018), as well as therapeutic and preventive properties (Andréia *et al.*, 2019). Apples contain catechins (Giomaro *et al.*, 2014), pectin, and phenolic compounds (Kalinovska *et al.*, 2014). The method of high-performance liquid chromatography turned out to be quite indicative of phenolic compounds (Parvaneh *et al.*, 2019) and the presence of 4-hydroxybenzoic, vanilla and fumaric acids (Demirci *et al.*, 2018). The authors obtained experience of determining polyphenols in apples through the formation of metal nanoparticles (Scroccarello *et al.*, 2019). The interaction of apple polyphenols with enzymes is shown (Sun *et al.*, 2019) using the fluorescence method. The authors used the example of a Siberian apple tree to study the polyphenolic profile of fruits (Rudikovskaya *et al.*, 2015). The authors established the dependence of the content in apples of flavonoids depending on the region (Fernández-Jalao *et al.*, 2019). Atomic emission spectrometry with inductively coupled plasma mass spectrometry demonstrated high content of B, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Se, Ti, and Zn in apples in Central Greece (Skordas *et al.*, 2013). Twenty-two old varieties of apples from Poland were studied for the BAS content using the quadrupole flight mass spectrometry method (Oszmiański *et al.*, 2018). The Indian Himalayas apples demonstrate a change in the content of flavonoids with a change in altitude above sea level (Dhyani *et al.*, 2018). The authors found a close correlation between the content of the pectin-glucose or pectin-galactose complex with the hardness of the fruits, as well as the relationship between the color, diameter of the fruit, the content of soluble solids, and water with the duration of storage (Ornelas-Paz *et al.*, 2018). Gala and Florina apples' varieties helped to establish the genetic nature of allergenicity due to the presence of specific enzymes (Parizh *et al.*, 2017). Despite the high vitamin value of apples, the sweetness of fruits remains the primary determining factor in consumer preferences (Charles *et al.*, 2018).

The purpose of the research was to analyze the content of biologically active

substances and trace nutrients of the fruits of all apple varieties sold in the retail chain of the Lipetsk region, to identify possible relationships between indicators and assess the level of heavy metals in the fruits of these varieties.

2. MATERIALS AND METHODS

The studies were conducted in 2016-2018 in the agrochemical research laboratory of Yelets State University. The fruits were analyzed in October. The dry substances content was determined by the arbitration method, which consisted of weighing the fruit before and after drying in a desiccator. The total acidity in terms of malic acid was determined by titration of the aqueous extract of the fruit with a decinormal NaOH solution in the presence of a phenolphthalein indicator. KFK-3 photometer used to determine the following by the light density: the carotene content is from a gasoline extract at a wavelength of 420 nM, the amount of carotenoids is from a 96% alcohol extract at a wavelength of 440.5; 649 and 665 nM, the content of anthocyanins is from the HCl extract (1%) at a wavelength of 490 nM, flavonols — from an alcoholic 50% extract at a wavelength of 400 nM, catechins — from an alcoholic 50% extract at a wavelength of 540 nM. The ascorbic acid content was determined by titration of the extract based on a mixture of 1% HCl and 1% oxalic acid in the presence of indicators: KJ and 1% starch solution. 0.001N solution of KJO₃ was used as a titrant. The sum of coloring and tanning substances was determined by titration of the aqueous extract of fruits with a decinormal solution of KMnO₄ in the presence of indigo carmine and 20% sulfuric acid. The tannin content was determined by titration of the aqueous extract with a decinormal solution of KMnO₄ in the presence of indigo carmine. The content of pectic substances was determined by weighing calcium pectate, filtered from the acid and alkaline extracts of the fruit. The pH of the pulp was determined on the "Expert-001" pH meter ion meter. The content of trace nutrients was determined by the atomic adsorption method on the "Spectrum-5" spectrophotometer. The relationship between the indicators of the quality of the fruit was performed by the method of correlation analysis using Excel.

3. RESULTS

The authors studied 35 varieties of apples. The Antonovka (ordinary) variety has the largest fruit, and Siberian Crab Apple has the

smallest fruit (Table 1).

The Belle-Fleur variety is the richest in ascorbic acid, while the varieties from the Krasnodar region Mutsu, Idared, Royal Gala, and Red Delicious contain the least amount of it (Table 2).

The Liberty variety is the richest in water-soluble pectic substances, while the Ionika variety contains the least of them (Table 3).

Due to the use of pesticides, mineral fertilizers, and fuel and lubricants in gardens, toxicants, including heavy metals, get into apples through the soil (Zhu *et al.*, 2018). The study of fruits according to the medical and biological requirements for the content of trace nutrients and heavy metals showed that some varieties fail to comply with the required parameters (Table 4).

Averaging the data obtained by groups of varieties, it is possible to associate the content of biologically active substances with the period of fruit ripening (Table 5).

The highest concentrations of mineral elements are found in winter varieties (Table 6).

4. DISCUSSION

The content of dry substances in the fruits varied from 9.4–9.5% (March and Antonovka (ordinary) varieties) to 16.6–16.7% (Florina and Orlik varieties). Judging by the pH, the Orlik variety has the sourest pulp, while Golden Delicious and Red Delicious varieties have the least sour pulp. Correlation analysis helped to establish that the pulp's pH does not depend on the content of organic acids (the regression coefficient is $r = -0.36$).

The Antonovka (ordinary) variety is the most saturated with organic acids, while the Granny Smith and Renet Simirenko varieties are the least saturated with such acids. The Scarlet Anise variety is the richest in tanning and coloring substances, including tannins, while the Zhigulevskoe variety contains the least amount of them.

The Cherry variety contains the least ascorbic acid among the varieties of the central part of the Russian Federation. The Scarlet Anise variety is the richest in carotenoids, including β -carotene, while the Belle-Fleur, Cherry, Golden Delicious, Lobo, Royal Gala, and Red Delicious

varieties contain the least amount of them. The Spartan variety is the richest in coloring P=active substances (anthocyanins), while Northern Sinap, Sinap Orlovskiy, and Boy-Ken varieties contain the least amount of them. The Orlik and Zvezdochka variety are the richest in yellow coloring P-active substances - flavonols. The Siberian Crab Apple variety contains the least amount of them. The Antonovka (ordinary) variety is the richest in astringent P-active substances (catechins), while the Ionika, Cherry, Lobo, March, and Renet Kichunova varieties contain the least amount of them.

The Zhigulevskoe, Gala, and Cinnamon Striped varieties are the richest in protopectic and pectic acid, while the Florina variety contains the least amount of them. The Zhigulevskoe variety contains the highest total number of pectic substances, while the Ionika variety contains the least amount of them.

The chemical elements of hazard class 1 found in the fruits, namely, Ni, Pd, Cd, are alarming. MAC of nickel should not exceed 0.5 mg/kg. The Idared, Boy-Ken, Gala, Golden Delicious, Zvezdochka, March, and Mutsu varieties contain the MAC-exceeding content of nickel, while the Red Delicious variety exceeded nickel MAC two times.

Fruits are allowed to contain up to 50.0 mg/kg of iron. Only the Florina and Gala varieties contain the MAC-exceeding amount of iron. The Florina variety is the richest in cobalt, and the varieties of Belle-Fleur, Boy-Ken, Golden Delicious, Zhigulevskoe, Zvezdochka, Rossoshanskoe Striped, Red Delicious, and Slava Pobeditelyam contain only traces of cobalt. The content of zinc should not exceed 10.0 mg/kg. Its amount did not exceed the permissible rate in all varieties, that is, it was at the level of the trace nutrient. The Florina variety is the leader in the content of this trace nutrient, and the Zhigulevskoe variety contained the least of it. The content of copper should not exceed 5.0 mg/kg. The content of this nutrient exceeded the MAC, so the following apple varieties of The Idared, Antonovka (ordinary), Cherry, Golden Delicious, Granny Smith, Ionika, March, Renet Simirenko, Rossoshanskoe Striped, Royal Gala, Red Delicious, Slava Pobeditelyam, Florina, and Champion varieties contain it at the level of heavy metals. The Antonovka (ordinary) variety is the richest in manganese, while its content in the Cherry, March, and Red Delicious varieties was in traces. The content of lead should not exceed

0.4 mg/kg. The Idared, Gala, Golden Delicious, Granny Smith, Zvezdochka, Mutsu, Siberian Crab Apple, Red Delicious, Royal Gala, Tambov Striped, and Florina varieties demonstrated the excessive content of this heavy metal. The content of cadmium should not exceed 0.03 mg/kg. Only Mutsu variety had excessive cadmium content.

Autumn varieties contain the highest amount of ascorbic acid, carotenoids, including carotene, as well as tanning substances, including tannin. The fruits of winter varieties contain the least catechins. The content of pectic substances, anthocyanins, and flavonols, reaches its maximum in winter varieties fruits. No differences have been established between varieties of different maturity for other biologically active substances.

The content of flavonols most strongly varies, and the least - pH and content of organic acids of all the biologically active substances in apple fruits. The content of iron varies the most, and least of all - cadmium of the mineral elements in fruits. The content of all mineral elements varies most strongly in winter apple varieties.

There are no dependencies between the content of some biologically active substances with others, but there is a dependency between iron and zinc content ($r = 0.8$). The content of mineral elements in the summer varieties is the lowest. The content of mineral elements and flavonols in apple fruits increases with the transition from summer varieties to autumn, and then to winter. Considering that the storage life of autumn varieties is longer than that for summer varieties, and that of winter varieties is the longest, it becomes evident that with an increase in the content of flavonols, pectins, anthocyanins, Fe, Zn, Cu, Ni, Pb, and Co in fruits, the shelf life of apples increases. It is possible to increase the content of some of the presented elements, for example, Zn, by spraying the leaves with zinc-containing agents (Wójcik and Filipczak, 2019).

5. CONCLUSIONS

1. The Antonovka (ordinary) apples are the largest fruits and are most saturated with organic acids, P-active catechins, and manganese of the apple varieties sold in the retail chain of the Lipetsk region.

2. Orlik apples are the richest in dry

substances and P-active flavonols. Zvezdochka apples are also rich in flavonols.

3. Golden Delicious and Red Delicious apple varieties have the least sour pulp.

4. The leader in the content of tanning and coloring substances, including tannin, as well as carotenoids, including β -carotene, is fruits of the Scarlet Anise apple variety.

5. The greatest amount of ascorbic acid is found in fruits of the Belle-Fleur apple variety.

6. The highest concentration of anthocyanins is found in the fruits of the Spartan apple variety.

7. Water-soluble pectic substances are most commonly found in apples of Liberty variety, protopectic and pectic acid - in fruits of Zhigulevskoe, Gala, and Cinnamon Striped varieties, all pectic substances - in Zhigulevskoe apples.

8. Autumn varieties contain the highest amount of ascorbic acid, carotenoids, carotene, tanning and coloring substances, and tannin. The fruits of winter varieties contain the least catechins. The content of pectic substances, anthocyanins, and flavonols, reaches its maximum in winter varieties fruits.

9. Florina apples are the richest in cobalt and zinc.

10. Fruits of some varieties had the content of heavy metals higher than MAC: The Idared, Boy-Ken, Gala, Golden Delicious, Zvezdochka, Mutsu, March, and Red Delicious varieties - in nickel; Florina, and Gala in iron; the Idared, Antonovka (ordinary), Cherry, Golden Delicious, Granny Smith, Ionika, March, Rennet Simirenko, Rossoshanskoe Striped, Royal Gala, Red Delicious, Slava Pobeditelyam, Florina, and Champion varieties - in copper; the Idared, Gala, Golden Delicious, Granny Smith, Zvezdochka, Mutsu, Siberian Crab Apple, Red Delicious, Royal Gala, Tambov Striped, and Florina varieties - in lead; the Mutsu variety - in cadmium.

11. The content of flavonols most strongly varies of all the biologically active substances in apple fruits, and the lowest variance is observed in pH and content of organic acids. The content of iron varies the most, and least of all - cadmium of the mineral elements in fruits. The content of

all mineral elements varies most strongly in winter apple varieties.

12. The shelf life of apples increases with an increase in the content of flavonols, pectic substances, anthocyanins, Fe, Zn, Cu, Ni, Pb, and Co in fruits. At the same time, the closest correlation is established between the content of Fe and Zn in fruits ($r = 0.8$).

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Table 1. Qualitative indicators of the studied varieties of apples

Variety	Average fruit weight, g	Pulp pH	Substance content, %			
			dry	organic acids	coloring and tanning	tannin
Idared Apple	150.0	3.32	12.8	0.3	0.6	traces
Scarlet Anise Apple	63.0	3.44	11.5	0.4	6.2	1.25
Antonovka (Ordinary) Apple	280.0	2.96	9.5	1.2	2.8	traces
Belle-Fleur Apple	210.0	3.40	14.4	0.5	1.3	0.01
Bogatyr Apple	160.0	3.00	14.1	0.8	0.8	0.4
Boy-Ken Apple	148.0	3.27	10.5	0.8	0.8	0.41
Cherry Apple	115.0	3.23	13.0	0.6	1.3	0.01
Autumn Gala Apple	130.0	3.83	13.6	0.4	0.7	0.6
Golden Delicious Apple	170.0	4.06	13.1	0.6	0.7	traces
Granny Smith Apple	200.0	3.34	12.8	0.2	0.5	traces
Zhigulevskoe Apple	160.0	3.07	12.5	0.4	0.1	0.01
Zvezdochka Apple	108.0	3.11	12.5	0.7	1.2	traces
Ionika Apple	175.0	3.42	12.1	0.3	0.6	0.01
Cinnamon Striped Apple	85.0	3.54	12.4	0.3	0.3	traces
Liberty Apple	140.0	3.50	11.1	0.4	0.3	0.08
Lobo Apple	140.0	3.48	11.5	0.4	1.1	0.01
March Apple	150.0	3.31	9.4	0.3	0.6	0.03
Mechta Apple	150.0	3.81	14.5	0.4	0.7	0.01
Mutsu Apple	170.0	3.25	14.1	0.3	0.3	0.01
Orlik Apple	110.0	2.68	16.7	0.4	0.3	traces
Saffron Pippin Apple	110.0	3.26	10.8	0.5	1.3	0.41
Siberian Crab Apple	11.0	3.60	15.8	0.4	1.7	traces
Rennet Kichunova Apple	113.0	3.33	14.1	0.7	1.1	traces
Rennet Simirenko Apple	175.0	3.44	10.8	0.2	0.7	0.65
Rossoshanskoe Striped Apple	180.0	3.34	11.4	0.5	0.6	0.58
Royal Gala Apple	150.0	3.50	13.1	0.4	0.6	traces
Red Delicious Apple	105.0	4.10	12.9	0.3	0.3	traces
Sinap Orlovskiy Apple	150.0	3.44	11.6	0.8	0.3	traces
Northern Sinap Apple	120.0	3.23	11.5	0.5	0.3	0.41
Slava Pobeditelyam Apple	140.0	3.41	11.3	0.5	2.2	traces
Spartan Apple	130.0	3.54	12.4	0.4	1.8	traces
Start Apple	132.0	3.37	12.8	0.6	0.8	traces
Tambov Striped Apple	194.0	3.26	13.7	0.4	1.9	traces
Florina Apple	175.0	3.78	16.6	0.3	0.9	traces
Champion Apple	175.0	3.66	14.5	0.4	1.4	0.01

Table 2. The BAS content in the fruits of the studied varieties, mg%

Variety	Ascorbic acid	β -carotene	Sum of carotenoids, mg%	P-active substances (bioflavonoids)		
				Anthocyanins	Flavonols	Catechins
Idared Apple	2.2	0.1	0.1	5.5	30.5	0.8
Scarlet Anise Apple	3.1	2.5	2.6	3.6	93.7	0.8
Antonovka (Ordinary) Apple	4.4	0.6	0.7	1.5	10.5	13.4
Belle-Fleur Apple	26.4	traces	0.1	7.9	50.4	3.2
Bogatyr Apple	16.7	traces	0.4	4.3	53.3	1.6
Boy-Ken Apple	7.0	0.1	0.3	0.6	16.4	0.7
Cherry Apple	2.2	traces	0.1	2.6	11.7	traces
Gala Apple	2.6	traces	0.3	6.9	12.9	4.7
Golden Delicious Apple	2.6	traces	0.1	9.0	39.8	0.1
Granny Smith Apple	3.1	traces	0.6	6.3	10.5	0.4
Zhigulevskoe Apple	11.5	0.3	0.6	5.2	56.2	4.7
Zvezdochka Apple	17.6	traces	0.8	5.6	130.0	7.9
Ionika Apple	2.6	traces	0.4	2.0	4.7	traces
Cinnamon Striped Apple	9.3	0.2	0.3	2.6	1.2	13.4
Liberty Apple	4.4	0.1	0.9	1.0	78.5	0.2
Lobo Apple	2.6	traces	0.1	3.8	4.7	traces
March Apple	2.6	traces	0.4	1.3	22.3	traces
Mechta Apple	13.2	traces	1.0	12.2	70.3	0.4
Mutsu Apple	1.8	traces	0.7	2.2	44.5	0.2
Orlik Apple	17.6	traces	0.8	5.5	131.2	0.8
Saffron Pippin Apple	2.2	0.7	0.8	5.5	91.4	0.8
Siberian Crab Apple	17.6	traces	0.9	16.0	0.1	7.9
Rennet Kichunova Apple	3.5	traces	0.3	1.4	10.5	traces
Rennet Simirenko Apple	5.7	traces	0.8	5.8	62.1	0.1
Rossoshanskoe Striped Apple	6.2	0.4	0.4	5.1	22.8	4.1
Royal Gala Apple	2.2	traces	0.1	7.5	11.7	0.3
Red Delicious Apple	2.2	traces	0.1	7.5	7.0	4.0
Sinap Orlovskiy Apple	6.2	traces	0.6	0.6	8.8	0.7
Northern Sinap Apple	6.2	0.2	1.2	0.4	11.7	0.3
Slava Pobeditelyam Apple	3.5	0.4	0.4	4.7	8.2	12.7
Spartan Apple	8.8	1.1	1.4	21.6	118.3	2.4
Start Apple	8.8	traces	0.9	8.1	5.9	0.1
Tambov Striped Apple	17.6	traces	0.2	6.0	11.7	2.8
Florina Apple	2.6	traces	0.8	6.6	15.2	0.1
Champion Apple	7.9	traces	0.6	3.8	9.4	0.7

Table 3. *The content of pectic substances in fruits*

Apple variety	Water-soluble pectic substances, %	Protopectic and pectic acid, %	Total amount of pectic substances, %
Idared Apple	0.55	0.6	1.15
Scarlet Anise Apple	0.95	0.85	1.8
Antonovka (Ordinary) Apple	0.46	3.24	3.7
Belle-Fleur Apple	0.8	1.8	2.6
Bogatyr Apple	0.6	1.2	1.8
Boy-Ken Apple	0.37	0.61	0.98
Cherry Apple	0.41	0.36	0.77
Gala Apple	0.52	5.36	5.88
Golden Delicious Apple	0.73	2.46	3.19
Granny Smith Apple	0.64	4.8	5.44
Zhigulevskoe Apple	0.7	5.5	6.2
Zvezdochka Apple	0.6	2.4	3.0
Ionika Apple	0.12	0.18	0.3
Cinnamon Striped Apple	0.8	5.0	5.8
Liberty Apple	1.9	1.5	3.4
Lobo Apple	0.31	0.13	0.44
March Apple	0.22	0.5	0.72
Mechta Apple	0.5	0.2	0.7
Mutsu Apple	0.45	0.47	0.92
Orlik Apple	0.6	1.3	1.9
Saffron Pippin Apple	0.62	0.86	1.48
Siberian Crab Apple	0.9	1.3	2.2
Rennet Kichunova Apple	0.6	1.02	1.62
Rennet Simirenko Apple	0.61	0.14	0.75
Rossoshanskoe Striped Apple	0.73	0.74	1.47
Royal Gala Apple	0.64	0.28	0.92
Red Delicious Apple	0.53	0.84	1.37
Sinap Orlovskiy Apple	0.45	0.67	1.12
Northern Sinap Apple	0.36	0.64	1.0
Slava Pobeditelyam Apple	0.66	0.59	1.25
Spartan Apple	0.7	1.8	2.5
Start Apple	0.6	1.4	2.0
Tambov Striped Apple	0.6	1.6	2.2
Florina Apple	0.39	0.09	0.48
Champion Apple	0.59	0.4	0.99

Table 4. MAC and the actual content of heavy metals in fruits, mg/kg of wet weight

Variety	Hazard class 1			Hazard class 2			Hazard class 3	
	Ni	Pb	Cd	Co	Zn	Cu	Mn	Fe
	MAC of heavy metals in fruits							
	0.5	0.4	0.03	0.5	10.0	5.0	10	50.0
The actual content of the elements in the fruit								
Idared Apple	0.693	3.315	0	2.953	3.410	5.408	3.791	41.875
Antonovka (Ordinary) Apple	0	0	0	2.044	5.870	5.763	8.374	21.718
Belle-Fleur Apple	0.164	0	0	0	3.068	2.696	1.421	11.436
Bogatyr Apple	0.423	0.214	0	0.700	4.135	3.598	3.180	19.757
Boy-Ken Apple	0.656	0	0	0	2.631	3.069	3.200	18.706
Cherry Apple	0	0	0	1.300	4.106	5.919	0	17.081
Gala Apple	0.842	4.824	0	2.370	4.440	4.334	5.972	51.168
Golden Delicious Apple	0.597	1.477	0	0	3.939	9.945	5.307	4.324
Granny Smith Apple	0.100	0.900	0	1.563	7.931	7.087	2.975	20.325
Zhigulevskoe Apple	0.304	0.079	0	0	2.434	2.496	1.250	12.271
Zvezdochka Apple	0.600	1.130	0	0	5.430	4.720	1.840	23.630
Ionika Apple	0	0.157	0	0.706	2.813	5.477	1.136	13.864
Lobo Apple	0	0	0	0.831	3.381	3.688	1.163	18.706
March Apple	0.663	0	0	2.953	5.225	5.700	0	29.912
Mechta Apple	0.143	0	0.029	0.143	2.846	3.321	2.532	11.061
Mutsu Apple	0.575	0.737	0.112	0.388	4.356	2.575	3.367	10.575
Orlik Apple	0.236	0.057	0	0.264	2.789	1.929	2.257	17.714
Siberian Crab Apple	0.359	0.878	0.014	0.207	4.543	2.337	1.658	20.137
Rennet Kichunova Apple	0.175	0	0	0.681	3.763	3.575	5.363	25.213
Rennet Simirenko Apple	0.013	0.188	0	0.894	3.050	6.663	1.538	14.738
Rossoshanskoe Striped Apple	0	0	0	0	3.352	9.412	1.671	22.610
Royal Gala Apple	0.438	1.163	0	1.625	6.431	8.950	5.906	14.387
Red Delicious Apple	1.124	0.928	0	0	3.779	6.930	0	24.059
Slava Pobeditelyam Apple	0	0	0	0	6.238	6.875	3.000	15.813
Spartan Apple	0.307	0.264	0	0.114	2.900	2.589	1.979	17.657
Tambov Striped Apple	0.457	0.521	0.005	0.475	5.746	3.571	1.832	17.400
Florina Apple	0.344	4.234	0	3.438	33.062	7.063	6.328	83.594
Champion Apple	0.188	0.188	0	1.063	7.131	6.794	7.025	28.663

Table 5. The BAS content in the fruits, depending on the ripening period

Indicator	Summer varieties	Autumn varieties	Winter varieties
Dry substances, %	12.9 ± 1.6	12.7 ± 3.2	13.0 ± 3.6
Ascorbic acid, mg%	8.4 ± 4.9	14.5 ± 11.9	9.9 ± 7.7
β-carotene, mg%	0.2 ± 0.2	1.3 ± 1.2	0.6 ± 0.5
Sum of carotenoids, mg%	0.7 ± 0.3	1.4 ± 1.2	0.8 ± 0.6
Anthocyanins, mg%	8.5 ± 3.7	8.8 ± 7.2	11.0 ± 10.6
The amount of tanning and coloring substances, %	1.5 ± 0.7	3.3 ± 2.9	1.0 ± 0.8
Tannin, %	traces	0.6 ± 0.6	0.3 ± 0.3
Flavonols, mg%	39.3 ± 31.0	46.9 ± 46.8	61.5 ± 56.8
Catechins, mg%	6.5 ± 6.1	7.1 ± 6.3	4.0 ± 3.9
Organic acids, %	0.4 ± 0.1	0.8 ± 0.4	0.5 ± 0.3
Water-soluble pectic substances, %	0.6 ± 0.1	0.6 ± 0.4	1.0 ± 0.8
Protopectic and pectic acid, %	0.4 ± 0.2	2.8 ± 2.6	2.8 ± 2.7
Total amount of pectic substances, %	1.0 ± 0.2	3.1 ± 2.8	3.3 ± 2.9

Table 6. The content of macro- and trace nutrients in the fruits depending on the ripening period, mg/kg of wet weight

Element	Summer varieties	Autumn varieties	Winter varieties
Ni	0.07 ± 0.07	0.503 ± 0.339	0.568 ± 0.556
Pb	traces	0.66 ± 0.5	2.157 ± 2.077
Cd	0.029 ± 0.01	0.01 ± 0.004	0.112 ± 0.01
Co	0.143 ± 0.01	1.288 ± 1.082	1.776 ± 1.662
Zn	4.86 ± 1.378	4.972 ± 2.159	17.748 ± 15.314
Cu	5.098 ± 1.777	5.644 ± 3.306	6.22 ± 3.725
Mn	2.766 ± 0.234	4.755 ± 3.619	3.745 ± 2.583
Fe	13.437 ± 2.376	31.302 ± 19.866	43.959 ± 39.635