Impact of technological scheme of apple tree cultivation on fractional content of pectin substances

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Abstract. The trend of the modern society is to consume ecologically safe products or products with improved ecological properties. The article reviews some advantages and disadvantages of intensive and organic horticulture systems. It shows feasibility of an integrated system development. The object of the research is Prima apple cultivar, treated with the growth regulators such as foliton, vermicoffe, potassium, melafen and mettalocen. The article describes impact of growth regulators on the fractional composition of pectin substances. It proves that treatment of apple trees with potassium increases the weight fraction of soluble pectin while treatment with melafen and metallocen increases proto pectin content. Taking into account chemistry of pectin substances, fractional composition changes under different factors may be explained with structural changes of homogalaturonan and rhamnogalactoronan - i. The obtained experimental results have led to the conclusion that it is reasonable to use apples from trees that have been treated with melafen and metallocen for dry pectin production while those that have been treated with potassium should be used for pectin extracts. So, the obtained data showed the viability of the studied cultivation schemes in commercial apple orchards for organizing production of pectin and pectin-containing food products with improved ecological properties.

1. Introduction

In modern conditions, organizing rational eating patterns of a person is considered, primarily, if there is a guarantee of food safety. This has lead to the emergence of eating theories based on consumption of ecologically safe food and products with the improved ecological properties.

Taking into account the tendency in the modern society development, such terms as “natural”, “ecologically clean” and “organic” are often used on food products labels. First, these terms are synonyms. However, in the modern world organic and natural food products are not the same.

In most developed countries natural products mean any product, received from plants and animals that have not been chemically, synthetically or genetically modified. However, different chemical matter can be used in these products cultivating [1].

Organic foods are produced and cultivated without (or with very little use of) synthetic pesticide, synthetic mineral fertilizers, growth regulators, artificial food additives and without genetically modified products. In practice it means that production of agricultural products is carried out under strict control of special authorities. All technological chains, starting with production of agricultural products and finishing with their processing, must be certified.

The world leader in producing and consuming this kind of goods is the United States of America.
According to the report of the International Federation of Organic agriculture movement (IFOAM) from 09.02.2018, the world volume of organic goods production has been doubling every 5 years since 2000. This data is supported by the fact that development of organic products sector is given priority on the modern food market.

Production of organic goods is practiced in more than 160 countries on more than 37 million hectares of agricultural land. Russia has certified 150000 hectares of agricultural land for the organic production [2].

In recent years many countries have been facing the development of organic horticulture. It suggests decreasing or abandoning any mineral (especially nitrogen-containing) fertilizers and pesticides due to the use of agronomical and biological means of plants protection, this way providing safety of fruit products.

A lot of studies are devoted to the problems of organic horticulture [3, 4, 5]. The results of the studies prove promise for using in organic orchards clone and seed fruit rootstock which has weak reaction to additional mineral nutrition and resistance to big amount of toxic metals in soil. However, despite the demand on organic fruit, its production, at present, involves low profitability because of orchards low harvest capacity.

It explains why the main horticultural systems are still the traditional and organic ones. Considering the advantages and disadvantages of these systems, it is relevant to construct a system that would provide a reasonable balance between the produce volume and quality, between the scale of invested natural and technological resources and environmental damage [5]. The combination of these factors characterizes the whole idea of adaptive or integrated horticultural systems. It suggests a significant decrease in pesticide burden and in the amount of mineral fertilizers, and provides sufficiently high (for an apple tree about 18–20 tones per 1 hectare) and stable harvest in different soil and climatic conditions in comparison to the intensive technological system.

Processing of apples and other seedlings into juices has become a developed industry. Juices, both clarified and nonclarified, has turned into a mass product sold all over the world as a consumer commodity. According to the assessment, given by the Russian Juice Producers Union, apple juice is the most popular kind among consumers. The share of natural juices (among which apple juice is the leader) is not less than 20%.

Juice manufacturing creates 15–20% of secondary raw materials which are the industrial source of pectin substances [6]. We are aware of the wide range of influence that pectin products have on human body. For example, pectin can bind and remove heavy metals, including radionuclide, from the body system. Application of therapeutic dose of pectin medicine, average 2–10 g per day in terms of dry pectin matter, does not have any side effects even during long-term use.

Taking into account minimal preventive daily consumption rates recommended by the World Health Organization (2g per day) [7], annual consumption of pectin-containing products per 100 million people is about 70000 tones.

Meanwhile, according to the professional data, the world production of pectin reached 74000 tons in 2018. The biggest producer and seller of pectin in the international market are CP Kelco Company (USA) [8].

Manufacturing of pectin-containing food products (pastry, bakery products, vegetable and fruit canned goods, drinks and etc.) in Russia is based on imported high-ester pectins. Apart from that, such pectins can improve the efficiency of some medications, minimize their toxic impact on the human body, eliminate some side effects and regulate the blood cholesterol and glucose level [7, 9–11].

Most of foreign and Russian research is related to the study of apple raw material in intensive technological horticultural system [12–14]. There is very little data on the impact of the integrated horticultural system on the fractional content of the apple pectin matter.

2. Materials and methods
We have chosen a research farm of Kuban State Agricultural University as an experimental base. This choice is explained by the fact that the University scientists carry out different research on establishing
the scientific basis for organic gardening. They have developed some technology of apple trees cultivation without pesticide and with the limited use (or no use) of mineral and nitrogen fertilizers [5].

The object of this study is Prima, which is a commercial autumn period apple cultivar of American selection. This cultivar originated from M. floribunda 821 and Welsy, Melba, Rome Beauty, Golden Delicious and their derivatives. It is characteristic and widely spread in the South of Russia as a scab immune cultivar.

Fruit (Figure 1) is medium in size, medium flattened and round, often symmetrical and smooth. Apple peel is slightly glossy, a little waxed during storage, with a little russet in a narrow and deep eye basin. It is of light yellow or greenish-yellow color with red, striped, often solid, dark blush covering the biggest half of the apple. The flash is cream colored with tender, juicy texture and sweet sub-acid flavor. Fruit matures in the second-third of August. Chemical composition of fruit: solids – 13%, sugars – 9.9%, titrate acids – 0.8%, ascorbic acid – 7.9mg/100g, P-active agents – 80-150mg/100g in raw mass. During growing and fruiting the trees of this apple cultivar were treated with plant growth regulators: foliton, vermiCoffe, potassium, melafen and metallocen.

The test samples were the ones that had not been treated with plant growth regulators. Foliton – highly effective anti-stress biological stimulant, acquired in protein hydrolysis process and having high amino acids content both free and integrated with peptides and polypeptides. It penetrates flows of plant generated juice which impedes nutrients absorption and plant regeneration. Chemical composition is the following: free amino acids – 10%; protein nitrogen – 8.5%. General characteristics: pH = 6.5%; density – 1.25%; free amino acids – 54%. At root application the norm is 15–20 l/he, depending on the application method.

VermiCOFFE contains all the components of vermicompost in soluble state: humins, fulvic acids, vitamins, natural phytohormones, micro and macro elements in forms of bio-available organic compounds and spores of effective soil micro-organisms. Fungicide and bactericide properties of the drug are explained by the presence of natural fungies and antibiotics, produced by the intestinal micro flora of earthworms in vermicultivation process. This is a complex of natural and ecologically clean and safe growth stimulant for plant development. Its application has a positive effect on the growth process, metabolism and photosynthesis. The chemical composition is nitrogen – 1500g/l; phosphorus -1400 g/l; potassium – 2500; pH=7.5–10.5: humin substances; 1.8–2.4 g/l. It is applied in form of water detergent 1:30–1:50 at watering during budding and blooming.

Potassium, along with nitrogen and phosphorous, is one of the major essential elements needed for mineral nutrition. Unlike nitrogen and phosphorus it is not incorporated in organic structures of plants but is located in plant cells in ionic form as soluble salts, in cell juices and, partly, in form of weak adsorbent complexes with cytoplasm colloids. If plants experience potassium shortage it dramatically weakens photosynthesis, plant growth becomes sharply suppressed, root system does not develop properly, harvesting and seedling productivity decrease, fruit become smaller, plants get exposed to
different diseases and are damaged by pests. Potassium contains 60% of active matter. This fertilizer is applied in the dose of 15–20 g per square meter.

Melafen – growth regulator with a wide range of effect, is produced in small and very small doses (concentration 10–9–10–7%) in 200 ml bottles. Active matter forms nana sized associates with water molecules and it significantly changes the working detergent properties. Melafen, possessing high physiological activity and anti-stress properties, stimulates plant growth and development, significantly increases harvesting and quality of products. The content of the active agent is 10.4 g/l. Melafen is a synthetic drug that is effective in low concentration $1 \cdot 10^{-8} - 1 \cdot 10^{-7}$.

Metallocen is a complex of macro and micro elements in a soluble form, easily available for plants and enriched with highly effective growth stimulant. This liquid, complex and stimulating fertilizer is intended for seed treatment prior to sowing and plant treatment during vegetation period. Application of this fertilizer increases the intensity of photo and bio synthesis; improves efficiency of absorbing mineral fertilizers and macro elements from soil to 20%; strengthens plant immune system and makes them resistant to pathogens; increases plant resistance to negative environmental factors; provides harvesting growth and improves the quality of agricultural products.

Fruit samples from the treated apple trees were examined for the mass fraction of pectin substances. Method of calculating quantity of pectin substances in plant raw material is based on extraction of pectin and its transformation into soluble state. The research of hydro and proto pectin extracts is based on the calcium-pectin method and precipitation with ethanol.

3. Results and discussion

As we know, fruit ontogenesis involves changes in the content of general pectin and in ratio of soluble and proto pectin usual for each fruit type. Soluble pectin and protopectin are located in different parts of a plant cell and fulfill different functions. Protopectin is part of cell walls and is one of the main components of middle lamella; soluble pectin is located in vacuole juice and within intercellular spaces of mature fruit tissue [15]. The total pectin matter content and ratio between proto and hydropectin dictate the need for different technology of pectin substances extraction and explain the difference in their physic and chemical properties.

To define the influence of different growth stimulants we studied quantity content of soluble and protopectin. Figure 2 shows the data of the experimental research of the weight fraction of soluble pectin in the general volume of pectin substances. Figure 3 shows data on the impact of different growth stimulant on the change of mass fraction of proto pectin in the general volume of pectin substances in the studied apple cultivar.

The results of the experimental studies have shown that the biggest weight fraction of protopectin in the general volume of pectin substances is found in apple fruit from the trees treated with melafen. In order to assess technological feasibility of the researched apple material we calculated the percentage ratio between hydropectin and protopectin fractions (Figure 4). Calculations have shown that the highest ratio of SP/PP is discovered in fruit from the trees that had been treated with potassium, the lowest – by metallocen. This result meets the results of the experimental research.

Pectins in a plant cell are presented by three polysaccharides components: Homogalacturonan, Rhamnogalacturonan-I and Rhamnogalacturonan-II. Each of these polysaccharides contains galacturonic acid [15]. Homogalacturonan makes up 24% of the cell wall mass and 57–69% in an overall content of pectin polysaccharides, Rhamnogalacturonan-I – 7–14% and 20–33%, Rhamnogalacturonan-II – 4% and 10–11%. Taking into account chemistry of pectin substances, changes of their fractional content, depending on different factors, can be explained, first of all, by structural changes of homogalacturonan and rhamnogalacturonan-I.

Homogalacturonan-I consists of D-galacturonic acid residue, bound by α(1→4) linkages. Rhamnogalacturonan-I consists of negatively-charged residues of D-galacturonic acid, bound together into fragments. Disaccharides, consisting of L-rhamnopyranose (1→4) D-galactopyranose-α(1→2) L-rhamnopyranose are inserted at the fragments intervals. The last residue of galacturonic fragments is bound by L-rhamnose disaccharide glucose α(1→2) linkage. Presence of L-rhamnose residues and
α(1→2) linkage in Rhamnogalacturonan-I leads to the breached molecule structure. These breaches serve as the attachment points for neutral pectins (for example, arabinans and galactans), connecting rhamnogalacturonan-I molecules with hemicelluloses molecules. Such chemical composition of homo- and rhamnogalacturonan explains the increase of mass fraction of soluble pectin in apple samples that come from the trees treated with potassium that is a cation.

Figure 2. Weight fraction of hydropectin in the general volume of pectin substances

Figure 3. Weight fraction of protopectin in the general volume of pectin substances

Figure 4. Ratio between fractions of hydro and proto pectin in the studied samples of apples

The higher fraction of protopectin in samples treated with melafen, in our opinion, can be explained by its physiological activity and ability to form nana-sized associates with water. This property creates conditions for pectin chains linkage. This linkage is the result of multivalent metals
ions bound with non-esterified groups COOH and leads to ionic bridges formation. The same ability can be suggested for metallocen.

So, the results of experimental studies showed that apples taken from melafen and metallocen treated trees are preferable for dry pectin matter production, while apples taken from potassium treated trees are better for pectin extract.

4. Conclusion
The results of the research of different growth stimulants influence on Prima apples showed that the application of the stimulants changes fractional content of pectin substances.

It has been found that application of potassium on apple trees increases the weight fraction of hydropectin while application of melafen and metallocen increases protopectin fraction.

The obtained results prove that such schemes of commercial apple orchards cultivation are promising for manufacturing pectin and pectin-containing food products with improved ecological properties.

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References
[1] 2014 Encyclopedia of food safety ed Y Motarjemi (New York: Academic Press) 586 p
[2] 2003 Scientific Criteria to Ensure Safe Food Committee on the Review of the Use of Scientific Criteria and Performance Standards for Safe Food National Research Council (Washington: The national academies press) 401 p
[3] Dramlage W, Drake M and Lord W 1980 The influence of mineral nutrition on the quality and storage performance of pome fruits in North America (London) pp 28–39
[4] Sansavini S, Belfanti E, Costa F and Donati F 2005 European apple breeding programs turn to biotechnology Chronica Horticulture 45(2) 16–19
[5] Doroshenko T N, Ryazanova L G, Chumakov S S and Gegechkori B S 2018 Agrobiological basis for the production of high-quality fruit products (Krasnodar: Kuban State Agrarian University) 147 p
[6] Krasnoselova E A and Donchenko L V 2018 Development problems of regional AIC [in Russian – Problemy razvitiya APK regiona] 3(35) 176–181
[7] EU 432/2012 Commission Regulation 2012 Official Journal of European Union 40 p
[8] Trocenko A N 2013 Marketing in Russia and abroad [in Russian – Marketing v Rossii i za rubezhom] 1(93) 16–20
[9] Azimova S T, Kizatova M Z, Akhmetova S O and Admayeva A M 2017 J. of Security and Sustainability Issues 6(4) 719–728
[10] 2010 Food stabilisers, thickeners and gelling agents ed A Imeson (Oxford: Wiley-Blackwell) 372 p
[11] 2014 Pectin chemical properties, uses and health benefits ed P Bush (New York: Nova Science Publishers Inc) 268 p
[12] 2003 Advances in pectin and pectinase research eds F Voragen, H Schols and R Visser (Dordrecht: Kluwer Academic Publisher) 504 p
[13] 1996 Pectin’s and pectinases eds J Vasser and A G Voragen (Amsterdam: Eiservier Science) 990 p
[14] Zhirenchina Z U, Kizatova, M Z, Donchenko L V, Donchenko E V and Kurasova L A 2016 Research J. of Pharmaceutical, Biological and Chemical Sciences 3 18–22
[15] Mohnen D, Doong R L and Liljebjelkek 1996 Pectin’s and Pectinases: Proc. of an Int. Symposium (Netherlands) pp 109–125