Secondary raw materials of coffee plant processing are an alternative source of pectin substances

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Abstract. The article presents the results of studies of the content of pectin substances of secondary raw materials of coffee processing – pulp (CP). CP includes both the shell (skin, epidermis, exocarp) and the pulp itself (mesocarp). Industrial coffee varieties cultivated and processed in different regions of Ethiopia were selected as the object of research. The research results have shown that the coffee waste generated can be considered as a source of pectin substances for the development of functional nutrition products.

1 Introduction

A distinctive feature of the modern development of agro-industrial production in foreign countries with a developed market economy is an integrated approach to the use of agricultural raw materials. Technological processes of production and processing of agricultural products are aimed at maximizing the yield of useful products from it with a minimum amount of unused waste and compliance with strict environmental requirements for environmental protection from pollution by waste from agro-industrial production. With stable annual production volumes of agricultural products in these countries, only strict compliance with these requirements allows to be produced in sufficient quantity (taking into account exports) and of the required quality.

In addition, monitoring of the nutritional status of modern humans in industrialized countries has shown that their diets are characterized by excessive consumption of animal fats and easily digestible carbohydrates, but are deficient in essential substances: dietary fiber (pectin substances belong to this group), vitamins, macro - and microelements.

This leads to nutritional insufficiency, a decrease in the regulatory capabilities of the body, a change in its physiological functions, which contributes to the formation and spread of diseases such as atherosclerosis, hypertension, diabetes mellitus, alimentary obesity and others.

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In the light of th above mentioned, the organization of rational nutrition is relevant in modern society. This is possible on the basis of expanding the product line and increasing the volume of production of functional nutrition products.

In our opinion, pectin substances meet all the requirements of a functionally significant ingredient. Thus, they have high detoxification properties in relation to toxic metals [1]. In addition, in accordance with the EU432/2012 regulation, pectins are recommended for lowering cholesterol and glucose levels in the blood by 4 and 10 g/day, respectively [2].

The volumes of raw materials for the industrial production of pectin are significant. This is, first of all, the waste of the juice industry – apple and citrus pomace. However, this raw material is practically absent in industrial volumes in some regions of the world.

In this regard, research to identify alternative industrial sources of pectin is very relevant.

One of the most significant raw materials in terms of volume is coffee. In world trade, coffee occupies the second position, second only to oil [3]. At the same time, 90% of coffee production is concentrated in developing countries. The leading countries are Brazil, Vietnam, Indonesia and Colombia (Fig. 1).

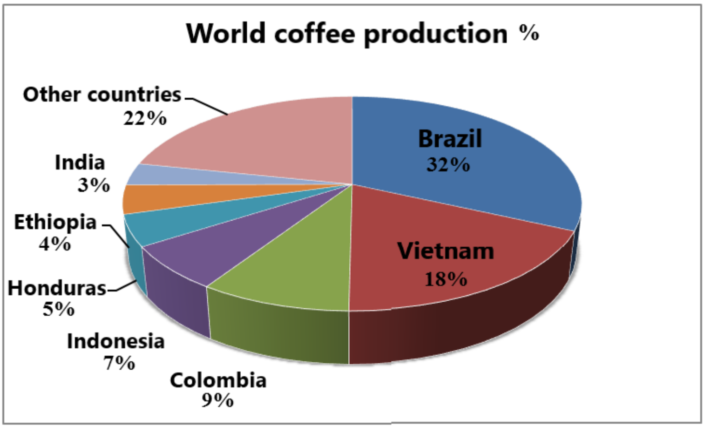

Fig. 1. World coffee production

Coffee is a large–tonnage agricultural commodity, the world production of which is about 9.5 thousand tons per year [4, 5].

During its production, a significant amount of waste is generated, the type of which depends on the type of grain processing after harvesting.

A coffee fruit consists of an outer shell, a pulp with a thin layer of gluten, a parchment shell and a coffee bean covered with a thin silver skin [6].

The very composition of the coffee fruit – the fruit of the coffee tree – is simple (Fig. 2). The fruit consists of an outer fruit shell (exocarp) (7); fruit pulp (mesocarp) (6); connective layer (5); pergamine (endocarp) (4); silver film, or seed peel (3), and endosperm (2).

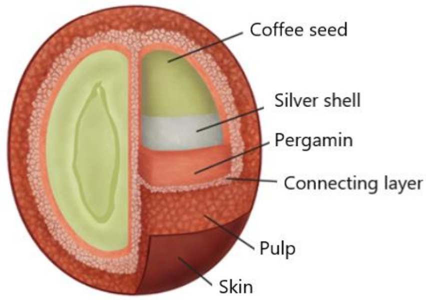

Fig. 2. The structure of the coffee fruit

The first by-product of coffee processing is pulp (CP). To separate it from fruits, a wet or dry process can be applied [7]. CP includes both the shell (skin, epidermis, exocarp) and the pulp itself (mesocarp). In the process of dry processing, coffee beans are dried and then mechanically cleaned, removing the husk, which is a mixture of the fruit shell and pulp, the connective layer and pergamine. The mass of the purified coffee fruit is approximately 50% of the mass of the dried coffee bean [7]. Wet processing of coffee fruits involves several stages and is considered more complex. First, the fruit shell and most of the fruit pulp are separated by pressing. Then the remaining pulp and connective layer are removed by fermentation and washing. After that, the grains are dried and cleaned of pergamine, the proportion of which is 6% of the mass of the dried coffee fruit [7].

Figure 3 shows a schematic diagram of coffee fruit processing.

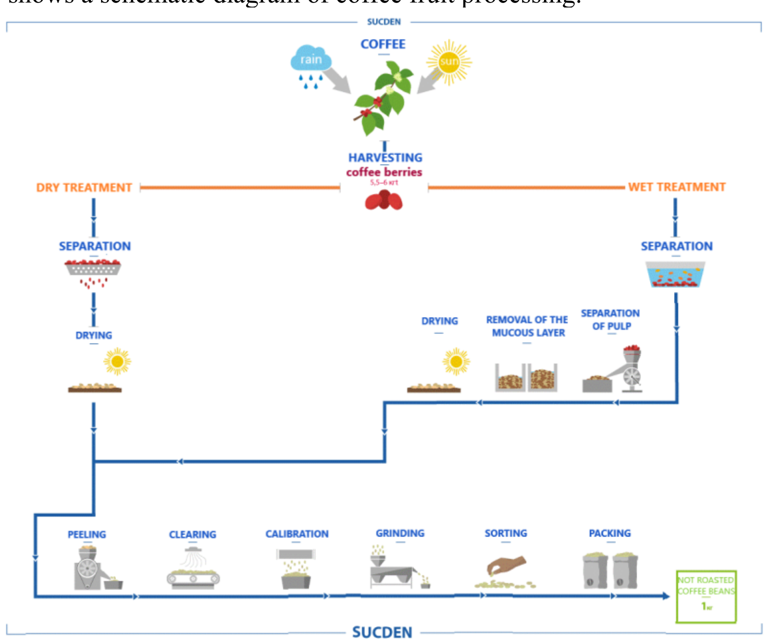

Fig. 3. Schematic diagram of coffee bean processing [8].

The production of CP residues worldwide is estimated at 9.4 million tons per year. It is a source of environmental problems for coffee-producing countries. CP in soils can affect the population of soil microflora (acidophilic fungi). The release of gases such as methane (CH_4) and nitrous oxide (N_2O), which are formed as a result of PC fermentation, is becoming a growing environmental problem. In addition to the appearance of unpleasant odors, due to the decomposition of CP, insects multiply; which can lead to possible health risks. Therefore, the disposal of coffee waste remains a difficult task in the regions of the world producing coffee [8].

The Joint Institute of High Temperatures of the Russian Academy of Sciences has developed an original technology for the production of synthesis gas from biomass (a mixture of carbon monoxide and hydrogen) [9], which is an environmentally friendly energy fuel and a universal raw material for the production of valuable chemical products (synthetic liquid fuels, alcohols, surfactants, flotation reagents, etc.).

Coffee pulp is approximately 40 to 50% by weight, and its composition varies depending on the type of coffee; for example, a wide range of macronutrients (per 100 g of dry matter) has been reported: 4-12 g of protein, 1-2 g of lipids and 45-89 g of carbohydrates. The content of minerals such as P, K, Ca and Mg is 2.48, 25.13, 4.10 and 1.39 g/kg of coffee pulp, respectively, and Fe and Mn are 77 and 46 mg / kg. The approximate percentage of caffeine is from 0.12 to 0.26%, pectin and tannins range from 1-9 g / 100 g of dry matter, or about 6% by weight. Coffee pulp also contains caffeic acid in an amount of about 16 mg / g of dry matter, gallic acid in an amount of about 3 mg / g of dry matter and chlorogenic acid in an amount of about 62 mg / g of dry matter. These concentrations may vary depending on the extraction and drying method used [10].

Due to the chemical composition of the dry fruit pulp, which is especially rich in reducing sugars and polysaccharides such as pectins and cellulose, it is a good substrate for the production of pectin enzymes (polygalacturonase) by cultivating *Aspergillus niger van Thiegem* in a solid state. At the same time, the pulp is detoxified, which turns the fermented pulp into a good material for animal feed, organic fertilizers and compost ingredient. The characteristics of polygalacturonase indicate the use of the enzyme in vegetable processing, including coffee processing [11].

However, in our opinion, promising areas are the use of CP as a raw material source for the production of pectin, which, as a hydrocolloid, has countless functional applications in food and related industries [12].

To this end, we have set the following research objectives:

- to study the fractional composition of pectin substances;
- to evaluate the analytical characteristics of pectin;
- to determine the functional orientation of the selected research objects.

2 Experimental site and research methods

As an experimental site, we selected 4 cultivation regions in the Republic of Ethiopia: Sidamo, Kaffa, Harrar, Tepi (Fig. 4).

Fig. 4. Geographical features of the choice of research objects depending on the method of cultivation

The content of pectin substances in the CP was studied. The method of quantitative determination of pectin substances in plant raw materials is based on the extraction of pectin from plant raw materials and its transfer to a dissolved state (Donchenko, 2000). The study of extracts of hydratopectin and protopectin is based on the calcium-pectate method and precipitation with ethyl alcohol. In addition, the content of the pectin preparations, the methoxyl component and the degree of esterification by the conductometric method were studied.

3 Results and Discussion

To confirm the industrial significance of CP as a pectin-containing raw material, we conducted studies to determine the content of pectin substances and their fractional composition in CPs from different regions of Ethiopia.

The research results showed that the total content of pectin substances (PS) in the CP is high and ranges from 3.56 to 6.27% in terms of absolutely dry mass.

At the same time, the content of protopectin varies within 2.40–4.71%. In addition, protopectin (PP) quantitatively prevails over hydratopectin (HP). This ratio of fractions is observed in all the varieties studied by us. The percentage of protopectin from the total amount of pectin substances (PP/PS) is 67.4–80.9%. In the Harrar region, the ratio of PP/PS is higher compared to other varieties and is 80.9%.

The amount of water-soluble fraction of HP practically does not change depending on the region.

The influence of the coffee cultivation region on the ratio of fractions of pectin substances in the pomace is shown in Fig. 5.

Analyzing the results obtained, it can be noted that the CP samples under study accumulate an unequal amount of pectin substances and their individual fractions, which causes a difference in the technological parameters of pectin extraction.

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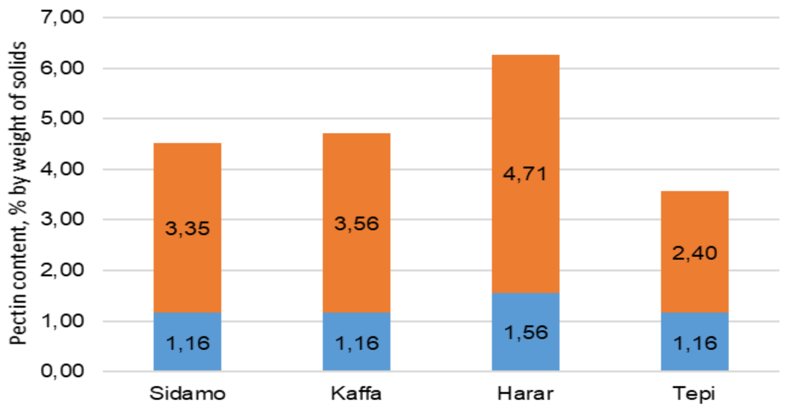

Fig. 5. The influence of the cultivation region on the fractional composition of pectin substances: 1 – Sidamo Province; 2 – Kaffa Province; 3 – Harrar Province; 4 – Tepi Province.

To assess the qualitative parameters of pectins contained in the studied CPs of different varieties, we studied their analytical characteristics – the content of polygalacturonic acid, the methoxyl component and the degree of esterification.

It was found that the highest content of pure polygalacturonic acid was observed in pectins isolated from a sample of CP from the province of Harrar (61.4%). The remaining 3 samples in terms of the content of pure polygalacturonic acid are approximately at the same level, and on average its content is 50.3 – 52.4%.

Data on the methoxyl component of the isolated pectins are shown in Fig. 6.

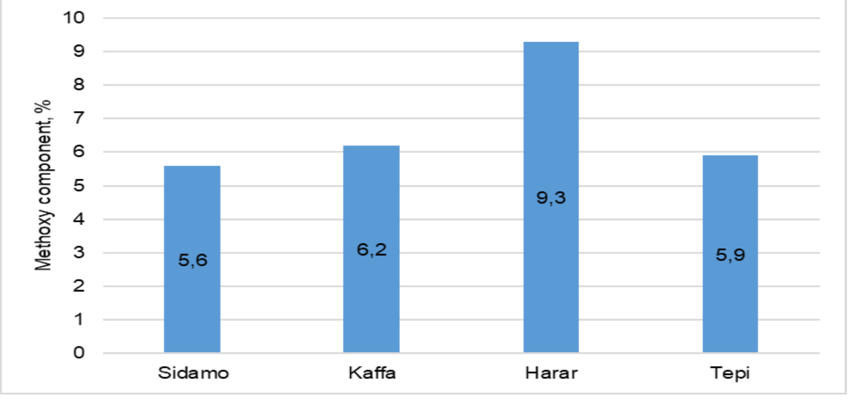

Fig. 6. The content of the methoxyl component of pectin substances in the studied CP samples

It follows from the experimental data that the methoxyl component ranges from 5.6 – 9.3%. Such values make it possible to predict the low jelly-forming ability of pectins.

Another equally significant characteristic that determines the direction of use of pectin substances is the degree of esterification. It determines the conditions of jelly formation and the ability to form a complex with toxic compounds.

With a high degree of pectin esterification (E > 50%), the free carboxyl groups in which C6 atoms are included are significantly removed from each other. In this case, calcium or strontium salts of pectin acid almost completely dissociate. With a decrease in the degree of esterification, i.e. with an increase in the charge of the macromolecule, the stability constant of pectinates increases. When the degree of esterification is less than 40%, a conformation change occurs, leading to the aggregation of pectin molecules, the formation of a strong intramolecular chelate bond of stable pectin compounds with metals. At the same time, there is also an increase in electrostatic repulsion and a decrease in the flexibility of the macromolecule chain [13, 14, 15]. The degree of esterification is the percentage of residues of D-galacturonic acid, the carboxyl group of which is esterified with ethanol. A higher level of esterification degree indicates a good ability of the gel [16].

We found that pectin from CP has a degree of esterification ranging from 52% to 65%. (Fig. 7) and is considered as pectin with molecules with a high content of esters [17].

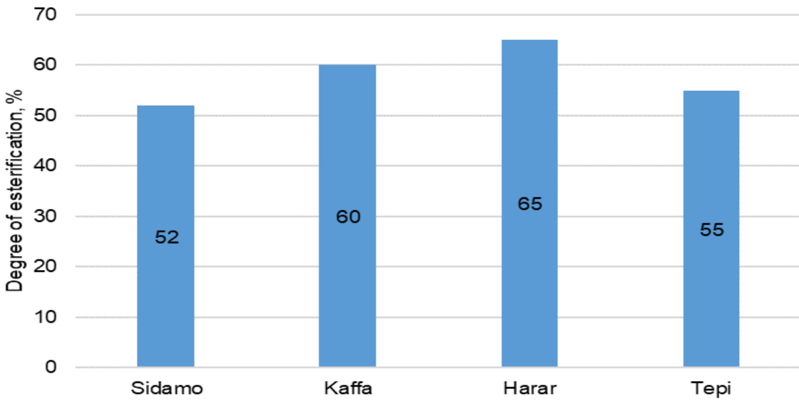

Fig. 7. The degree of esterification of pectin substances from the studied CPs, %: 1 – Sidamo Province; 2 – Kaffa Province; 3 – Harrar Province; 4 – Tepi Province.

Based on the results of our research, we have developed a method for producing pectin that meets the requirements of the standard of the International Pectin Producers Associations (IPPA) in qualitative terms [17, 18].

4 Results

Based on the above, it can be concluded that the samples of CP formed during the processing of coffee cultivated in different provinces of Ethiopia selected as the object of research. The results of the studies allow characterizing them as highly esterified pectins with a relatively high methoxyl component. Pectin with a high content of the methoxyl group is used as gelling agents for fruit jams, emulsion flavors and salad dressings, while pectins with a low content of the methoxyl group are used in puddings, fruit jelly in ice cream and low-calorie fruit jams [19].

5 Conclusion

Thus, the results of the conducted experimental studies give grounds for the conclusion about the expediency of considering the samples of PC selected for study, formed during the processing of coffee cultivated in different provinces of Ethiopia as an industrial raw material for the development of pectin-containing food products of functional nutrition.

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