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Biotechnology

New Energy-Saving Technology of Green Tea

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Thermal processes play an extremely important role in shaping the quality indicators of green tea. The primary technological process is fixation the purpose of which is to inactivate the oxidative enzymes of the tea leaf and keep the chemical compounds in it in their original state. Producing green tea is an energy-intensive process. The cost of electricity is 20% of the base cost of production. The price reduction is one of the most important objectives. An innovative energy-saving technological device for fixing a tea leaf based on the method of induction was developed (Georgian Patent 7427 B. 2022) and on its basis, a new energy-saving green tea technology. The paper presents the data of research and development of new energy-saving technologies and parameters of green tea production, the results of studying technological level of fixation methods and equipment, quality and chemical indicators and a safe finished product. The use of new fixation device and technology significantly reduces the cost of electricity and the cost of finished tea. The results of the study of catechins in experimental green tea extracts by high-performance liquid chromatography (HPLC) showed that epigallocatechin gallate is equally present in the green tea fixed by electromagnetic induction and evaporation and is superior to the product made by the roasting method. According to the results of research, toxic elements: lead (Pb), arsenic (As), cadmium (Cd), mercury (Hg), copper (Cu), as well as: zinc (Zn), manganese (Mn), iron (Fe) absorption spectrometer (AAS 6 000), confirmed the high level of safety of Georgian green tea in accordance with the established standards.

green tea, fixation, energy saving technology, quality indicators

Green tea is produced from tender shoots and leaves of *Camelia sinensis* (L) O. Kuntze using special technological processes of fixing, pre-drying, rolling and drying. According to its chemical composition, pharmacological action and physiological activity, green tea is more valuable and healing product than other types of products, due to the high content of polyphenols and catechins in it [1]. The optimal balance of the total amount of polyphenols, catechins and other quality-determining compounds in the tea leaves creates the best conditions for the maximum manifestation of the qualities of Georgian green tea [2]. Tea production is one of the most energy-intensive

industries in the agricultural sector. In the cost of finished tea, a significant part, about 25% constitutes energy costs. Reducing energy costs and the cost of tea products is an important objective, which is indeed possible as a result of the use of alternative energy sources and innovative technologies.

In the formation of quality indicators of green tea, the role of thermal processes is extremely important. The purpose of the main technological process of fixation is to inactivate oxidative enzymes and fix the chemical compounds contained in the leaf in its original state, making the leaf elastic and eliminating the smell characteristic of raw tea. The fixation of raw materials is carried out in various ways: frying, steaming, humid hot air and electrophysical methods (high frequency current, infrared energy, electromagnetic heating). The essence of the technological processes of green tea, with its thermochemical basis, is the same in all tea-producing countries, the difference lies in the methods of processing, technological methods and equipment [3-5].

Polyphenols and primarily catechins shape the most important taste properties and biological activity of green tea. The comprehensive studies showed the high P-vitamins activity, antioxidant, anti-inflammatory, antimicrobial, antiviral, anticancer and anticoagulant activities of these substances. The ability of catechins shows to alleviate cardiovascular, atherosclerotic, and hypertensive diseases, to reduce harmful levels of cholesterol in the body. The health benefits of green tea are significantly determined by the positive effects and amount of epigallocatechin gallate. Tea consumption correlates with a low incidence of cardiovascular disease and cancer [6-12]. Green tea epigallocatechin gallate has the pronounced ability to prevent obesity and metabolic syndrome [13-17]. Tea consumption can play an important role in providing the human body with antioxidants. The antioxidant activity of tea is largely shaped by phenolic compounds and individual catechins, the amount and ratio of which depend on the plant variety, environmental conditions, the period of raw material production, the technological process and some other factors [2]. In line with both international and national standards, tea quality control involves the determination of the total amount of polyphenols and catechins. [18, 19]. In addition, the essential trace elements in humans can be supplemented through drinking tea because tea leaves contain potassium, manganese, selenium, boron, zinc, strontium, and copper [20].

The traditional methods of green tea production cannot ensure an increase in qualitative and economic indicators. The development of new technology and machinery based on modern energy-saving methods is important.

The paper aims to research and develop new energy-saving technology and parameters of green tea in real conditions as well as to study fixation methods and the technological level of equipment, quality and chemical indicators and the safety of the finished product.

Materials and Methods

The object of the study is an energy-saving device for fixing a tea leaf, created at the Institute of Tea, Subtropical Crops and the Tea Industry of the Agricultural University of Georgia (Georgian patent 7427 B. 2022) and a new green tea technology developed on its basis [17,18]. During the experiments, for the comparative analysis of the obtained data, the existing methods and devices for heat treatment of tea with a traditional heat source, and an electric heater - a control option were used [19]. The study of polyphenols and individual catechins was conducted in the following tea samples made by different methods of fixation: 1 - fixed with steaming; 2 - fixed with induction; 3 - fixed with roasting. The analyses were conducted using standard methods and the methods provided in literary sources [21, 22]. Catechins were determined by high pressure liquid chromatography. Chromatographic analysis was performed on a high-pressure liquid chromatograph Agilent 1260 Infinity (USA), using a Supelco-C18 chromatographic column (25cm×4.6mm, 5μm),

at a temperature of 35°C. To obtain the mobile phase, acetonitrile and 1% acetic acid dissolved in water were used, the gradient was carried out for 20 minutes, the ratio of acetonitrile and 1% acetic acid was from 10-90% to 20-80%, the detection of substances was carried out using a single-signal ultraviolet detector at a wavelength of 278nm.

From raw materials produced in a different ecosystem, 70 m and 165 m above sea level (respectively, Likhauri and Anaseuli, Ozurgeti municipality), toxic elements were determined in 2 samples (Li and An) of green tea made with new technology: lead (Pb), arsenic (As), cadmium (Cd), mercury (Hg) and copper (Cu). The analyses were performed using an Atomic Absorption Spectrometer (AAS 6 000) in accordance with the requirements for the quality and safety of food raw materials and food products. Zinc (Zn), manganese (Mn) and iron (Fe) have also been studied [22, 23]

Results and Discussion

The development, research and testing of the new green tea energy-saving technology in the real environment was carried out at the experimental base of the Institute of Tea, Subtropical Cultures and Tea Industry of the Agricultural University of Georgia, in Anaseuli in June - August 2023. The technological process was carried out as follows: green tea leaves are fed into a fixing machine, the main components of which are: cylindrical body placed in heat-insulating casing. The surface of the cylindrical body is heated by an inverter heater, with the power unit to which heating element is connected: an inductor made of copper tube, spirally wound around the cylindrical body. The number of turns depends on the heating intensity. The device is equipped with a cooling liquid circulation system in the inventory heater inductor. The alternating current received from the frequency converter passes through the inductor and creates an alternating magnetic field. The magnetic field is concentrated in the inner region of the inductor and its magnitude depends on the current passing through the inductor and the number of turns. An eddy current is induced in the walls of the tube placed inside the inductor. The walls of the tube have electrical resistance and

Table 1. The technological level of fixation methods and equipment in the production of green tea

Name of indicator	Tea leaf fixation method and equipment	
	Patent GEP 2022 7427 B (experimental)	Industrial equipment (control)
Productivity, kg / h	40	50
Electricity demand, kWh	4.0	45.0
The need for electricity per unit of production in the process of fixing, kWh/kg	0.4	3.6
The cost of electricity consumed in the process of fixing per 1 kg of finished tea, GEL.	0.1278	1.1506
Fixation uniformity, %	90.0	88.0
Organoleptic indicators: - aroma and taste, score	4.50 (+)	4.50
Water extract, %	38.2	37.8
Total polyphenols, %	18.9	18,5

Table 2. Mass fraction of toxic elements in green tea test samples

Name of indicator	Limit value	Results	
		Green tea (Li)	Green tea (An)
Lead (Pb), mg/kg	not more 10.0	0.001	0.001
Arsenic (As), mg/kg	not more 1.0	0.059	0.066
Cadmium (Cd), mg/kg	not more 1.0	0.035	0.029
Mercury (Hg), mg/kg	not more 0.1	0.017	0.018
Copper (Cu), mg/kg	not more 100.0	3.60	5.13

therefore heat is generated. In the process of fixing tea leaves, the body of the technological device directly participates in the generation of electromagnetic induction, the working surface of which is heated by electromagnetic induction. The duration of the fixation process is 180-210 seconds (the time of inactivation of oxidative enzymes) at a temperature of the steam-air mixture inside the equipment case - 145-155^{0}C. The fixed and partially dried leaves go to the next technological process. Pre-drying is an essential process to bring the fixed leaves into a condition suitable for the normal operation of the curling process. During drying, the moisture content of the tea leaf is adjusted to 60-64%. The fixed and dried leaves are rolled in a new design roller, consisting of a rotating cylinder, a table and a special press. In the process of rolling for 50-60 minutes. Next, the rolled tea mass is fed for drying to remove excess moisture (dehydration of the product up to 3-5%), ensuring the safety of the product and the final formation of the specific taste properties of green tea. The process is carried out in a drum-type tea-drying machine of a new generation at a temperature of 80-90^{0}C [18]. The results of testing the new energy-saving green tea technology in a real environment are shown in Table 1.

The data in Table 1 show that under the new technology, the energy consumption per unit of finished tea in the process of fixing is 0.40 kWh/kg, which is reduced several times less than the same indicator of existing equipment. The results of the development and testing of the new energy-saving technology in the real environment prove that it is possible to reduce the cost of green tea by at least 1 GEl. According to the primary qualitative and chemical indicators, the difference between the test and control green tea is practically not detected.

The results of the study of chromatographic separation of catechins show that the peak of epigallocatechin gallate is sharply defined and the most precisely quantifiable. In green tea fixed by the induction method and steaming, epigallocatechin gallate is practically equal and more present than that made by the roasting method.

Based on the results of quantitative determination of catechins, the high content of total catechins and epigallocatechin gallate in tea extracts fixed by induction and evaporation was confirmed. Induction-fixed tea retains more simple catechins than fixed with steaming (Figure).

The results of the study of toxic elements lead (Pb), arsenic (As), cadmium (Cd), mercury (Hg) and copper (Cu) showed that their concentrations in green tea made from raw materials of different natural conditions with new technology are practically identical and many times less than the permissible limit value (Table 2). In addition, we additionally studied the following elements: zinc (Zn),

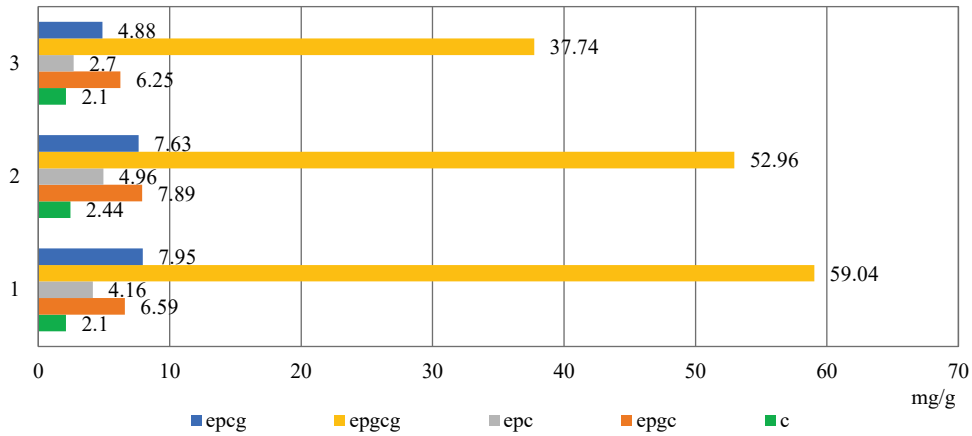

Fig. Comparative amounts of five catechins in experimental green tea extracts (mg/g)
1 - fixed with steaming; 2 - fixed with electromagnetic induction; 3 - fixed with roasting.

manganese (Mn) and iron (Fe). The following results were obtained for the new technology green tea samples, respectively: (Li) and (An) : Zn: 0.397 - 0.374; Mn: 0.078-0.79 and Fe: 1.046-1.263. These data provide an opportunity to get more information about the safety of Georgian tea.

Conclusion

On the basis of the new technical and technological data obtained as a result of the conducted research and testing in the real environment, a new energy-saving technology and parameters of green tea were developed, which ensure a significant reduction in the consumption of electricity and the cost of the finished product. Furthermore, with the use of the new technology, it is possible to reduce the consumption of electricity per unit of ready-made tea is reduced several times during the fixing process, and the cost price by at least 1 GEL.

The results of the study of catechins in experimental green tea extracts using the high-performance liquid chromatography method (HPLC) showed that epigallocatechin gallate is equally present in the green tea fixed by electromagnetic induction and evaporation and is superior to the product made by the roasting method. Green tea obtained as a result of fixation by the induction method has a high amount of both total and simple catechins and the dominant catechin – epigallocatechingallate.

The results of the study of toxic elements: lead (Pb), arsenic (As), cadmium (Cd), mercury (Hg), copper (Cu), as well as: zinc (Zn), manganese (Mn), iron (Fe) confirm the high-level safety of Georgian tea in accordance with established standards.

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ბიოტექნოლოგია

მწვანე ჩაის ენერგოდამზოგი ახალი ტექნოლოგია

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** საქართველოს აგრარული უნივერსიტეტი, ჩაის, სუბტროპიკული კულტურების და ჩაის მრეწველობის ინსტიტუტი, ანასეული, ოზურგეთი, საქართველო*

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მწვანე ჩაის ხარისხობრივი მაჩვენებლების ჩამოყალიბებაში უაღრესად მნიშვნელოვან როლს ასრულებს თბური პროცესები. მთავარი ტექნოლოგიური პროცესია ფიქსაცია, რომლის დანიშ-

ნულებაა ჩაის ფოთლის მჟანგავი ფერმენტების ინაქტივაცია და მასში შემავალი ქიმიური ნაერთების საწყის მდგომარეობაში ფიქსირება. მწვანე ჩაის დამზადება ენერგოტევადი პროცესია. თვითღირებულების მეოთხედს ენერგეტიკული დანახარჯები შეადგენს. მისი შემცირება განეკუთვნება უმნიშვნელოვანეს ამოცანას. ჩატარებული კვლევების საფუძველზე შემუშავდა ინდუქციის მეთოდზე დაფუძნებული ჩაის ფოთლის ენერგოდამზოგი ინოვაციური საფიქსაციო ტექნოლოგიური დანადგარი (საქართველოს პატენტი 7427 B. 2022 წ.) და მის ბაზაზე მწვანე ჩაის ენერგოდამზოგი ახალი ტექნოლოგია. ნაშრომში მოცემულია მწვანე ჩაის ენერგოდამზოგი ახალი ტექნოლოგიის და პარამეტრების რეალურ გარემოში შემუშავების და კვლევის შედეგები, ფიქსაციის მეთოდების და დანადგარების ტექნოლოგიური დონის და მზა პროდუქტის ხარისხობრივი, ქიმიური და უსაფრთხოების მაჩვენებლების შესწავლის შედეგები. ახალი საფიქსაციო დანადგარის და ტექნოლოგიის გამოყენების პირობებში მნიშვნელოვნად მცირდება ელექტროენერგიის დანახარჯები და მზა პროდუქტის თვითღირებულება. ექსპერიმენტული მწვანე ჩაის ექსტრაქტების კატეხინების მაღალი ხარისხის თხევადი ქრომატოგრაფიის მეთოდის (HPLC) გამოყენებით შესწავლის შედეგებმა აჩვენა, რომ ელექტრომაგნიტური ინდუქციის მეთოდით და დაორთქვლით ფიქსირებულ მწვანე ჩაიში, ეპიგალოკატეხინ გალატი პრაქტიკულად თანაბრად არის წარმოდგენილი და აღემატება მოხალვის მეთოდით დამზადებულ პროდუქტს. ტოქსიკური ელემენტების - ტყვია (Pb), დარიშხანი (As), კადმიუმი (Cd), ვერცხლისწყალი (Hg), სპილენძი (Cu), თუთია (Zn), მანგანუმი (Mn), რკინა (Fe) - ატომურ-აბსორბციული სპექტრომეტრის გამოყენებით (AAS 6 000) კვლევის შედეგად დადასტურებულია ქართული ჩაის უსაფრთხოების მაღალი ხარისხი დადგენილი ნორმების მიხედვით.

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