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THE IMPORTANCE OF THE CHEMICAL COMPOSITION OF THE STEM JUICE OF SWEET SORGHUM IN THE PREPARATION OF FEED FOR BEES

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Abstract: This article discusses the topic of the shortage of natural organic food products throughout the world, which is one of the most topical problems of our time, in particular, as a result of the increase in consumer culture of the population, the demand for natural and medicinal food products is increasing, including the growing demand for honey and honey products. In order to provide bee colonies raised in our republic with natural food rich in vitamins and minerals during the off-season period, sugar sorghum was chosen as the object of study, since in our republic the sugar sorghum plant is domesticated, and there is also a sufficient raw material base and conditions for growing. The article also presents methods and results of chemical analysis of processed sugar sorghum stem juice. The amount of vitamins, minerals, carbohydrates, heavy metals, amino acids and proteins contained in the stem juice of sugar sorghum is determined and the information obtained from the results on the beneficial properties intended for creating food for bee colonies is provided. Based on a study of the sugar sorghum plant, it was found that the stem juice is rich in carbohydrates, vitamins, macro- and microelements, and the plant itself produces the expected yield even in arid and saline climatic conditions. When feeding bee colonies in the autumn and early spring months with food prepared by adding condensed sugar sorghum juice, no side effects were observed, and the food was well absorbed by the bees.

Keywords: sweet sorghum, stem juice, chemical composition, result, carbohydrates, vitamins, micro- macroelements, protein, amino acids, heavy metals, arid.

ЗНАЧЕНИЕ ХИМИЧЕСКОГО СОСТАВА СТЕБЛЕВОГО СОКА САХАРНОГО СОРГО ПРИ ПРИГОТОВЛЕНИИ КОРМА ДЛЯ ПЧЕЛ

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Аннотация: В данной статье затрагивается тема нехватки натуральных экологически чистых продуктов питания во всем мире, являющаяся одной из наиболее актуальных проблем современности, в частности, в результате повышения потребительской культуры населения возрастает спрос на натуральные и целебные продукты питания, в том числе, растёт спрос на мед и медовую продукцию. С целью обеспечения пчелиных семей, выращиваемых в нашей республике, натуральным, богатым витаминами и минералами кормом в межсезонный период, в качестве объекта исследования выбрали сахарный сорго, так как в нашей республике растение сахарного сорго является одомашненным, а также имеется достаточная сырьевая база и условия для выращивания. В статье также представлены методы и результаты химического анализа переработанного

стеблевого сока сахарного сорго. Определено количество витаминов, минеральных веществ, углеводов, тяжелых металлов, аминокислот и белков, содержащихся в стеблевом соке сахарного сорго и приведены информации полученных результатов о полезных свойствах, предназначенных для создания корма пчелиным семьям. На основе изучения растения сахарного сорго, установлено что стеблевой сок, богат углеводами, витаминами, макро- и микроэлементами, а само растение даёт ожидаемый урожай даже в засушливых и засоленых климатических условиях. При кормлении пчелиных семей в осенние и ранние весенние месяцы кормом, приготовленным добавлением сгущенного сока сахарного сорго побочных эффектов не наблюдалось, и корм хорошо усваивался пчёлами.

Ключевые слова: сахарный сорго, стеблевой сок, химический состав, результат, углеводы, витамины, микро- макроэлементы, белок, аминокислоты, тяжёлые металлы, засушливый

INTRODUCTION

The growth of the world's population presents a number of global challenges; along with resources necessary for human needs such as drinking water, electricity, natural resources, etc. it causes food shortages and lack of naturalness. Therefore, the duty and task of the intelligentsia is to contribute to the solution of these problems. It is crucial to expand the range of natural food products and preserve the naturalness of their composition. As a result of the growth of consumer culture in countries around the world, the demand for honey and honey products is increasing. This, in turn, requires solving problems associated with feeding bee colonies.

The unique natural and climatic conditions of our republic are very favorable for the cultivation and development of a bee colony based on new technologies. That’s why beekeeping is one of the leading branches of agriculture. However, due to the reduction in the size of natural green spaces, parks and green areas in our country, even during the season, there is a lack of nutrition for bee colonies. For the development of the beekeeping industry, for the life and reproduction of bees, it is necessary to create natural and environmentally friendly feeds containing proteins, fats, carbohydrates, minerals and vitamins. All this means that providing the beekeeping industry with additional food products is one of the important and topical tasks[1].

Therefore, in recent years, due to the chronic feeding of the bee colony with sugar syrup in the republic and the lack of vitamins, fats, carbohydrates, amino acids, micro- and macroelements in such feeds, bees after winter become weak, susceptible to diseases and have weak ability to reproduce. This requires feeding bees with natural, vitamin- and mineral-rich food sources [2].

Today, about 50-55% of the arable lands of our republic are subject to varying degrees of salinization. The sugar sorghum plant chosen as the object of study can be grown in any climatic conditions of our republic, including in arid and saline lands. Sugar sorghum is not only a high-yielding plant, but also removes 31 to 75 t/ha of salts from the soil, as well as toxic substances such as chlorides and sulfites. The sugar sorghum plant is so resistant to salt that when irrigated with salt water from the Caspian Sea, the yield of green mass was 52.7 t/ha [3;4].

High-sugar varieties of this plant are considered domesticated, and some varieties can be harvested up to twice a year.

The amount of dry matter in the varieties of sugar sorghum selected for the study with a high level of sugar content “Karabosh”, “Orange-160”, “Uzbekistan 18” is 18-23% in average, which is significant when extracting juice up to 70-80% from the stem [5;6].

The stem juice of sugar sorghum is rich in carbohydrates, amino acids, minerals and vitamins, and serves to ensure the normal functioning of bees and the production of high-quality honey, which helps to improve the food supply of beekeeping farms.

Purpose of the study. The purpose of the ongoing scientific research is to conduct a chemical analysis of the processed juice of the sugar sorghum varieties “Karabosh”, “Orange-160”, “Uzbekistan 18”.

RESEARCH METHODS AND MATERIALS

One of the objectives of the study is to prepare environmentally friendly natural food with high nutritional value to replace traditional food with sugar in the off-season for bees. While sugarcane juice contains only sucrose (crystallizing sugar), sugar sorghum juice contains glucose and soluble starch in addition to sucrose, which inhibit crystallization. This, in turn, reduces the crystallization of honey. In terms of content, sugar obtained from sugar sorghum is superior to sugar from beets and sugar cane, since in addition to sucrose it contains fructose and glucose. Sugar sorghum stalk syrup contains the following minerals: Ca, P, Mg, K, Na, Cu, Zn, Co, Mn, Fe, S, protein up to 3%, all essential amino acids, vitamins B_1, B_2, PP, E and C. This condensed juice can be used not only for feeding, but also in the food industry, and this is currently very relevant. The amount of sugar in the juice obtained from selected varieties is 18-25%, that is, 18-20% of the total mass is sugary substances [6;18].

Experiments conducted in Russia have shown that in the conditions of the North Caucasus (September-March) some varieties of sugar sorghum can be stored in bunches for 170 days. This makes it possible to provide manufacturing enterprises with raw materials for a long time. Currently, in many foreign countries, sugar sorghum is used in the food industry for the production of juices, syrups, streams and in various other areas.

From an economic point of view, 1 ton of sugar from sugar sorghum is 20% cheaper than 1 ton of beet sugar. If beet sugar is replaced with sugar sorghum syrup, the cost of confectionery products and soft drinks will decrease [19].

In order to fully analyze the chemical composition of the stem juice of sugar sorghum, chosen as the object of study, experiments were carried out together with leading specialists in the laboratory of the Institute of Bioorganic Chemistry named after Academician A.S. Sadykov of the Academy of Sciences of the Republic of Uzbekistan.

Several methods were used in the experiment. To determine the amount of water-soluble vitamins, GOST 32903-2014 was used. The analysis was carried out by HPLC (high performance liquid chromatography) using a diode array detector (DAD).

Method of determining the amount of water-soluble vitamins. 5-10 g of sample was weighed on an analytical balance and placed in a flat flask with a capacity of 300 ml. 50 ml of 40% ethanol solution was added to it. The mixture was boiled with vigorous stirring for 1 hour, equipped with a magnetic stirrer and reflux cooler, and then stirred at room temperature for 2 hours. The mixture was cooled and filtered. 25 ml of 40% ethanol was added to the remainder and re-extracted 2 times. The filtrates were combined and filled to the mark with 40% ethanol (5÷10%) into a 100 ml volumetric flask. The resulting solution is centrifuged at a speed of 7000 rpm for 10 minutes. Part from the upper surface of the resulting solution was taken for analysis.

Working solutions of water-soluble vitamins with a concentration of 1 mg/ml were prepared. To do this, 50 mg of each vitamin standard was weighed on an analytical balance and dissolved in 40% ethanol in a 50 ml volumetric flask.

Phosphorus, acetate buffer systems and acetonitrile were used as eluents in the determination of water-soluble vitamins by HPLC (high-performance liquid chromatography). Initially, working standard solutions were introduced into the chromatograph, and then prepared working solutions [24; 25].

Determination of carbohydrates in concentrated sugar sorghum juice. Determination of the amount of carbohydrates, that is, monosaccharides, in the stem juice of sugar sorghum was carried out using high-performance liquid chromatography. To do this, the contents of the sample being determined are degreased and a certain amount of the defatted substance is taken. The resulting sample is extracted with water and kept for a certain time in an ultrasonic water bath to speed up the extraction process. After completion of the extraction process, it is filtered or centrifuged, the supernatant (liquid part) is collected and quantitative analysis is carried out using high-performance liquid chromatography (HPLC) [25].

The determination of the amount of free amino acids *was carried out according to the method presented in GOST 34230-2017.* The composition and quantity of amino acids in the sample were determined by the Cohen Daviel method in the form of FTC derivatives of free amino acids.

Precipitation of proteins and peptides from the aqueous extract of the sample was carried out in centrifuge dishes. To do this, 1 ml (exact volume) of 20% TSA was added to 1 ml of the test sample. After 15 minutes of centrifugation at 8000 min^{-1} for 10 minutes, a precipitate formed. 0.1 ml of supertant was separated and lyophilized (freeze dried). The hydrolyzate was evaporated, the dry residue was dissolved in a mixture of triethylamine-acetonitrile-water and dried. This process was repeated 2 times to neutralize the acid

Phenylthiocarbamyl derivatives (PTC) of free amino acids were prepared by reaction with phenylthioisocyanate according to the method of Stephen A., Cohen Daviel. Amino acid derivatives were determined by HPLC.

Determination of the amount of heavy metals, macro- and microelements in juice by inductively coupled plasma mass spectrometry ICP-MS.

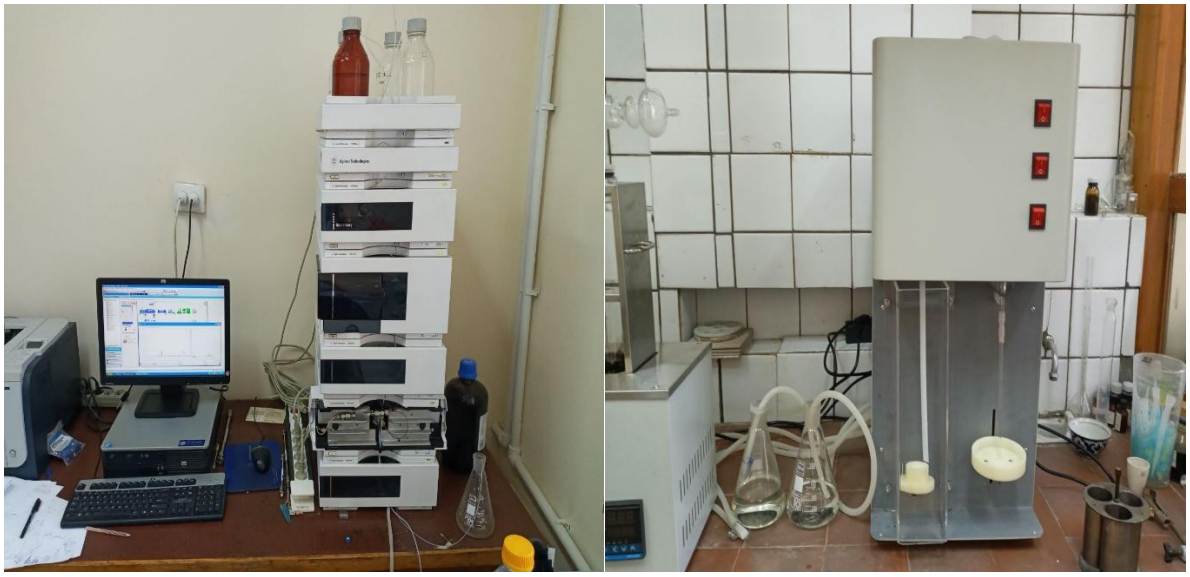
This method is used to determine the amount of macro- and microelements in food products. To do this, 0.0500 ÷ 0.500 g of the test substance is weighed on an analytical balance and placed in a Teflon container of an autoclave, then filled with the appropriate amount of purified concentrated mineral acids (nitric acid and hydrogen peroxide). The autoclave is closed and placed in a programmable Berghof microwave oven (MWS-3+). Depending on the type of substance being tested, the appropriate program is determined.

After decomposition of the substances placed in the autoclave, they are placed in volumetric flasks with a capacity of 50 or 100 ml and adjusted to the required level with 0.5% nitric acid.

The amount of substances was determined by inductively coupled plasma mass spectrometry (ICP-MS).

Determination of the amount of protein in condensed sugar sorghum juice.

One of the methods for determining the amount of protein is the Kjeldahl method. This method involves calculating the amount of total protein by determining the amount of nitrogen. The essence of the method is the hydrolysis of organic substances in the sample using concentrated sulfuric acid (an amino group in the protein) with the formation of ammonium sulfate salts.



а) High-peformance liquid chromatography	б) Equipment for protein determination using the Kjeldahl method

Nitrogen-containing organic matter $+H_2SO_4$ $(NH_4)_2SO_4+CO_2+H_2O$. (1)

After hydrolysis was completed, the resulting ammonium sulfate was treated with sodium hydroxide to convert it into ammonia:

$$(NH_4)_2SO_4+2NaOH \longrightarrow Na_2SO_4+2NH_4OH \begin{matrix} \nearrow 2H_2O \\ \searrow 2NH_3 \end{matrix} \quad (2)$$

The ammonia or ammonium hydroxide formed as a result of neutralization is absorbed by a solution of sulfuric acid.

The remaining acid is titrated with an alkali solution and the amount of nitrogen is calculated from the calculated amount of ammonia. An accurate sample weighing 0.1 g was weighed from the test sample into a test tube for analysis, the error of which should not exceed 0.1%. Quantitative analysis of the sample is carried out in a Kjeldahl flask. Next, the experiment was carried out according to the instructions.

Processing of the obtained results: the mass fraction of nitrogen (X) in the analyzed sample is calculated using the formula as a percentage of the sample mass by volume after titrating the amount of ammonia passed through dilute sulfuric acid.

$$X = \frac{(V_1 - V_0) * K * 0.0014}{m} * 100\%, \quad (3)$$

where V_0 is the volume of 0.1 mol/l sodium hydroxide solution used for titration of 0.1 mol/l sulfuric acid solution, remaining from the trial experiment; V_1 is the amount of 0.1 mol/l NaOH (sodium hydroxide) solution used for titration of sulfuric acid; K – 0.1 mol/l sodium hydroxide solution used for titration; 0.0014—the amount of nitrogen equivalent to 1 ml of 0.05 mol/l sulfuric acid solution; m – mass of the final result obtained from five parallel indicators, g; X is the mass fraction of nitrogen in the sample.

When preparing additional food for bee colonies from the stem juice of sugar sorghum, the amount of carbohydrates in the bees' main source of nutrition is taken into account. For this reason,

the amount of carbohydrates was regularly determined by the refractometric method according to ISO 2113-2013 at the growth stages of sugar sorghum varieties [20; 21].

At the same time, the pH of the juice produced in the stem when growing the varieties of sugar sorghum “Karabosh”, “Uzbekistan 18”, “Orange 160” was also monitored. The pH of sugar sorghum stem juice was studied by the potentiometric method on a Voltcraft PH-100 ATC pH Meter (Germany) with an external electrode [22].

Research results and discussion. Based on research results, it has been established that the stem juice of sugar sorghum contains a sufficient amount of glucose, fructose, sucrose, maltose, all water-soluble vitamins C, B, mineral elements, amino acids and partial protein to create food for bees.

Table 1. Results of chemical analysis of sugar sorghum condensed juice

	Amount of carbohydrates, mg %		Amount of vitamins, mg/g		Protein %
variety Oranjevoye 160	Fructose	5.475	B_1	1.256	0.74
	Glucose	11.18	B_2	2.95	
	Sucrose	28.12	B_6	0,324	
	Maltose	1.71	B_9	0,952	
			B_{12}	0.845	
			PP	2.23	
			C	2.89	
	Total	46.48	Total	11.447	0.74
variety Karabosh	Fructose	5.411	B_1	-	0.24
	Glucose	11.33	B_2	8.360	
	Sucrose	27.59	B_6	0.126	
	Maltose	1.69	B_9	0.500	
			B_{12}	3.463	
			PP	0.956	
			C	-	
	Total	46.02	Total	11.405	0.24
variety Uzbekistan 18	Fructose	6.98	B_1	-	1.03
	Glucose	12.24	B_2	5.835	
	Sucrose	26.91	B	0.391	
	Maltose	1.57	B_9	0.161	

			B_{12}	7.641	
			PP	0.474	
			C	0.812	
	Total	47.43	Total	13.405	1.03

As can be seen from the results of Table 1, the amount of carbohydrates in the stem juice of the variety "Oranjevoye 160" is 46.48%, "Karabosh" 46.02%, "Uzbekistan 18" 47.43%. The amount of water-soluble vitamins in the variety "Oranjevoye 160" is 11.447 mg/g, in the variety "Karabosh" 10.405 mg/g, and in the variety "Uzbekistan 18" 13.405 mg/g. It has been established that the nutritional value of sugar sorghum juice, which is the object of the study, is quite high.

The amount of macro- and microelements and heavy metals in the juice was determined before the concentration of the juice, with a dry matter content in the juice of about 18÷23%. Macro- and microelements are found in almost the same quantities in all three varieties and provide the bees with the necessary minerals during the off-season. The results obtained are presented in Table 2.

Table 2. The amount of macro- and microelements in sugar sorghum stem juice

	Macro- microelements, *100 mg/g*							
	Na^+	Mg^+	Al^+	Ca^+	K^+	Fe^+	Mn^+	P^+
Sugar sorghum stem juice	2.480	172.71	2.10	3.009.1	980.	109.2	2.909	77.43
	Macro- microelements, *100 mg/g*							
	Mo^+	S^+	Cu^+	Se^+	Cr^+	Si^+	Sn^+	Co+
	0.015	1.032	0.197	0.019	0.019	37.71	7.199	1.377

The table shows that the juice used as food for bee colonies contains macroelements such as Ca (3.0091 mg/g), K (9.806 mg/g), Fe (1.092 mg/g), Mg (1.7271 mg/g), P (7.743 mg/g) and provides the mineral content of the juice. The presence of such useful microelements as Al, Mn, Cu, Co, Si, Cr, Mo, S, Se, Zn was found in certain percentage amounts in the stem juice.

In the toxicology of food products there are elements belonging to the category of heavy metals, the limit of which is strictly defined in SanPiN. Exceeding the established limit can have a negative impact not only on the bees' body, but also on the quality and suitability of honey products for consumption.

Table 3. Amount of heavy metals in sugar sorghum stem juice

The product's name	The specified rate doesn't exceed, *mg/g*					
	Zn	Cu	Pb	Cd	Hg	As

Oranjevoye 160	1.377	0.197	0.029	0.002	0.005	0.005
Karabosh	1.012	0.37	0.028	0.001	0.749	0.030
Uzbekistan 18	1.158	0.2	0.67	0.002	0.549	0.7
According to SanPiN standards	10.0	5.0	0.3	0.03	0.1	0.005

According to the results obtained, the amount of Zn in the stem juice of the Oranjevoye 160 variety is 1.377 mg/g, which is 7.7 times less than the permissible standard given in SanPiN 0366-19, the amount of copper (Cu) is 25 times less than the standard, the amount of lead (Pb) is 10.3 times less, the amount of cadmium (Cd) is 15 times less, the amount of mercury (Hg) is 20 times less, and the amount of arsenic (As) is within the acceptable range, and it has been proven that the stem juice of sugar sorghum, offered as food for bees, meets the requirements of SanPiN.

Particular attention should be paid to food raw materials grown in natural environments with an increased level of geochemical anomalies in the amount of heavy metals; in areas where enterprises of the metallurgical, mechanical engineering, mining, and chemical industries are located; near major highways and cities.

Table 4. The amount of amino acids in condensed sugar sorghum juice

Amino acids	mg/g	Amino acids	mg/g
Serin	0.38	Proline	0.814
Glycine	0.502	Tyrosine	0.822
Asparagine	0.91	Valin	0.501
Glutamine	0.543	Methionine	0.125
Cysteine	1.28	Histidine	0.750
Threonine	0.534	Isoleucine	0.171
Argenine	0.870	Leucine	0.33
Alanin	0.204	Tryptophan	0.22
Phenylalanine	0.22	Lysine	0.201
Total			9.92

According to the results of the 4-table, it was found that 18 of the 20 types of amino acids known in nature are present in the juice and their amount is 9.92 mg/g in average.

Table 5. Results of determining the chemical composition of stem juice in the field

Maturation period	Karabosh		Oranjevoye 160		Uzbekistan 18	
	a.d.m.,%	pH	a.d.m.,%	pH	a.d.m.,%	pH

Grain formation	15.0 ± 1	5.0	15,4 ± 2	5.40	15,8 ± 2	5.25
Milk ripeness	16.0 ± 1	5.40	17,4 ± 3	5.30	17,8 ± 2	5.20
Full ripeness	19.0 ± 1	5,30	21, 2 ± 1	5.20	21, 4 ± 2	5.1

Note: a.d.m. – *amount of dry matter ; pH - acidity of juice*

According to the table, the amount of dissolved substances in the stem juice of sugar sorghum at full ripening is 19÷22 % in average, for the early-ripening variety Karabosh up to 20.2÷22 % for the mid-ripening variety Oranjevoye 160 and late-ripening variety Uzbekistan 18 is 22.4÷23 %.

It has been established that the pH value in the juice of sugar sorghum of the three varieties does not differ significantly and is 5.15 for the early ripening variety "Karabosh", 5.20 for the variety "Orange 160" and 5.1 for the variety "Uzbekistan 18".

CONCLUSION

In conclusion, the results of our analyzes show that the juice obtained by processing sugar sorghum stalks is rich in beneficial properties. The amount of carbohydrates in the juice is 46.48% and the total amount of amino acids is 9.915 mg/g, which further improves the quality of the new food used for bee colonies kept on local feeds of various compositions, prepared with the addition of sugar syrup due to the lack of natural crops , plants and shrubs. Bees can get enough protein and amino acids only from plant pollen. The content of amino acids and partially protein in sugar sorghum juice ensures the achievement of this goal. The presence in the juice of almost all water-soluble vitamins, essential macro- and microelements, and partly protein also increases the energy value of the studied feed. In addition, it has been established that the sugar sorghum plant produces the expected yield in all regions of our republic, even in arid, low-water areas, and there is also sufficient opportunity to obtain juice from the stem, which does not cause any particular difficulties in creating feed.

It was noted that the recommended feeds were well received by bee colonies, no side effects were observed. As a result, we can conclude that this food serves to solve the problem of natural food shortage in beekeeping.

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