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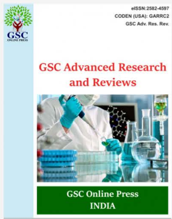

(Research Article)

Churchkhela: Georgian delicacy

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Abstract

This product is an ancient Georgian national sweet. It is unknown by whom and where in Georgia it was originally made. Churchkhela is still produced by national technology, the main components of which are pressed and condensed grape juice (Badagi), cereal (wheat, corn) flour, and filling consisting of walnuts or nuts, etc., threaded onto a string. The paper presents an overview of the disadvantages of a product manufactured using traditional technology, large-scale studies conducted and appropriate biotechnological methods developed to overcome these disadvantages. The result is an environmentally friendly method using modern means of mechanization, paving the way for this product to enter the international market.

Keywords: Churchkhela; Grape juice; Walnut; Concentration; Wheat flour; Dough mass; Purification; 5-hydroxymethilfurfural; Caramelans

1. Introduction

1.1. Research in improving the technological process

The traditional technology used to make Churchkhela is quite simple and includes the following operations: obtaining grape juice by crushing grapes, which is concentrated in a suitable vessel to reduce the amount of water by at least half. The resulting Badagi is thickened with flour, the homogenized mass is processed at a high (> 100 °C) temperature for several hours, while walnuts or nuts are threaded on a string and then dipped in condensed grape juice (Tatara, Pelamushi). The thread should end with a special loop for hanging. Churchkhela strings are then left to dry for several days until they are no longer sticky to the touch (to prevent moisture or mold growth). Churchkhela is produced in considerable quantities domestically, but is not exported in significant quantities. The current production technology has many disadvantages that should be overcome as soon as practicable. These disadvantages include:

- Glucose and fructose are the main carbohydrates in grape juice. Tartaric acid and malic acid are major acids in grape juice. If we add to these factors the heat treatment of grape juice at a temperature above 100 °C to remove excess moisture, it becomes clear that in Badagi a large amount of harmful 5-hydroxymethylfurfural is formed, which, according to doctors, promotes the occurrence of tumors in the body;
- High-temperature processing of grape juice leads to the oxidation of phenolic compounds contained in it, which is why Badagi turns dark chestnut. According to various authors (Natsvlishvili, 1978; Tsereteli, 1995; Shatirishvili, 2005), sulfur dioxide, bentonite with polyacrylamide, and polyoxyethylene are among wine fining agents. Probably, caramelans are also formed in it. Although we have developed an intensive method for removing excess moisture from liquids at relatively low temperatures (<68°C) by exposure to atmospheric air (Copyright # 5870, Saqpatenti, 2014), it is not possible to completely avoid the formation of dark coloring agents (Fig. 1.3);

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- The type of vessels used in Churchkhela production is very important. In particular, stainless steel or enamelware vessel is most preferred. Any other material (aluminum, cast metal, etc.) will inevitably lead to the formation of undesirable substances. This situation is still not getting the attention it deserves;
- Due to the weak catalytic activity of organic acids, even under conditions of starch hydrolysis, one should not expect the main transformations of polysaccharides of cereal flour mixed with grape juice and processed at high temperatures: its decomposition with the formation of oligosaccharides can occur only with the participation of a heat stable α-amylase, which is absent in grapes. At high temperatures, only irreversible denaturation of flour proteins can be assumed. Churchkhela produced in this way loses plasticity and becomes hard to chew, which is undesirable.

2. Material and methods

The aim of the research was to preserve the biological properties and ecological purity of the initial product (grape juice), improve the consistency of the mixture of processed flour and grape juice, reduce the share of manual labor and time cost in production processes, and achieve appropriate indicators of exports of finished products.

2.1. Materials required for research

- Grape juice (Badagi), with an initial concentration of at least 20% by weight, with minimal acidity (pH>4);
- Wheat flour of at least Grade 1 with a residual moisture content of 12-13 wt%;
- Enzyme preparation α-amylase, thermostable, in liquid or powder form, with established activity, without excipients;
- Commercial preparation of sulfur dioxide;
- Zeolite (Clinoptilolite) with a crystal thickness of 3-5 mm, cleared of impurities (soil, etc.).

2.2. Materials processing:

- Grape juice after extraction from the whole grapes was quickly filtered using a dense fabric and a centrifuge, and a residual juice turbidity (sediment) was further removed by passing through a layer of zeolite (clinoptilolite), which had been previously cleaned of foreign substances (for example, soil) and small fractions (with a diameter of less than 3 mm), then the grape juice was concentrated in an open or closed wide-mouthed vessel, multiplying the evaporation surface area, under the above copyright (# 5870, 2014), in a double-walled boiler (inner - stainless material). The concentration was performed with the maximum amount of supplied gas (atmospheric air or CO_2), with a concentration of at least 80 wt.%, eliminating the need to sterilize the concentrate, storage - under CO_2, at normal temperature, in the dark.
  In the processes described above, the color of the grape juice could not be preserved during thickening: its darkening was observed when the concentration of 50 wt.% was reached. Later, sulfur dioxide was used, which made it possible to preserve the desired color and carry out the process of formation and separation of sediment. This was followed by concentration under copyright # 5870.
- Wheat flour was processed in the form of an aqueous suspension, with a ratio of 3:7 based on dry matter with the addition of α-amylase. Starch was liquefied under conditions of 80-85°C (15 minutes), then by increasing the temperature to 85-90°C (0.5 hours) by removing excess water from the resulting dough (Tatara, Pelamushi), so that the concentration of Tatara was 43-45 mass%.

3. Results and discussion

3.1. Research of biochemical studies of Churchkhela

3.1.1. Concentration of grape juice

For this process, we used a double-walled boiler (inner- stainless steel) with water in between the walls. Compressed air from the compressor was supplied to the grape juice poured into the inner pot through a bubbler, which was cleaned of oil vapors through a layer of clinoptilolite placed in a filter, heated to a predetermined temperature, and due to this, the evaporation surface area in the boiler was increased. The temperature in the water jacket ranged from 61-66°C, this indicator for the material to be processed was 52-57°C, and the intensity of concentration (humidity reduction) at the initial stage was 15-17 wt.% per hour. Finally, the concentration of grape juice increased from 21 to 82 wt.%, ensuring the shelf life of Badagi without sterilization - before consumption (Bogdanov, 1997, 2002). The content of 5-hydroxymethylfurfural in Badagi did not exceed 30-41 mg / kg, which is explained by the coexistence of organic acids in grapes. In invert sugar syrup, the same indicator did not exceed 6 mg/kg due to the absence of acids in the sugar ("Multitest" Testing Laboratory data, 2017).

1 and 2 - obtained by new technology, 3 - oxidized (discolored)

Figure 1 Concentrated (78.5-81% by weight) samples of grape juice

3.1.2. Partial hydrolysis of wheat flour

Thermostable α-amylase was added to the aqueous suspension of flour with a composition of 3:7 based on dry matter, depending on the activity of the preparation (starch content usually ranges from 48-57%), the temperature of the suspension rose to 85-90°C in the same double-walled boiler with constant stirring, after which the mixture acquired non-dense dough consistency. In this mode, the dough was processed through a homogenizer for half an hour. After that, the dough was cooled to 65-66^{0}C, grape juice was added in an amount of 8-9% of the total mass of the dough and the mixture was concentrated with heated air supplied from the compressor so that its concentration was 43-45 mass%. Churchkhela strings were dipped in the resulting mixture, the remaining gaps between the individual particles were filled with Tatara without dripping, which accordingly preserved the resulting product in its traditional (Fig. 2) form. According to the qualitative analysis (Fiehe's test) conducted at "Biotex" LLC, 5-hydroxymethylfurfural was not detected at all in the wheat flour hydrolysate. The sample below (2a) clearly shows the result of an inappropriate processing temperature of the Churchkhela material, which is caused by the oxidation of the grape juice and, probably, the formation of 5-hydroxymethylfurfural in it ("Multitest" Testing Laboratory, 2022).

A	B

Figure 2 a) Churchkhela made by traditional technology; b) Sample made using a new technology

3.1.3. Further processing (drying) of Churchkhela strings

Freshly dipped Churchkhela strings are sticky, so they should be separated from each other by 5-6 cm. Instead of the usual wooden stocks, we prepared a double-walled cylindrical thermostat with lid, electric and gas heater, water in between the walls. The atmospheric air from the outside was supplied to the suction fan mounted on the thermostat through a pipe installed in the cover, which received the necessary temperature from the heated interior walls. Churchkhelas hung on hooks of a special design inserted into the thermostat were dried with air blown by the fan and heated inside, the temperature of which at the beginning of drying should not be more than 25°C (2 hours), then gradually (every 2 hours) increases by 5°C to 40-45°C until they are no longer sticky to the touch. Drying was then continued in a conventional drying cabinet with internal aeration at 60-65°C for 2-3 hours, bringing them to a constant mass At the end of the process, the dried Churchkhela strings were softened by spraying water (spray gun) or by immersion in a bath 2-3 times for a short time (for 4-5 seconds each) to wash off simple sugars from the surface. Then, we additionally dried Churchkhela strings for 30 minutes at $40\text{-}45^0$, which improved its consistency and allowed them to be packed together, which is the final stage before selling the product. Churchkhela gets its final state in 28-30 hours.

3.2. The main technological equipment

Technological equipment necessary for the production of Churchkhela includes

- To concentrate grape juice
  - Pump for compressed atmospheric air supply;
  - Oil vapor removal filter;
  - Calorifier with thermometer;
  - Vaporizer with stainless or enameled steel body, water jacket, bubbler and thermometers.
- To produce dough from partially hydrolyzed flour:
  - Double-walled dough kneader with mixer and automatic heater;
  - Compressor for supplying air with a lower temperature through a bubbler to the dough kneader;
  - Drying cabinet with active ventilation inside.

To make churchkhela, in the future, it will be necessary to create several non-standard devices, namely: threading churchkhela filling, dipping into Tatara, hanging the product to dry, removing threads after drying, packaging of finished products, which is still done manually. Today's equipment can perform the most labor-intensive work, which will increase production volumes and reduce the cost of production, but this is not enough to improve the process.

3.3. Technical and economic evolution.

We have overcome the following disadvantages of the traditional technology of Churchkhela

- Of the seasonal work of making components, only Badagi is to be prepared. Its high concentration (80-82 wt.%) allows to create a year-round supply. Therefore, Churchkhela can be produced continuously throughout this period;
- The changes we have made in the production of Badagi allow to radically reduce the content of 5-hydroxymethylfurfural in it (up to 30-41 mg / kg), and the average amount of this substance in Tatara will decrease ten times, because in a partially hydrolyzed flour dough, which makes up 90% of the total mass, this substance is not produced. Thus, there is no longer a danger that export products will be rejected for this reason;
- The consistency of Churchkhlea prepared using the new technology has also improved: it is more elastic, making it more enjoyable for customers;
- It is likely that Churchkhela made using advanced technology will be more profitable due to its ecological purity and increased export potential. As a result of improving the quality and reducing production costs, the income received from the sale of Churchkhela will be 20-25% more in the case of exports.

4. Conclusion

- Churchkhela, made by traditional Georgian methods, along with a number of positive features (palatability, content of basic nutrients, shelf life, non-deficient components), has several obvious disadvantages: formation of 5-hydroxymethylfurfural and caramelans in the production process (effect of high temperature), undesirable physical stability (hardness), primitive methods of preparation, that affect its price and become a deterrent on the international market;

- With the help of the technology developed by the author, which includes a method of concentrating one of the components of Churchkhela - Badagi - in a low-temperature (T = 50-57°C) mode, it is possible to prevent the causes of the formation of 5-hydroxymethylfurfural and caramelans, which is one of the main requirements for assessing the quality of this product;
- In order to overcome one of the main disadvantages in the process of preparation of Badagi - darkening, cleaning Badagi from sediment formed as a result of exposure to sulfur dioxide, protects its color during the concentration process, and later - during the storage period of the finished concentrate - carbon dioxide is used for the same purpose;
- Instead of preparing a mixture of wheat flour and Badagi at high temperature, used in traditional technology, a method for processing an aqueous suspension of flour by adding the enzyme α-amylase has been developed, which made it possible to achieve partial hydrolysis of natural starch with the formation of oligosaccharides and the addition of Badagi concentrate to the dough at a relatively low (up to 60°C) temperature. Thus, it became possible to produce a more plastic form of Tatara and preserve ecological purity in Badagi, and to dry the finished products in a special thermostat (on average T = 40-45°C) with active ventilation. In the next stage, a relatively high temperature (T = 60-65°C) is used in the same drying cabinet, for a shorter period of time (2-3 hours). This made it possible to reduce the total duration of the drying process to 28-30 hours;
- To simplify the whole process and replace most manual operations, a device has been created for cleaning and thickening the Badagi, preparing Tatara and drying Churchkhela, although there are no necessary technical means for other work. They should be created in the future;
- The presented innovative technology makes it possible to produce export products of Churchkhela in compliance with sanitary and hygiene rules, with significantly lower labor costs, with the ability to produce products throughout the year and enter the international market and establish a place, which will benefit Georgian viticulture.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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