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REVIEW ARTICLE

Characteristics and biochemical composition of *kombucha* – fermented tea

Charakterystyka oraz skład biochemiczny *kombuchy* – fermentowanej herbaty

Karolina Patrycja Jakubczyk[1,A,D-F], **Gabriela Piotrowska**[1,B-D], **Katarzyna Janda**[1,A,D,F]

[1] *Department of Human Nutrition and Metabolomics, Pomeranian Medical University, Szczecin, Poland*

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Abstract

Introduction. Kombucha is a fermented tea beverage produced by using a symbiotic culture of bacteria and yeast, so-called SCOBY. The tea fungus comes from the regions of East Asia, and was brought to Europe from eastern Siberia. Kombucha is also known under other names, modst commonly as Chinese or Japanese mushroom. In process of fermentation of kombucha many metabolites are produced which are responsible for its pro-health properties.

Objective. The aim of the study is to present a review of the current state of knowledge concerning the chemical reactions, and chemical and microbiological composition of kombucha.

Brief description of the state of knowledge. The components found in the beverage are organic acids, mainly acetic acid, vitamins and mineral components, polyphenols, flavonoids, enzymes and fats, as well as sugars. In microbiological terms, it is a mixture of acetic acid and lactic acid bacteria and yeast. *Acetobacter xylinum* bacteria and *Schizosaccharomyces pombe* yeast are most often present in the beverage. Yeast cells consume most of the fructose in the process of glycolysis, producing ethanol and carbon dioxide. In turn, ethanol is converted into acetic acid due to acetic acid bacteria present in the beverage. Kombucha shows antimicrobial, antioxidant, anti-diabetic properties, reducing the level of cholesterol, supporting the immune system, and also stimulating liver detoxification.

Conclusion. Differences in chemical and microbiological composition of kombucha depend mainly on the variety and type of tea, the amount of sugar used, temperature, pH, and fermentation time.

Key words

kombucha, tea, fermentation, biochemical composition, SCOBY

Wprowadzenie

Kombucha to fermentowany napój herbaciany, wytworzony przy udziale symbiotycznej kultury bakterii i drożdży, tzw. SCOBY. Grzyb herbaciany wywodzi się z rejonów wschodniej Azji, a do Europy przybył ze wschodniej Syberii. Kombucha znana też jest pod innymi nazwami, takimi jak grzyb chiński lub grzyb japoński. W procesie fermentacji kombuchy powstaje wiele metabolitów, które są odpowiedzialne za jej właściwości prozdrowotne.

Cel pracy. Celem niniejszego artykułu był przegląd aktualnego stanu wiedzy na temat reakcji chemicznych oraz składu chemicznego i mikrobiologicznego kombuchy.

Skrócony opis stanu wiedzy. W skład napoju wchodzą kwasy organiczne, głównie kwas octowy, witaminy i składniki mineralne, polifenole, flawonoidy, enzymy, tłuszcze, a także cukry. Pod względem mikrobiologicznym jest to mieszanina bakterii kwasu octowego, mlekowego oraz drożdży. Najczęściej obecne w napoju są bakterie *Acetobacter xylinum* i drożdże *Schizosaccharomyces pombe*. Komórki drożdżowe wykorzystują większość fruktozy w procesie glikolizy, wskutek czego powstaje etanol i dwutlenek węgla. Etanol przekształcany jest z kolei do kwasu octowego, dzięki obecnym w napoju bakteriom kwasu octowego. Kombucha wykazuje właściwości przeciwdrobnoustrojowe, przeciwutleniające, przeciwcukrzycowe, obniżające stężenie cholesterolu, wspomagające układ immunologiczny, a także stymulujące detoksykację wątroby.

Podsumowanie. Różnice w składzie chemicznym oraz mikrobiologicznym kombuchy zależą głównie od odmiany i rodzaju herbaty, ilości użytego cukru, temperatury, pH oraz czasu fermentacji.

Słowa kluczowe

fermentacja, herbata, kombucha, skład biochemiczny, SCOBY

INTRODUCTION

Kombucha is a beverage produced by fermentation of the tea fungus and tea, most often black or green, and sugar. The tea mushroom comes from the East Asia, and was brought to Europe from eastern Siberia. Kombucha is also known under other names, most commonly, Chinese or Japanese mushroom [1]. The tea mushroom is a symbiotic culture of acidic acid bacteria and yeast. This symbiosis is called SCOBY (*Symbiotic Culture of Bacteria and Yeast*) and initiates the fermentation process. It contains anaerobic and aerobic microbial strains which are present in the cellulose membrane which floats on the fermented tea beverage [2]. The fungus forms a colony that resembles a jellyfish, hence

Address for correspondence: Karolina Jakubczyk, Pomeranian Medical University, Szczecin, Poland
E-mail: jakubczyk.kar@gmail.com

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its botanical Latin name – *Medusomyces gisevii*. The upper part of the *Medusomyces* is firm and shiney, whereas the bottom resembles small dangling threads. This is where the growth of SCOBY and the fermentation process occur, during which metabolites with pro-health properties are formed [1]. Fermentation occurs with the participation of yeast and bacteria, accompanied by the formation of a cellulose thick biofilm at the liquid-air interface.

Chemical reactions occurring during kombucha fermentation. During the fermentation process, various metabolites are produced in kombucha [1]. The process takes place at room temperature for the period of 7–14 days. Fermentation of kombucha is the combination of three fermentations: lactic, alcohol and acetic [7]:
lactic fermentation – decomposition of glucose which occurs due to lactic acid bacteria. As a result of this reaction, lactic acid is formed:

$$C_6H_{12}O_6 \rightarrow 2CH_3CHOHCOOH$$

alcohol fermentation – decomposition of glucose under the effect of yeast to ethyl alcohol with carbon dioxide discharge.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2\uparrow$$

acetic fermentation – decomposition of ethyl alcohol under the effect of oxygen and acetic bacteria to acetic acid and water.

$$C_2H_5OH + O_{295} \rightarrow CH_3COOH + H_2O$$

SCOBY, i.e. tea fungus, is a symbiotic growth of acetic acid bacteria yeast, and consists mainly of *Acetobacter xylinum* bacteria and yeast *Schizosaccharomyces pombe* [4]. Bacteria present in the tea fungus are responsible for the production of acetic acid, while yeast is part of the osmophilic group, i.e. leads to decomposition into saccharose into glucose and fructose. Subsequently, glucose is converted into carbon dioxide and ethanol. Ethanol produced during glucose decomposition is oxidized by acetic acid bacteria to acetic acid and acetaldehyde. *Acetobacter* are also responsible for the oxidation of glucose to glucuronic and gluconic acid. During this process cellulose synthesis occurs [5, 6, 7].

Metabolites and chemical composition of kombucha. The main metabolites occurring in kombucha are, among others, organic acids, such as acetic, gluconic, tartaric, malic and citric acid. Acetic acid is dominant in the fermented solution, therefore it has a sour taste [8]. The beverage also contains vitamins and mineral components, as well as ethanol, proteins and polyphenols present in the tea [3, 8, 9] (Tab. 1). The biochemical composition of the beverage may differ slightly, due to changes in such factors as: amount of sugar, type and amount of the tea used, temperature, pH and fermentation time [8, 10, 11] (Tab. 2). Kombucha shows anti-microbial, anti-oxidant, and anti-diabetic properties, which reduce the level of cholesterol, support the immune system, and also stimulate liver detoxification [3, 6, 7, 9, 10, 11, 12].

The beverage is prepared mainly with white sugar, i.e. saccharose, which is a source of energy indispensable for conducting the fermentation process [4]. The added saccharose is hydrolyzed to glucose and fructose, as shown below [8, 12]:
1. Saccharose + Water → Glucose + Fructose
2. $C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$

Table 1. Main metabolites in kombucha tea [1, 3, 8]

Metabolites in kombucha tea
Organic acids: • Acetic, Gluconic, Tartaric, Malic, Citric, Glucuronic, Lactic, Malonic, Succinic
Mineral components: • Copper, Manganese, Nickel, Zinc, Iron
Vitamins: • Vitamin C, Vitamin B1, Vitamin B2, Vitamin B6, Vitamin B12
Enzymes: • Protease, Catalase , Saccharase , Amylase, Kinase, Carbohydrase, Trypsin, Zymase
Sugars: • Glucose, Fructose, Saccharose
Lipids: • Fatty acids, Phospholipids, Sterols
Others: • Polyphenols, Chlorophyll, Xanthophyll, Ethyl alcohol

Table 2. Differences in the content of metabolites in kombucha beverage according to the type of tea and fermentation time [11]

Type of tea	Black tea		Green tea		Rooibos tea	
Metabolites mg/ml:	day 7	day 14	day 7	day 14	day 7	day 14
Glucose	11.20	15.12	11.40	15.89	8.60	18.10
Saccharose	36.23	26.13	37.14	26.21	42.08	33.65
Fructose	4.83	5.5	5.12	6.92	4.07	8.83
Glucuronic acid	1.36	3.23	1.78	1.96	1.70	2.87
Acetic acid	3.18	9.18	4.22	7.65	1.65	4.89
Ethanol	4.69	5.83	2.81	4.18	0.64	1.14

Black tea, one of the main components of the beverage, is rich with flavonoids and polyphenols (e.g. theaflavin and tearubigine). Polyphenols and flavonoids present in the tea are responsible for the anti-oxidative effect of kombucha. During fermentation, the amount of polyphenols and flavonoids increases and tearubigine is converted into teaflavin, therefore kombucha changes its colour from dark to bright with a prolonged fermentation time [10, 11]. Also, microorganisms, e.g. *Candida tropicalis*, are capable of degrading various polyphenols [13]. Catechins present in the tea may be degraded by bacteria and yeast to simpler particles, thus increasing the anti-oxidative strength [8, 13, 14].

Tea fungus contains cellulose which is produced by acetic acid bacteria. Synthesis of cellulose requires the presence of oxygen and is based on intercellular communication (Fig. 1) [8]. Fructiose also shows the capability to produce cellulose through its ability to convert into glucose-6-phosphate, due to the enzymes fructose and phosphoglucose isomerase. Due to the effect of the yeast cells, fructose may not be used by acetic acid bacteria [8].

Microbiological composition. SCOBY, i.e. tea fungus, is a symbiotic growth of acetic acid bacteria yeast, and according to many researchers, it consists mainly of *Acetobacter xylinum* bacteria and the yeast *Schizosaccharomyces pombe* [4]. Bacteria present in the tea fungi are responsible for the production of acetic acid, whereas yeast is a part of the osmophilic group, i.e. lead to the decomposition of saccharose into glucose and fructose. Subsequently, glucose is converted into carbon dioxide and ethanol. Ethanol produced during

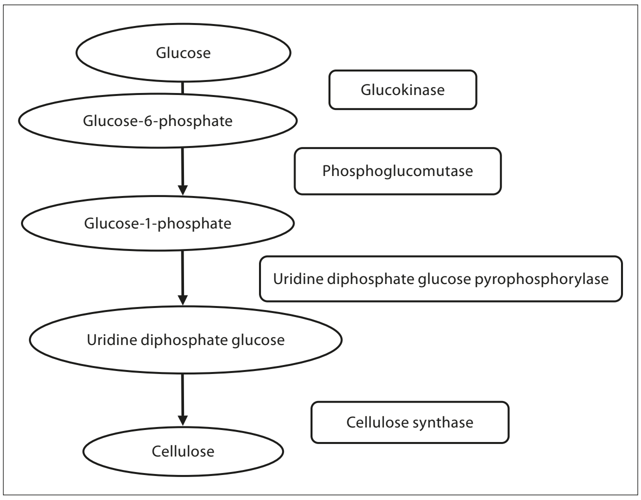

Figure 1. Scheme for the formation of cellulose [8]

glucose decomposition is oxidized by acetic acid bacteria to acetic acid and acetaldehyde, with the participation of acetic acid bacteria. *Acetobacter* are also responsible for the oxidation of glucose to glucuronic and gluconic acid. During this process, cellulose synthesis occurs [5].

Bacteria and yeast develop on the whole surface of kombucha. The percentage of individual microbes changes in the subsequent days of fermentation [10]. Celullose biofilm is the metabolite of acetic acid bacteria. It contains microbial cells, and their percentages in the beverage may differ according to the origin of the fungus [8]. The dominant bacteria present in kombucha are AAB bacteria, which include: *Acetobacter xylinoides*, *Acetobacter aceti*, *Acetobacter pasteurianus*, *Bacterium gluconicum* and *Gluconobacter oxydans* (Tab. 3) [3]. The presence of oxygen is an absolute necessity for the growth of these bacteria, using ethyl alcohol as a substrate to produce acetic acid. Yeasts contained in the beverage are responsible for the formation of biofilm. Analysis of qualitative composition of microorganisms demonstrated the presence of *Schizosaccharomyces pombe*, *Candida krusei* and *Issatchenkia orientalis* [3].

Table 3. Microbiological composition of kombucha [3, 8, 10, 11]

Group of miocroorganisms	Genera or species
Lactic acid bacteria	LAB (Lactic Acid Bacteria), *Lactobacillus and Lactococcus* .
Acetic acid bacteria	AAB (Acetic Acid Bacteria), *Gluconobacter: G. entanii, G. oxydans, Acetobacter aceti and Komagataeibacter: K. intermedius, K. rhaeticus*
Yeasts	*Schizosaccharomyces pombe, Zygosaccharomyces bailii, Saccharomyces cerevisiae, Saccharomyces ludwigii, Torulaspora Delbrueckii, Kloeckera apiculata, Brettanomyces bruxellensis. Candida krusei, Issatchenkia orientalis, Hanseniaspora.*

CONCLUSIONS

Kombucha, i.e. fermented tea, gains increasingly greater popularity and is consumed not only in Asia, but also in Europe and North America. Fermentation of kombucha is the combination of the processes of lactic, alcohol and acetic fermentation. Fermentation time and type of tea are important parameters which condition the chemical and microbiological composition of kombucha, and metabolites produced during these processes, e.g. lactic, acetic, glucuronic and gluconic acid, as well as polyphenols, provide the health-promoting properties of this beverage.

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