GLUCURONIC ACID CONTAINING FERMENTED FUNCTIONAL BEVERAGES PRODUCED BY NATURAL YEASTS AND BACTERIA ASSOCIATIONS

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ABSTRACT
Synthesis of glucuronic acid, well-known as significant detoxicant, by natural Kombucha associations has been studied. The aim of this review is to overview the possibility to obtain Kombucha-like healthy beverages with a high content of glucuronic acid by the integration of several optimal conditions of fermentation system.
The article demonstrates the obtaining of fermented beverages with a high content of glucuronic acid by applying natural associations of bacteria and yeasts, known as Kombucha, for the proof of the concept that synthesis of glucuronic acid is a characteristic property of Kombucha symbiosis. A direct relationship between the Kombucha fermentation process conditions, composition of the fermentation medium and the yield of glucuronic acid has been proved. The initial hypothesis of this review about glucuronic acid synthesis as a property of Kombucha, regardless of the origin and composition of the symbiosis used, has been confirmed. The experimental studies overviewed have confirmed the assumption that it is possible to increase the yield of glucuronic acid by changing fermentation medium and independent variable conditions of the process.

Keywords: *glucuronic acid, uridine diphosphate glucuronic acid, uridine diphosphate, glucuronosyltransferases, detoxication, glucuronidation, kombucha symbiosis*

1. INTRODUCTION
Glucuronic acid (GlcUA) is well-known in the prophylaxis of human health as a significant detoxicant. UDP-glucuronosyltransferases (UGTs) - the family of enzymes responsible for the glucuronidation have many isoforms and broad substrate specifity that allows conjugating GlcUA with many foreign and natural compounds. Glucuronidation is an important process for detoxication and excretion of exogenous chemicals - xenobiotics, as well as, for biotransformation of endogenous reactive metabolites, such as bilirubin, oxidized fatty acids and excess of steroid hormones. The conjugation of GlcUA with undesirable compounds results in the decreased toxicity due to the increased solubility of them that further facilitates transport and elimination from the body. This article overviews the obtaining of fermented beverages with a high content of GlcUA by applying Kombucha cultures from various parts of the world (France, Tunisia, Russia, Serbia, Iran, India, Indonesia, Korea, Japan, Sudan, USA), that makes clear a difference in the composition of symbionts; the active ingredients and their quantitative relations in final products are variable, but all Kombucha symbiosis studied synthesize GlcUA. The scientists have studied possibilities to enhance the production of GlcUA by modifying fermentation medium and process parameters. The interest about the production of GlcUA and GlcUA oligomers has increased significantly during the last decade.

2. THE APPLICATION OF KOMBUCHA SYMBIOSIS FOR THE PRODUCTION OF GlcUA CONTAINING FERMENTED BEVERAGES
Kombucha symbiosis is used to produce a tasty and healthy drink that is obtained by fermenting of sucrose-sweetened tea. The first records on the Kombucha use come from China in 221 BC, where it has been consumed for at least two thousand years. The present review is aimed to demonstrate the possibility to increase the yield of GlcUA by changing the conditions of Kombucha fermentation. The synthesis of Kombucha products is mainly determined by the following conditions: sugar and tea used, duration and temperature of fermentation. GlcUA is produced when glucose-containing sugars, such as sucrose, maltose, lactose and others are available in the medium in sufficient concentration. Using sucrose as a carbon source, first the enzymatic hydrolysis of the sugar substrate takes place to release free fructose and glucose. Exhaustive biochemistry of the Kombucha metabolite composition remains largely unknown [1].
Many researchers have studied a symbiotic association of acetic acid bacteria and yeasts, called Kombucha. The following is reported about the microbiology of Kombucha symbionts: Kombucha is actually a symbiosis of yeasts and acetic acid bacteria [2, 3]. The main acetic acid bacteria found in the tea fungus are: *Acetobacter xylinum* [4], *Acetobacter xylinoides, Bacterium gluconicum* [5], *Acetobacter aceti, Acetobacter pasteurianus* [6], *Gluconobacter oxydans* [7, 8]. Several lactic acid bacteria have been isolated from Kombucha associations as well [6-9]. Yeasts

isolated from Kombucha beverage are *Schizosaccharomyces pombe, Saccharomycodes ludwigii, Kloeckera apiculata, Saccharomyces cerevisiae, Zygosaccharomyces bailii, Torulaspora delbrueckii, Brettanomyces bruxellensis, Brettanomyces lambicus, Brettanomyces custersii, Candida stellata, Torulopsis sp., Pichia sp., Brettanomyces sp*. [7, 8]. Furthermore, other *Candida* and *Pichia* species have been isolated from Kombucha symbiosis [1, 4, 6, 10]. Recently two strains unique for Kombucha symbiosis - bacteria *Gluconacetobacter kombuchae sp.* [11] and a new ascosporogenous yeast species *Zygosaccharomyces kombuchaensis* [8, 12] have been identified. The composition of yeasts and acetic acid bacteria in the Kombucha symbiosis is highly variable [7]; therefore, if used as a therapeutic substance or functional beverage, Kombucha should be defined and standardized with regard to its microbiological and chemical composition [13]. Various Kombucha symbiotic associations have been cultivated by the authors cited below, and GlcUA production is reported for all of them. GlcUA should not be confused with gluconic acid, resulting from the oxidation of carbons at different positions of glucose molecule (Figure 1).

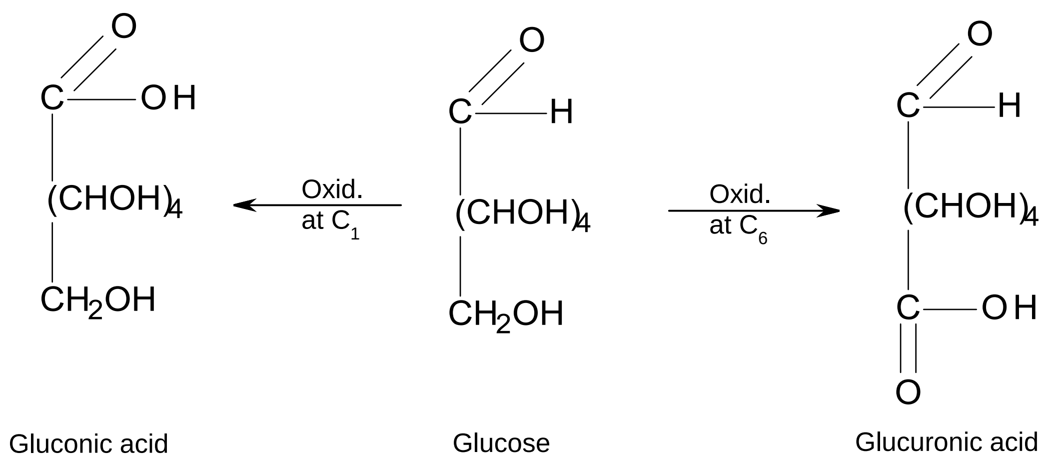

Figure 1. Formation of glucuronic acid and gluconic acid by oxidation of glucose.

Both GlcUA and gluconic acid are found in the fermented drinks known as Kombucha. Plenty of different compounds, significant for the human health protection, are produced during fermentation of Kombucha symbiosis: a range of organic acids such as glucuronic, gluconic, lactic, acetic, succinic acid, butyric, malic and usnic acid; vitamins, in particular, of group B and vitamin C, free amino acids and different active enzymes. GlcUA is considered to be one of the key compounds found in Kombucha beverage due to its detoxifying action and claimed health effects [14, 15]; it prevents chronic degenerative cardio-vascular, neurodegenerative diseases and cancer [16, 17].

As it has been mentioned by Lončar et al. [14], in the preliminary studies GlcUA is often cited as Kombucha metabolite, but without quantitative analysis.

3. FERMENTATION SYSTEM

Fermentation system that includes a composition of the medium and variable parameters of the process is the main determinant of the results obtained by the cultivation of Kombucha symbiosis. Two different starter types for Kombucha fermentation can be used to evaluate the influence of the process parameters on the production of GlcUA: Kombucha layer from the fermented liquid surface, and/or Kombucha liquid (mainly 10%) from the previous fermentation [18]. The independent variables monitored have been sugar and tea substrates, temperature and time of fermentation process, while the response variables are the yield of biomass, yield of GlcUA, residual sucrose, and pH value.

3.1. Sugar Substrate - Carbon Source In The Growth Medium

The traditional carbon source for Kombucha fermentation is sucrose [19]. Fermentation of Kombucha is made by using 5-20% sucrose-sweetened media [5, 12, 16, 20-23]. Sugar substrates must be used at high concentrations (5, 10, 15, 20 g/l) because sugar is consumed as a carbon source for the growth of microorganisms and sucrose in fermentation medium is the principal factor limiting the increase of GlcUA yield. The studies overviewed testify that glucose-containing sugars, i.e., sucrose, lactose, mannose is appropriate for the production of GlcUA, since glucose is the main source for the synthesis of GlcUA. Besides pure sucrose, various complex sucrose-containing products, in particular, some agricultural and industrial by-products, as molasses from sugar beet processing can be used as sugar substrate. As a good source for the growth factors such fermentation media are attractive because of their low costs [24].

3.2. Tea Substrate

Results of Kombucha fermentation depend on what kind of tea is used. Black tea (BT) and green tea (GT) are the usual substrates for the preparation of Kombucha beverages [5, 22]. Studies have been carried out on a broad concentration range (1,25 g/l – 12,5 g/l w/v) of tea substrate [14, 24-27]. Tea leaves are rich in polyphenols, known as effective antioxidants; some other metabolites of fermented drinks (e.g. vitamin B_2, C) also can act as antioxidants [28]. The search for a fermentation medium rich in antioxidants has led to new trends in the research - the fermentation of Kombucha on herbal teas used in traditional medicine [23, 28-30] and on other food-grade substrates to enrich these products by natural compounds of microbial origin beneficial for human health. Several studies on fermented milk [18, 19, 31, 32], cheese whey [25, 33] and on agricultural and industrial by-products, such as molasses from sugar beet processing [24] have been carried out. A special subject is applying the fruits and berries juices rich in potent antioxidants for the fermentation of Kombucha culture [34-36].

3.3. T^0 – Temperature

Originally, Kombucha fermentations have been carried out at the room temperature. As it follows from the investigations overviewed higher temperature causes faster decrease of sucrose concentration and faster increase of GlcUA yield and the yield of other acids as well [35, 36].

3.4. T – Fermentation Time

Production of GlcUA and other valuable compounds of Kombucha are related to a fermentation time – time-temperature interaction is very significant: usually Kombucha fermentations have been carried out at ambient temperature for 7–10 days. The increase of the temperature stimulates the Kombucha layer growth and yielding of the metabolites in a shorter time [7, 37-39].

3.5. pH

pH values of the fermentation media decreased during the incubation of Kombucha due to the synthesis of different organic acids [14], however it has been noted that pH dynamics in Kombucha beverage does not depend only on the production of organic acids [22]. A mechanism of pH stagnation in spite of the growing total acidity has been proposed, according to which carbon dioxide is released at first slowly and much faster after 2-3 days; dissociates of that produce the hydrocarbonate anion (HCO_3^-), which easily reacts with hydrogen ions (H^+) from organic acids, preventing further changes in the H^+ concentration and contributing to a buffer character of the system [5, 17, 22, 40]. The ability of Kombucha symbiosis to buffer the fermentation system has an important role from the biotechnological viewpoint towards the maximization of valuable organic acids production.

3.6. Biomass

The yield of the biomass is closely related to the kind and concentration of sugar and tea substrates used, fermentation temperature and the presence of the growth factors [27, 36, 41].

The following examples, arranged in order of growing yields of GlcUA, are demonstrating this characteristic feature – production of GlcUA - of Kombucha symbiosis.

3.6.1. Example 1

Blanc [42] has reported about the Kombucha association of microorganisms consisting of at least two groups of microorganisms: the acetic acid bacteria *Acetobacter xylinum* and yeasts *Zygosaccharomyces rouxii*, *Candida sp.* and others. The symbiotic culture was grown traditionally on sucrose-sweetened black tea under aerobic conditions for 7 days as it was reported previously by other authors [5, 6, 43]. The fermentation gave pleasantly sour and sparkling beverage. Several metabolites were identified and quantified: ethanol and organic acids - lactic, acetic, usnic, gluconic and GlcUA. The GlcUA, that is highly responsible for the curative effects of Kombucha beverage, was produced at the concentrations up to 10 mg/l [42]. Curative effects, including detoxifying properties characteristic for GlcUA, presence of vitamins B_1, B_2 and B_6 and antibacterial properties caused by the presence of usnic acid have been mentioned by the researchers [42].

3.6.2. Example 2

The Kombucha colony characterized as a mixed culture of *Acetobacter xylinum* and *Zygosaccharomyces sp.* [20] was used in the study of Lončar et al. [14]. The influence of different concentrations of sucrose on the production of

GlcUA was studied. Fermentations were performed according to the usual recipe on black tea, sweetened by sucrose and incubated in a thermostat at 28 ^{0}C for 21 days. The production of GlcUA was depending on the period of Kombucha symbiosis fermentation and sucrose concentration. The maximal production of GlcUA (3,39 mg/l) was obtained on black tea sucrose medium (100 g/l) at 21th day of fermentation. Taking into account the importance of GlcUA as the main detoxifier, the researchers considered that the beverage obtained under the described conditions could be acknowledged as pharmacologically useful one [14]. These results are in accordance with the data given by Sievers et al. [20], who used black tea supplemented by 67,5 g/l sucrose. A fermentation balance of the sugar substrate used and the products obtained have been calculated on the basis of carbon-mass equation [20].

3.6.3. Example 3

Kombucha culture reported as consisting of *Acetobacter xylinum* and yeasts of the genera *Brettanomyces*, *Zygosaccharomyces*, *Saccharomyces* and *Pichia* was used [44]. The influence of variable environmental conditions, such as type of sugar substrate, fermentation temperature and time and pH value as well on the production of GlcUA was studied. Three initial levels of pH 4, 5 and 6; temperature 25, 31 and 35 ^{0}C; time 3, 5 and 7 days and different sugar containing substrates - corn syrup, molasses and sucrose were applied in the study on GlcUA synthesis [44]. The best results – maximal yield of GlcUA 44,5 mg/l in the final beverage was achieved by sucrose as a substrate. The advantage of sucrose as a sugar substrate, relatively high temperature, i.e., 31 ^{0}C and less acidic fermentation medium (pH=6) were the conditions preferable for the increase of the GlcUA yield. These results show that Kombucha association, fermented under conducted conditions, can produce the beverage that can be used as a healthy drink due to the increased level of GlcUA.

3.6.4. Example 4

Jayabalan et al. [15] have reported about the possibility to get higher levels of GlcUA by varying the tea substrate, than it has been cited by other researchers [14, 42, 44]. 1,2 % of BT, BT manufacture waste and GT were used in the study [22]. The fermentation was carried out at 24 - 37^{0}C for 18 days and changes in the content of organic acids - glucuronic, acetic, lactic and citric acid were examined. GT and BT were found to be the best substrates for the production of GlcUA (1,73 ± 0,14 g/l and 2,33 ± 0,24 g/l, respectively). GlcUA reached maximum on 15th day in GT and on 12th day in BT, respectively. Kombucha fermented beverages had excellent antioxidant properties [22]. The extent of the antioxidant activity depended upon the starter culture, kind of tea material used, time and temperature of fermentation. Among three tea substrates tried, GT was found to have the highest DPPH scavenging ability (88 %) on 18th day of fermentation [22].

3.6.5. Example 5

This example discusses the microbial synthesis of polyglucuronic acids, called also as GlcUA oligomers (GAOs). GAOs produced are subjected to the hydrolysis by enzymes of bacteria and fungi [45-48] and, as a result, free GlcUA is released in the medium. Unknown till the beginning of the nineties, polyglucuronic acids have risen the interest of the scientific community [48], and the studies on polyglucuronic acids as rich source of GlcUA for application in foods and medicine have increased significantly [49-52]. Pokalwar et al. [53] have reported about the production of bacterial cellulose by specific strain of *Gluconacetobacter sp.*, that has also simultaneously synthesized GAOs as by-products [49-52]. Certain strains of *Gluconacetobacter*, previously classified as *Acetobacter*, are reported as Kombucha symbionts [4-8]. A cellulose-producing strain of *Gluconacetobacter sp.*, isolated from rotten apples and identified as *Gluconacetobacter hansenii* PJK [54], was extensively investigated under various experimental conditions and was used to produce GAOs in increased quantities [49, 54-59]. The oligomers were found to consist of α-D-GlcUA as a single monomer unit [49, 51]. For manufacturing of GAOs at bigger quantities waste from beer fermentation broth (WBFB) was chosen as a cost effective alternative to the basal medium; on WBFB large quantities of GlcUA (112,65g/l) were produced [54]. It is known that fermentation medium can influence greatly the composition and chemical structure of the oligosaccharides synthesized [60]. Two differences between oligomers from basal medium and from WBFB have been proved, first, GAOs from WBFB are in the form of sodium oligoglucuronate, and second, those are partly acetylated [50, 61, 62] and have an overall better thermal stability, improved by acetylation, according to Gröndahl et al. [63].

3.6.6. Example 6

Yavari et al. [35] have reported about extremely high yield of GlcUA achieved by Kombucha symbiosis cultured in medium rich in natural antioxidants different from tea polyphenols. Sour cherry juice (SCJ) was examined as the source of antioxidants such as neochlorogenic acid, 3-coumaroyl-quinic acid, chlorogenic acid and catechins; the highest antioxidant activity, anti-inflammatory properties and prevention of various human degenerative diseases are reported for them [64-66]. Actively growing Kombucha layer was used as inoculum for SCJ fermentation [67].

Kombucha from Persian Culture Collection, IROST, grown in traditional Kombucha fermentation medium – sucrose-sweetened black tea produced 3,67 g/l of GlcUA. In order to enhance the GlcUA production the researchers modified the fermentation process by changing three variables: sucrose content, duration of the process and temperature. This increased the yield of GlcUA up to maximum 132,5 g/l at 37 ^{0}C within 14 days on 8 % sucrose-sweetened SCJ. Total concentration of organic acids had increased from 9, 2 g/l in unfermented SCJ to 292,5 g/l in final product; total acidity and value of pH depended significantly on duration of the process. The reduction of sucrose concentration was temperature dependent and the lowest remained sucrose content (2,1 g/l) was reached on 14th day. Therefore juices of various fruits and berries, rich in compounds with antioxidant properties, can be prospective for the increase of GlcUA yield in beverages fermented by natural associations of bacteria and yeasts like Kombucha and as a result, for the increase of the functional value of these beverages.

3.6.7. Example 7

Currently the highest yield of GlcUA achieved by the use of Kombucha symbiosis has been reported by Yavari et al. [36]. The same Kombucha symbiosis and an analogous plan of investigation as in the previous example 6 was applied, only the fermentation medium was changed – the grape juice (GJ) was fermented instead of SCJ. According to the authors the following hypothesis were used for the development of the conception: comparing diets among western countries, it had been noted that although the people of France tended to consume high levels of animal fat, the incidence of heart disease remained relatively low, a phenomenon, as suggested, occurred from protective benefits of regular consuming grape wine [68]. Antioxidants of GJ, such as resveratrol, bears a significant transcriptional overlap with the beneficial effects in heart, skeletal muscle and brain [69], whereas anthocyanin's tend to be the main polyphenolics beneficial for human health [70]. Production of GlcUA was performed using 10% Kombucha inoculum from the previous fermentation. Temperature, time and sucrose concentration were chosen as independent variables of Kombucha cultivation process, while the response variables obtained were the yield of GlcUA and the yield of biomass (Kombucha layer). The fermentation was carried out on sucrose content 5, 7 and 9 g/l at three constant temperatures 18, 27 and 37 ^{0}C for 4, 9 and 14 days. The optimum medium composition for predicted maximum GlcUA production appeared to be 7% sucrose-sweetened GJ. After two weeks of fermentation at 37 ^{0}C the yield of GlcUA increased from initial level of 34 g/l to very high one - 178 g/l. At 27 ^{0}C with 9 g/l of sucrose only 160 g/l of GlcUA was produced after 14 days of fermentation. It showed that increased temperature was a significant factor for a more active production of GlcUA. The yield of GlcUA obtained on GJ was much higher if compared to the production of GlcUA in black tea 2,3 g/l [15] (example 4) and even in sucrose-sweetened SCJ - 132,5 g/l [35] (example 6). In those three investigations overviewed (examples 4, 6 and 7), fermentation times are comparable (12, 14 and 14 days, respectively); the same is to say about sucrose concentration 7-8 g/l**.** It may suggest the effects of carbohydrates in grape juice as additional source of carbon, different antioxidants and other natural compounds as source of nitrogen and nutrients in BT, SCJ and GJ, on the dynamics of the process and metabolites produced. The biomass increased significantly during 14 days of fermentation: the lowest mass of Kombucha mat was 112,43 g, the highest - 478,15 g. Parallelism between the increase of biomass and the yield of GlcUA was marked: the addition of 7 g/l of sucrose to GJ was enough for obtaining of both maxima; the increase of temperature from 27^{0}C to 37 ^{0}C gave the significant increase of both, yield of biomass (from 413 g to 478 g) and yield of GlcUA (from 160 g/l to 178 g/l). Slightly carbonated, acidic, refreshing Kombucha-analogue beverage was obtained that, according to the conclusions of the researchers, might have high pharmaceutical value [36].

4. THE APPLICATION OF MICROBIAL GlcUA IN FOODS

It has been recognized that according to the increasing intake of xenobiotics nowadays, the quantity of GlcUA synthesized in human body is not sufficient for detoxication and elimination of xenobiotics and for promotion of fat-soluble endobiotics normal metabolism. The supplemental consumption of additional sources of GlcUA is advisable and GlcUA containing beverages fermented by Kombucha could help to solve the problem. Kombucha - fermented green or black tea drink is a source rich in GlcUA. D-Glucurono-γ-lactone (DGL) that regulates the formation of D-GlcUA has been offered as a GlcUA source as well. The fact that the two compounds, DGL and GlcUA, are physiologically interchangeable opens a new perspective - a number of studies have revealed that even at high dosages the compound is relatively safe [71]. DGL can be found in minimal amounts naturally, with wine being the richest source with 20 mg/l. The DGL is safe at supplemental dosages (e.g. 500-3000 mg/day) and is short-lived in the humans; it is quickly absorbed via oral administration, metabolized and excreted in the urine. DGL hepatoprotective and detoxifying properties are reported [71].

GlcUA oligosaccharides (GAOs) are less sweet, have fewer calories than sucrose and thus are useful as bulking agents in the foods. The main physico-chemical property of oligosaccharides - their ability to form many hydrogen bonds with different compounds, is characteristic also for α-(1,4)-D-polyglucuronic acid, synthesized by *Gluconacetobacter hansenii* [51, 52]. That determines ability of GAOs of surface coating or enveloping and, as a result, their stabilizing activity against free radical damages regarding to essential unsaturated fatty acids. It makes GAOs valuable as components in food application. GAOs possess good emulsifying properties and have sufficient thermal stability in order to be developed commercially [72]. The optimum concentration of GAOs for maximal emulsifying ability is found to be 0,10 % w/v. A linear homopolymer of partially acetylated GlcUA synthesized by *Gluconacetobacter* [73] has been offered as a substitute for pectin and alginate in the foods because of its remarkable gelling or thickening properties [74]. GAOs are superior in this as compared to carbohydrates that do not contain carboxyl groups, because they are more water-soluble; GAOs carbon skeleton is mentioned to be an advantage for achieving the complexing or stabilizing activity [75].

5. FERMENTED BEVERAGES – MOTIVATION OF THE CHOICE

Functional beverages are an important subsector within functional food scope. In US the market shares of the functional beverages account for 48,9 % of the 118,3 milliard dollar worth non-alcoholic industry [76] with the highest annual growth rate of 15 % to 20 % [77]. This market is predicted to have the increase because people have become more proactive in illness prevention and control; they focus on natural healthy ingredients. Functional beverages include non-traditional ingredients in their formulation, so as to provide specific health benefits that go beyond general nutrition, such as heart health, improved immunity and digestion, joint health and weight management, which increase worries about obesity and its implications on health [76, 78]. Common improvement of health and wellness by the decrease of sugar and calories consumption and increase of consumption with daily dose of essential vitamins and minerals, as brewed functional beverages are excellent source of B vitamins, help meet the demands of energy metabolism, and source of antioxidant vitamins E and C to help protect the body of active individuals [79]. Functional beverages produced are targeted to solve a problem of organism's hydration in a healthy way [79, 80] and energy/rejuvenation [81] – the last products are rated number one in growth with a wide range of varieties targeting different health related concerns [82]. One of the trends is probiotics for gut health and boosting immune system; memory and mental sharpness is also coming into focus: fermented beverages, rich in neuroactive amines tyramine and histamine are produced [83]. Preventive effects of green tea on diabetic nephropathy have been demonstrated [84], that points on possible influence of Kombucha fermented green tea beverages on protection against degenerative kidney diseases. Due to the lactose maldigestion problem and allergy to milk proteins, widespread in human population, non-dairy drinks which are also cholesterol free are demanded; antioxidants from medicinal herbs and fruit extracts are among the ingredients that protect consumers from free radicals caused risks and, as a result, from many chronic degenerative diseases [85].

Kombucha - symbiotic association of bacteria and yeasts has been cultured for obtaining the healthy beverages long ago [12]. The popularity of Kombucha fermented beverage is mainly due to its refreshing ability and ascribed curative effects. The American Centre of Disease Control (CDC) has investigated all reports of health concerns and Kombucha fermentation final product is generally recognized as safe [GRAS] by USA Food and Drug Administration (FDA) [86, 87].

6. CONCLUSIONS AND FUTURE PROSPECTS

The present review provides an overview of GlcUA synthesis by Kombucha symbiosis: all associations being used produce GlcUA; the yield of GlcUA can be regulated by changing the fermentation medium and the process parameters. The studies overviewed have shown that fermentation media rich in glucose containing sugars **-** source of carbon, additional sources of nitrogen and antioxidants (GT and BT, teas of medicinal herbs, waste beer fermentation broth, juices of sour cherry and grape) are perspective for further research how to intensify the production of GlcUA in Kombucha-like beverages. Regular supply of GlcUA is very important in respect to health maintenance and different curative effects: use of Kombucha beverages containing GlcUA is recommendable for the elimination of xenobiotics. The studies on the consumption of Kombucha beverages suggest their suitability for the prevention of metabolic disorders that make them perspective for development of fermented functional beverages for health prophylaxis

7. ACKNOWLEDGEMENTS

This research was supported by ERAF 2.1.1.1 Contract No. 2010/0322/2DP/2.1.1.1.0/10/APIA/VIAA/108

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