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(Review Article)

Exploring the nutritional factors and health benefits of artisanal alcoholic rice beverages

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Abstract

Fermentation is an ancient preservation technique used to transform complex food materials into simpler biologically active compounds, which enhances their nutritional content. Various microorganisms, including Lactic acid bacteria, Acetic acid-producing bacteria, moulds, and yeasts, produce a diverse array of compounds ranging from simple saccharides to complex biogenic amines and peptides during fermentation. While fermented foods and beverages are widespread, this review paper focuses on artisanal alcoholic rice beverages (ARB) produced in East Asian nations and some parts of India, where more than 100 varieties are produced by different ethnic communities. The nutritional nature of all ARBs is similar despite the differences in production processes, and a starter cake is used to initiate the fermentation process. The starter cake comprises different plant materials mixed with rice flour, along with a diverse microbial population, including yeast, moulds, and bacteria, that aids in different fermentation stages. Microbes break down starchy materials, produce organic acids and volatile compounds responsible for aroma, and maintain the drink's acidity. The plant materials also act as a microbial reservoir, preventing fermentation spoilage, and enhance the beverage's nutritional quality. This review paper systematically compiles and analyzes the nutritional factors and their potential health benefits from a wide variety of ARB using various databases and search terms. It provides a comprehensive insight into the nutritional factors' functions and possible effects on human health. This review highlights the need for more studies on ARB's microbial composition and nutritional compounds and provides a platform for further research on ARB's nutritional properties.

Keywords: Fermentation; Artisanal alcoholic rice beverage (ARB); Nutritional factors; Microbial composition; Health benefits

1. Introduction

The process of fermentation is an age-old technique for preserving food materials. During fermentation, the microbial enzymes act on the substrate to transform complex materials into simpler biologically active compounds enhancing the nutrients content [1]. The Lactic acid bacteria (LAB), Acetic acid-producing bacteria (AAB), moulds and yeast with their enzymatic actions produce an array of compounds ranging from simple saccharides to very complex biogenic amines and peptides. These compounds add value to the food materials in addition to their nutrient properties [2]. However, fermented beverage accounts a portion in the vast field of fermented foods. In east Asian nations and few parts of India rice grain is fermented to produce alcoholic beverages. However, the techniques and methodologies to prepare these artisanal alcoholic rice beverages (ARB) vary according to tribes and communities leading to a difference in taste, appearance and. In India itself there are more than 100 varieties of ARB produced by different ethnic communities. Interestingly, the nutritional nature of all the ARB remains the same, despite the difference in their production process. This is because the basic fermentation and biochemical reactions during fermentation remain the same. In preparation of ARB, a starter cake is utilized to bring the entire fermentation process. Known by various names in different parts of

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the globe Koji (Japan), Jiuqu (China), Emau, Bakhor, Xaaj-pitha (India) it is prepared by mixing a variety of plant materials to rice flour [3,4,5,6]. The starter cake also contains a plethora of microorganisms including yeast, moulds and bacteria which aids in different steps of the fermentation process. The moulds and Bacillus break down the starchy material of the rice to simple sugar, on which yeast and a few LABs act to produce alcohol. The AAB and LAB through various fermentative pathways produce organic acids and volatile compounds which are responsible for aroma and maintain the acidity of the drink [6,7]. The plant materials also act as reservoir of the microflora and prevents the spoilage of fermentation. Additionally, the secondary metabolites and other organic molecules from plant material leach out into the ferment enhancing its nutritional quality.

Although there are plenty of studies reporting the composition and content of nutritional factors of ARB, a comprehensive literature describing the health potential of these nutritional factors would further increase the knowledge for its consumers. In this study, we have compiled the information on nutritional factors of a wide variety of ARB from existing literature and have given a detailed insight on their functions and possible effect on human health.

2. Literature review and search term

A systematic literature was carried out searching three online databases; electronic MEDLINE database via PubMed and ScienceDirect. The search terms used were a combination of terms "rice-wine", "rice-beer", "alcoholic rice beverage", "fermented rice beverage", "nutrition", "nutritional-factors", "metabolites", "microbiota". The search articles were limited to the year 2014 to 2020. The studies that did not incorporate either nutritional properties of ARB or its microbial composition were excluded. Since, only a limited number of studies have reported the microbial composition and nutritional compounds of ARB, a total of 36 articles were reviewed to estimate the nutritional properties of ARB.

2.1. Nutritional components of ARB

Table 1 Source, nutritional and biological roles of the major nutritional components of ARB

Compound	Source in ARB	Nutritional Role	Biological Role
Amino Acids	Synthesized through protein degradation by bacterial proteases	Building blocks of protein, source of nitrogenous compounds, responsible for flavour, texture, aging, and taste of ARB	Determining biological value, carriers of gene information, playing a specific biochemical role, Sulphur-containing amino acids act as signaling molecules, BCAAs serve as signaling molecules
Biogenic Amines	Formed by decarboxylation of amino acids	Precursors of hormones and co-enzymes, impart pharmacological effect, toxicity increases with their content in food materials	Polyamines have significance in growth and development process, responsible for maintaining metabolic activity and immunomodulatory function of the gut, regulate functioning of the nervous system
Pyroglutamyl Peptides	Produced by proteases released by molds to digest rice proteins	Resistance to degradation, improve solubility, enhance flavour and taste, can act as ACE inhibitors, antihypertensive, antiviral and antioxidant agents	Form cyclic non-proteinogenic amino acid containing γ-lactam ring, produced by moulds to digest rice proteins, lactic acid bacteria produce proteases that aid in their formation

Fermented products are considered a great source of nutrition as they contain a wide variety of nutritional factors. Based on our literature survey, it was observed that Saccharides (Simple sugars and Oligosaccharide), Sugar alcohols, Amino acids (free amino acids, Branched chain amino acids, and Biogenic amines), Proteins (in the form of peptides), organic acids (fatty acids and other volatile organic acids) forms the nutritional components of ARB [4,5,8,9]. Most of these components are direct derivatives of rice grain and other plant material or have been generated in the process of fermentation by microbial transformation as described in Table 1. However, determination and absolute quantification of these components in the ARB requires sophisticated analytical instrumentation and diligent techniques. In most of the studies High performance liquid chromatography in tandem with mass spectra determination has been employed to quantify a wide variety of compounds [2,8]. In a few of the studies Gas Chromatography Mass Spectroscopy is used [10], where absolute quantification is not possible. Nevertheless, these analytical techniques not only provide a dimension to study the nutritional factors but to understand the possible health impact of these compounds. In addition to the nutritional factors ARB is also rich in certain components such as phenolics, organic acids, which do not provide any nutritional value, but add value to the products with their presence. A summary of the major nutritional components of ARBs are summarized on Table 2

Table 2 List of all the major nutritional factors of ARB based on their class

Compound class	**Compound**	**Content**	**Method of determination**	**Rice beverage variety**	**Country of Origin**	**References**
Oligosaccharide and Monosaccharide	Isomaltotriose	0.31 g/L	HPLC	Hakka rice wine	China	45
	Isomaltose	0.96 g/L	HPLC	Hakka rice wine	China	45
	Panose	0.16 g/L	HPLC	Hakka rice wine	China	45
	Maltose	1.20 g/L	HPLC	Hakka rice wine	China	45
	Glucose	56 g/L	HPLC	Hakka rice wine	China	45
	Maltotetrose		HPLC	Lab prepared *Handia*	India	4
	Maltotriose		HPLC	Lab prepared *Handia*	India	4
	Frucotose		HPLC	Lab prepared *Handia*	India	4
	Maltose		HPLC	Lab prepared *Handia*	India	4
	Glucose		HPLC	Lab prepared *Handia*	India	4
	Trehalose	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Melibiose	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
Biogenic amines						
	Putrescine (PUT)	N/A	HPLC-MS/MS	Black glutinous rice wine & white glutinous rice wine	China	46
	Cadaverine (CAD)	N/A	HPLC-MS/MS	Black glutinous rice wine & white glutinous rice wine	China	46

	1,6-hexamethylenediamine (HEX)	N/A	HPLC-MS/MS	Black glutinous rice wine & white glutinous rice wine	China	46
	Tyramine (TYR)	N/A	HPLC-MS/MS	Black glutinous rice wine & white glutinous rice wine	China	46
	Phenylethylamine (PHE)	N/A	HPLC-MS/MS	Black glutinous rice wine & white glutinous rice wine	China	46
	Histamine (HIS)	N/A	HPLC-MS/MS	Black glutinous rice wine & white glutinous rice wine	China	46
	Tryptamine (TRY)	N/A	HPLC-MS/MS	Black glutinous rice wine & white glutinous rice wine	China	46
Phenolic compounds						46
	Gallic acid	2.02	HPLC	Lab prepared rice wine	China	46
	3,4-Dihydroxybenzoic acid	5.35	HPLC	Lab prepared rice wine	China	46
	p-Hydroxybenzoic acid	nd	HPLC	Lab prepared rice wine	China	46
	Chlorogenic acid	0.23	HPLC	Lab prepared rice wine	China	46
	Catechin	nd	HPLC	Lab prepared rice wine	China	46
	Vanillic acid	16.34	HPLC	Lab prepared rice wine	China	46
	Caffeic acid	0.37	HPLC	Lab prepared rice wine	China	46

	Syringic acid	1.72	HPLC	Lab prepared rice wine	China	46
	p-Coumaric acid	0.28	HPLC	Lab prepared rice wine	China	46
	Sinapic acid	nd	HPLC	Lab prepared rice wine	China	46
	Ferulic acid	6.42	HPLC	Lab prepared rice wine	China	46
		32.7	HPLC	Lab prepared rice wine	China	46
Vitamins						
	Folic acid	172.31 ug/100g	RP-HPLC	Lab prepared *Handia*	India	4
	Thiamine	1.63	RP-HPLC	Lab prepared *Handia*	India	4
	Riboflavin	16.41	RP-HPLC	Lab prepared *Handia*	India	4
	Pyridoxine	408.63	RP-HPLC	Lab prepared *Handia*	India	4
	Acorbic acid	500.25	RP-HPLC	Lab prepared *Handia*	India	4
Organic acids						
	Oxalic acid	ND	HPLC	*Makgeoli*	Korea	47
	Citric acid	0.155 mg/m L	HPLC	*Makgeoli*	Korea	47
	Tartaric acid	0.037 mg/mL	HPLC	*Makgeoli*	Korea	47
	Malic acid	0.174 mg/mL	HPLC	*Makgeoli*	Korea	47
	Succinic acid	7.689 mg/mL	HPLC	*Makgeoli*	Korea	47
	Lactic acid	0.082 mg/mL	HPLC	*Makgeoli*	Korea	47
	Acetic acid	1.256 mg/mL	HPLC	*Makgeoli*	Korea	47
Pyroglutamyl peptides	Pyroglutamyl-tyrosine	ND	Preparative IEF and RP-LC	*Sake*	Japan	21

	Pyroglutamyl-asparaginyl-isoleucine	ND	Preparative IEF and RP-LC	*Sake*	Japan	21
	Pyroglutamyl-asparaginyl-isoleucyl-asparagylasparaginyl	ND	Preparative IEF and RP-LC	*Sake*	Japan	21
Volatile compound	Acetaldehyde	40.41 mg/L	HPLC	*Makgeoli*	Korea	48
	Acetone	4.32 mg/L	HPLC	*Makgeoli*	Korea	48
	Methyl acetate	1.38 mg/L	HPLC	*Makgeoli*	Korea	48
	Ethyl acetate	66.09 mg/L	HPLC	*Makgeoli*	Korea	48
	Methyl alcohol	8.65 mg/L	HPLC	*Makgeoli*	Korea	48
	n-Propanol	110.90 mg/L	HPLC	*Makgeoli*	Korea	48
	Isobutanol	185.07 mg/L	HPLC	*Makgeoli*	Korea	48
	Isoamyl acetate	9.72 mg/L	HPLC	*Makgeoli*	Korea	48
	n-Butanol	7.21 mg/L	HPLC	*Makgeoli*	Korea	48
	Isoamyl alcohol	781.42 mg/L	HPLC	*Makgeoli*	Korea	48
	Ethyl caproate	1.62 mg/L	HPLC	*Makgeoli*	Korea	48
	Ethyl caprylate	ND	HPLC	*Makgeoli*	Korea	48
	Alanine	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Valine	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
Amino acids	Isoleucine	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Proline	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Glycine	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
Amino acids	Threonine	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Aspartic acid	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Cysteine	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Glutamic acid	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10

	Lysine	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Tyrosine	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Alanine	ND	HPLC	Hongqu	China	11
	Valine	ND	HPLC	Hongqu	China	11
	Isoleucine	ND	HPLC	Hongqu	China	11
	Proline	ND	HPLC	Hongqu	China	11
	Glycine	ND	HPLC	Hongqu	China	11
	Threonine	ND	HPLC	Hongqu	China	11
	Aspartic acid	ND	HPLC	Hongqu	China	11
	Cysteine	ND	HPLC	Hongqu	China	11
	Glutamic acid	ND	HPLC	Hongqu	China	11
	Lysine	ND	HPLC	Hongqu	China	11
	Tyrosine	ND	HPLC	Hongqu	China	11
	Arabitol	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Xylitol	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
Sugar Alcohols	Ribitol	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	Mannitol	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10
	myo-Inositol	ND	GC-MS-TOF/ GC-MS	*Makgeoli, Apong, Xaaj*	Korea & India	8,10

3. Amino acids

Amino acids, the building blocks of protein, form a very important part of daily dietary intake, as this molecule cannot be synthesized by our body. In alcoholic rice beverages (ARB), amino acids are synthesized through protein degradation by bacterial proteases [11]. Amino acids are responsible for flavour, texture, ageing, and taste of ARB; however, it also forms a rich source of nutrients for its consumers.

Amino acids are major building elements of protein, determining its biological value, carriers of gene information, and playing a biochemical role, specific for each amino acid. Free amino acids not only serve as building blocks for proteins but also substitute as a precursor for nitrogenous compounds in an organism [12]; nevertheless, the role of the specific amino acids varies. Sulfur-containing amino acids, in particular L-methionine and L-cysteine play an important role in signaling pathways, thus conferring benefits against age-related diseases [13]. Branch chain amino acids such as valine, leucine, and isoleucine can be converted into alanine. Alanine, a glucogenic amino acid, can be converted into pyruvate and glutamate by the catalytic enzyme glutamate-pyruvate transaminase in liver cells. Pyruvate is, in turn, converted into glucose through gluconeogenesis. Liver glucose enters the bloodstream through glucose transporter 2 (GLUT2) and can be taken up muscle cells to provide instant energy and prevent fatigue. Additionally, BCAAs also serve as signaling molecules and regulates metabolism of glucose, lipid and protein synthesis, intestinal healthy and immunity via signaling networks viz; phosphoinositide 3-kinase/protein kinase B/mammalian target of rapamycin (PI3K/AKT/mTOR) signal pathway [14]. Aspartic acid plays an important role in maintaining the endocrinological functions, especially in the regulation of the release and synthesis of LH and testosterone [15] (Fig. 1)

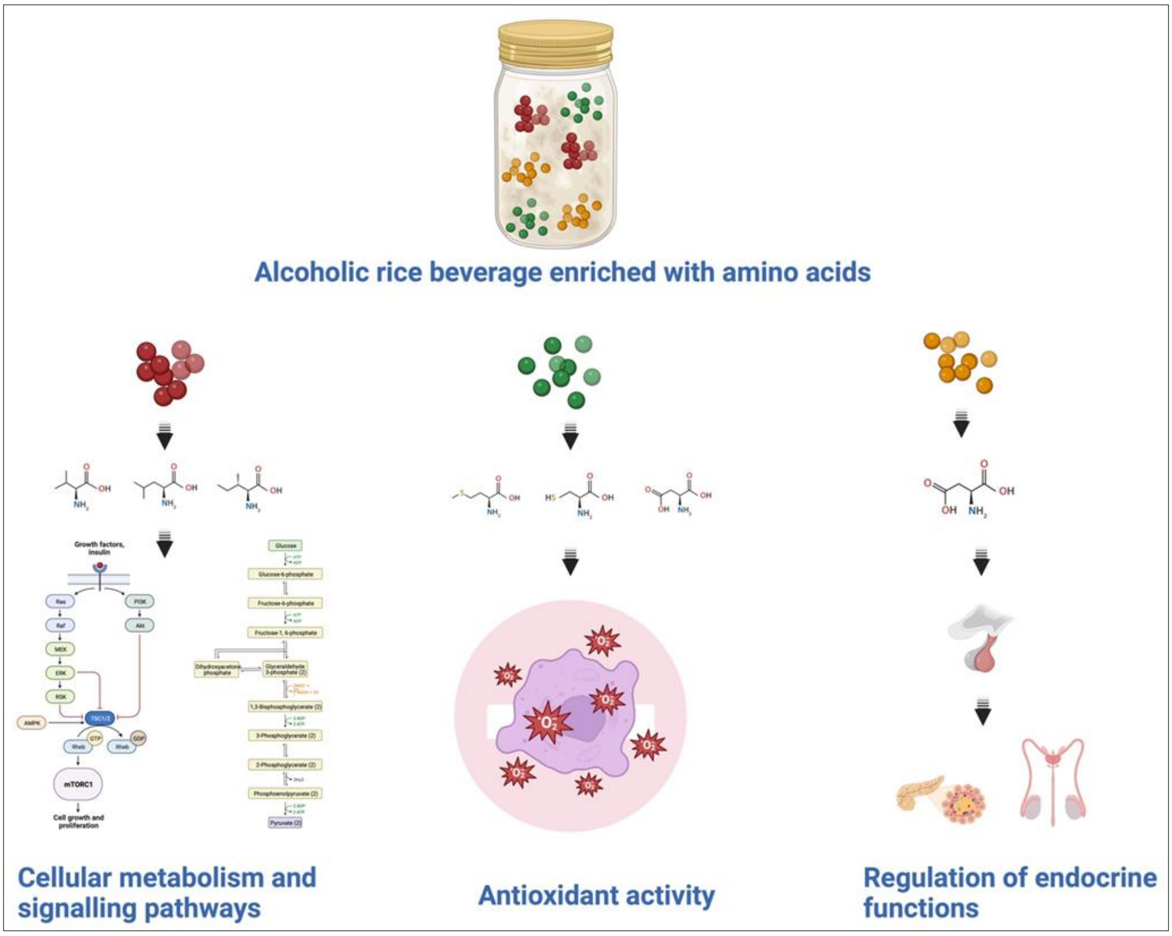

Figure 1 Schematic representation of the major classes of amino acids in ARD and their biological roles. BCAA like valine, leucine and isoleucine are involved in cellular metabolism and signalling pathways, Sulphur containing amino acids acts as antioxidants suppressing reactive oxidative species and aspartic acid is involved in the regulation of endocrine functions through the pituitary gland

Moreover, the gut microbiome can alter the bioavailability of amino acids by utilization of several amino acids originating from the alimentary canal. Microbes belonging to the Clostridiales family can utilize amino in the lumen of the small intestine. Certain studies reported that the microbiome of the small intestine utilizes lysine, methionine and phenylalanine [16].

Thus, amino acids present in ARB can also serve to maintain metabolism in addition to its nutritional values.

4. Biogenic amines

Biogenic amines (BA) are low molecular weight organic nitrogenous compounds formed by the decarboxylation of amino acids or by amination-transamination of aldehyde and ketone during metabolic processes. In food and beverages, microbial enzymes decarboxylates amino acids to form BAs. These moieties function as precursors of hormones and co-enzymes and imparts a strong pharmacological effect [17]. Bacteria such as Lactobacillus, Enterobacteria, Pseudomonas abundant in ARB [10] are key producers of BA. These moieties function as precursor of hormones and co-enzymes and imparts a strong pharmacological effect. Presence of BA in low amount in food and beverages normally do not possess any threat on human health, however their toxicity increases with the increase in their content in food materials. Ingestion of BA for more than 40 mg per meal can significantly increase the risk of food poisoning [18]. After ingestion, enzymes including monoamine oxidase, diamine oxidase and histamine-N-methyltransferases metabolizes BA. The polyamines (putrescine, spermidine and spermine) have significance in growth and development process and forms an integral component in living cells [17]. Human cells have the potential to synthesize polyamines, however such molecules are still absorbed by the intestinal cells from foods owing to the large demand of polyamines in rapidly growing tissues. Polyamines are also responsible for maintaining the metabolic activity and immunomodulatory function of the gut. catecholamines, indolamines and histamine, regulates the functioning of nervous system and also plays an pivotal role in regulation of blood pressure[17,18]. Phenylethylamine and tyramine triggers in rise of blood pressure, whereas histamine lowers blood pressure levels. Histamine also possesses a powerful biological function, being the first responder of allergic reactions (Fig 2).

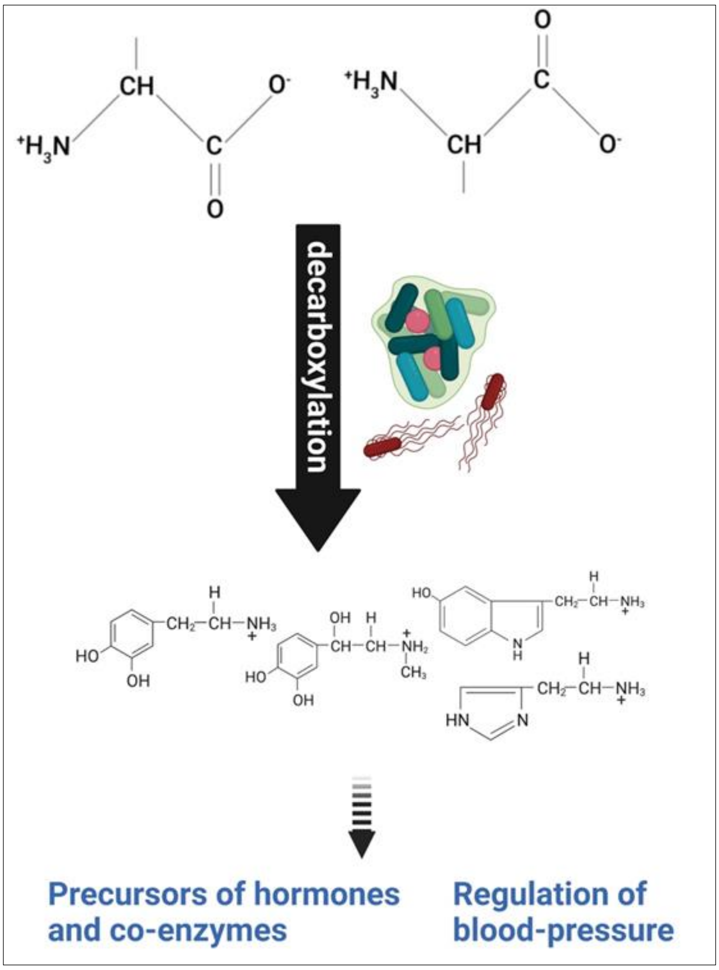

Figure 2 Schematic representation of formation of Biogenic amines (BAs) by microbial transformation process and their biological functions. Histamine, Dopamine, Epinephrine and Serotonin forms the major BAs and are involved in various biological process including acting as precursor molecules for hormones and co-enzymes and regulating blood pressures

Although toxic in higher amount, BA has important biological roles and forms a major nutritional factor in ARB.

5. Pyroglutamyl peptides

Pyroglutamyl peptides (pGlu) are formed by deamidation or dehydration of glutamine or glutamic acids. It forms a cyclic non-proteinogenic amino acid, containing a γ-lactam ring [19]. Peptides having glutaminyl or glutamyl residue at the N-terminal end gets converted into pGlu containing protein or peptide by intramolecular cyclization through enzymatic reactions [19]. In case of ARB, pGlu are produced by proteases released by molds to digest rice proteins [20]. Moreover, Lactic acid bacteria also produce proteases that aids in the formation of pGlu as seen in case of cheese fermentation [21]. The presence of γ-lactam or pyrrolidone moiety renders pGlu resistant to human digestive enzymes, and thereby increasing its bioavailability. Other factors determining the bioavailability are length of amino acid sequence, net charge and hydrophobicity. However, the presence of γ-lactam rings makes it less hydrophobic and enhances its availability to be utilized for various metabolic processes. It is reported that pGlu demonstrates hepatoprotection, antidepressant and anti-inflammatory activities in humans. Moreover, studies on mice model have revealed its ability to reduce acute hepatitis and colitis. As a matter of fact, pGlu-Leu and pGlu-Gly-Leu stimulate the murine enterocytes to produce bioactive compounds that enhances the microbiota to reduce inflammation and allied symptoms [21]. Additionally, these two pGlu promotes hippocampal neurogenesis through a pathway independent of brain derived neurotrophic factors (BDNF), thereby eliciting antidepressant activity [22].

6. Phenolic compounds

Phenolic compound (PC) are small molecules having at least one phenol unit in their structure. They originate in plant tissue through the shikimic acid and phenylpropanoid pathways and are often regarded as secondary metabolites [23]. Although not considered as nutrients, PC confers certain health protective effects due to its bioactive properties. The presence of PC in ARB is due to the extensive use of plant material in the starter cake, during the course of fermentation the macromolecule from the starter leaches out in the ferment [24,25]. Besides, during breakdown of rice starch to sugar, PCs are also formed by fungal enzymes. These compounds are closely associated with flavours, colour, colloidal and sensory properties of the rice-wine. Moreover, due to its antioxidant properties, it increases the stability and shelf-life of beverages. PCs Only one third of the dietary polyphenols are absorbed in the small intestine, and hence the majority of it passes into the colon [26] (Williamson and Clifford 2017). The microbiota metabolizes it to aromatic metabolites which then enters the bloodstream through the hepatic system. Polyphenols and hydroxycinnamic acids (cinnamic acid, caffeic acid, sinapic acid, coumaric acid, ferulic acid) modulate the gut microbiome to maintain intestinal integrity and systemic metabolism [27].

Gallic acid (GA) in addition to its antioxidant activity also bears additional anti-inflammatory and antineoplastic properties [28,29]. 4- hydroxybenzoic acid demonstrates estrogenic properties both in vivo and in vitro. Due to their bioactivity, both GA and 4- hydroxybenzoic acid have found applications in neuropsychological, metabolic disorders [30]. Chlorogenic acid (CA) forms another major PC found in ARB. In murine model experiments, it was found that CA reduces the expression of cyclooxygenase-2 (COX-2) and tumor necrosis factor-α (TNF-α), hence reducing renal oxidative stress and inflammation [31,32]. In the same experiment, CA also suppressed the activity of p53, caspase-3 and cyclin D1 conferring its antiapoptotic nature. Therefore, the presence of PC in beverages can confer its drinkers a wide variety of health benefits.

7. Sugar alcohols

Sugar molecules when attached to an alcohol group are termed as sugar alcohols. Also termed as polyols, these molecules form a major constituent of ARB. Such molecules are generated in the fermentation process by the microbial action on hexoses or hexose-phosphates. Polyols are absorbed in the small intestines in a limited amount based on their molecular weight, i.e., sugar alcohol with less carbons are ingested more readily. Post absorption, the polyols enter the bloodstream through a passive diffusion process [33]. The unabsorbed polyols are fermented to volatile fatty acids (VFA) by the colonic bacteria. 20% of fermented polyols are utilized by those microorganisms for their growth, while the remaining polyols enter the bloodstream and metabolise the liver to be stored as fatty content [34, 35]. However, sorbitol and xylitol absorbed in the intestine are often redirected to liver metabolism to generate energy to the same extent as glucose. In total, 50% of the total energy from polyols are made available to be utilized in the human body [36] (König et al. 2012). Since sugar alcohol are poorly digested, over consumption of it causes gastrointestinal discomforts. A daily dose exceeding 40-50 ml/day might result in conditions like osmotic diarrhea and flatulence [37].

Due to the fact that polyols are not readily absorbed, they are extensively used for various medical purposes. As polyols accumulate in the colon, during metabolism they absorb water causing a laxative effect. For this reason, many polyols are marketed as laxative and used in the treatment of constipation. Secondly, polyols can produce energy without interfering the blood sugar and hence such compounds are used as substitute for glucose as source of energy and also as an artificial sweetener [38]. Additionally, polyols are also applied in maintaining dental health. The mouth microbiome is not capable of fermenting polyols and thus avoid the generation of enamel solubilizing acids as seen in case of other sugars. Xylitol, in particular, has been extensively used for this purpose [37,39]. It is observed that polyols provide both calorific value and nutraceutical effects to the consumers of ARB, and hence forms an integral nutritional factor.

8. Microorganisms

The microorganism brings about the fermentation of ARB and forms an integral part of the nutritional factors. In many cases the microorganisms are removed or inactivated, prior to the consumption. However, in traditional practice, ARB is consumed along with the microorganisms [4]. The microbes that are consumed along with any food materials must pass through the highly acidic environment of the stomach and tolerate the bile juices and alkaline intestinal fluids, to make it to the colon. In the colon the bacteria must withstand the peristaltic motions and bowel movements in order to establish itself. Only the probiotic bacteria have such qualities to evade the gastric fluids and establish in the colon.

The microflora of ARB consists mainly of LAB, AAB, common environmental bacteria such as Pseudomonas, Rothia, and amylolytic bacteria such as Bacillus [6,10]. Among these LABs, a few Enterobacteriaceae and Bacillus are proven to have probiotic properties. These bacteria establish in the intestine and confer host cells with an array of benefits. Firstly, by occupying the space of the intestine they prohibit the entry of invading pathogenic microbes. Such bacteria help in the digestion process by secreting various enzymes, the complex carbohydrates materials which cannot be digested by human digestive juices are hydrolysed by such bacteria and produces SCFA in the process [40, 41]. Additionally, these bacteria also secrete vitamins and other essential components which can be directly absorbed by the enterocytes. Probiotics also induces a low levels of toxemia, which modulates the immune cells to synthesize antibodies and interferons in the circulatory immune system [41].

9. Conclusion and future perspective

Functional foods offer health benefits that extend beyond their nutritional value, and includes foods fortified with vitamins, minerals, probiotics, or fibre. Factors such as raised consciousness about human health, development of the food industry, and medicine and branches of natural science studying the relation between nutrition and health have led to the popularization of foods with proven health effects. Due to the health promoting potential such food materials are widely promoted in the market and have gained popularity among the consumers. However, the regulation presents significant challenges to the globalization of functional foods in many ways. Mainly, the regulatory variation between countries hinders global trade and marketing. For instance, most of the countries discussed take a relaxed approach to regulation, yet China's process for dietary supplement approval involves a strict testing protocol, in line with the US process for pharmaceutical approval. One strategy to evade such a challenge is by promoting local food and beverages as functional food. In the case of ARB, it is traditionally believed to be health-promoting and functional against numerous gastrointestinal ailments. Moreover, there is scientific evidence that ARB is enriched with components like polyphenols, fibres, oligosaccharides, and BCAA. Each of these molecules has a specific physiological preventive and/or health-promoting effect. Such characteristics enable various ARBs to be promoted as health promoting nutraceutical drinks. Another factor which provides hindrance, is the alcoholic nature of ARB. Due to the detrimental effect of alcohol and its role in inducing various diseases earns skepticism for ARB to be promoted as nutraceutical. Nevertheless, detailed investigation on the nutritional properties of ARB experimental models considering the associated pros and cons is required to strengthen its claim as a nutraceutical drink.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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