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Makgeolli - The Traditional Choice of Korean Fermented Beverage from Cereal: An Overview on its Composition and Health Benefits

Ganesh SHIMOGA[1*] and Sang-Youn KIM[1*]

Abstract

Food is a very basic survival need for the sustenance of life and it always register its impact along with beverages. Varieties of alcoholic/non-alcoholic beverages were invented globally under the influence of cultural topography, which drastically differ in western and eastern tradition. One such traditional Korean fermented beverage is *Makgeolli*, which is popularly known as "Korean rice wine" made wholly from rice and other cereal such as wheat, barley, and germinated grains by the process of fermentation using a main natural ingredient *Nuruk*, an amylase enzyme "source". The low alcohol content (6-9%) of *Makgeolli* with antioxidant constituents and benefiacial polyphenols like resveratrol, quercetin etc. endowing an interesting light sparkling tone of prominent astringency. The composition of fresh *Makgeolli* with significant amounts of lactic acid bacteria such as *Lactobacillus*, as well as starch, proteins, dietary fibers, free amino acids, vitamin nutrients and bioactive components are considered to be benefial to health, but it should be considered within that frame, since it is still an alcohol. The *Makgeolli* is considered as a probiotic liquor and claim detonated health benefits, often compared to yoghurt. In this short review, we mainly emphasize the composition of *Makgeolli* and offer a glimpse to its potential health benefits.

Keywords: alcohol; beverages; brew; fermentation; health benefits; *Makgeolli*; probiotics; rice wine.

Practical Application: This review provides the composition and health benefits of Korean rice wine – *Makgeolli*, aimed to its potential application in probiotic and natual cosmetic industries.

1 Background

The two most important words that unite people are 'Food' and 'Beverage'. When it is merged with the traditional values, it will reflect as a cultural code. The unique cultural history and advanced farming customs of Korea lead to the discovery of a variety of agro-based traditional alcoholic beverages (Marshall & Mejia 2012). In view of public health concern, the global people's demand is associated with a higher likelihood of consuming low alcoholic content wine beverages. Since they are in comprise of antioxidants, epicatechin, proanthocyanidins and bioactive compounds (Arranz et al., 2012). By adopting the wisdom of conventional brewing protocols, Koreans invented this traditional liquor *Makgeolli,* which is recognized for its low-alcoholic contents with exclusive health benefits (Durak et al., 1999). Since *Makgeolli* is still an alcohol, the health benefits should be considered within that frame.

Based on the fermentation process and filtration techniques (specifically in wine brewing from rice/cereal), widely popular traditional Korean beverages are classified as two major types such as (i) *Cheongju* (also known as *Yakju*, filtered clear rice wine) and (ii) *Makgeolli* (locally knows as *Nongju*, means farmer liquor, unfiltered turbid rice wine). In concern to improve the sensory experience, a variety of *Cheongju* (differ in fragrance and taste) were produced and consumed in thirteen to nineteen centuries, during Joseon Dynasty, zenith of traditional Korean liquor culture (Lee & Kim, 2019). The translation of *Yakju* literally means "medicinal wine". However, *Makgeolli* refers to 'rough' or "just filtered", with a distinguishing opaque milky appearance. Like many other variations in alcoholic drinks, *Makgeolli* also has a variety of flavors (including nutty, fruity, herbal, etc.).

In Korea, *Makgeolli* is also served by name *Dongdongju* (*Dong* = Floating and *Ju* = Alcohol), which means broken pieces of rice was served along with the turbid *Makgeolli*. In general, the distillation of *Cheongju* and *Makgeolli* will result in a familiar Korean spirit *Soju* (See Figure 1 for the snapshot of straining *Dongdongju* liquor). The traditional way of serving *Makgeolli* include, delicate circular swirling and shaking. Although, describing the taste of any food/beverage is purely depend on the perception of an individual, while experiencing the *Makgeolli*, one can effortlessly notice the blend of sweet, bitter, umami and sour tastes that trigger the taste buds with pleasant sparkling pungency at the palate.

2 *Makgeolli* processing

The brewing process to prepare *Makgeolli* has undergone tremendous variations from decades during saccharification process and many researchers did characteristic evolution of *Makgeolli* by experimenting to enhance the sensory properties by incorporating various accessary ingredients such as fruits, vegetables and herbs during fermentation process (Kim et al., 2013).

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[1] *Advanced Technology Research Center, Future Convergence Engineering, Korea University of Technology and Education, Cheonan-si, Republic of Korea*
*Corresponding author: shimoga@koreatech.ac.kr, sykim@koreatech.ac.kr

2.1 Nuruk production

The key ingredient required to produce *Makgeolli* is *Nuruk*. The grains enriched in starch, usually rice, barley and wheat are chosen to prepare *Nuruk*. Since wheat and barley imparts typical taste to *Makgeolli*, the *Nuruk* made of wheat and barley is widely used (Lee & Kim, 2017; Shin et al., 2017). Growing fungi or bacteria on the kneaded patty of wheat and/or barley granules at specific temperature conditions (below 40 °C) will end up the fermentation process (~ 8 to 9 days). Later these disc shaped molds were kept for dry aging for longer durations (15 days to 60 days) followed by packing. The flowchart to represent the *Nuruk* production was outlined in Figure 2.

2.2 Brewing protocol for Makgeolli

Typically, specific quantity of short grain glutinous rice was thoroughly washed, and soaked in cold water for at least 2-3 h before cooking. The rice was cooked in water and later allowed to dry for several hours in a breezy sunny weather so that texture of the rice should be dry-hard at the outside and moist-soft from the inside. By transferring the dried rice into an earthenware crock-pot, followed by adding powdered *Nuruk* and commercially available active dry baker's yeast, convenient amount of water was added by gently mixing the ingredients. The contents were uninterrupted and rest for overnight.

Due to fermentation, many bubbles will pop out of the surface. Care should be taken for the circulation of air by covering the earthenware crock-pot by a cotton cloth before closing the lid. On the next day, the rice slurry becomes slightly flowy and less bubbles are popping out at the surface. Gentle mixing of the ingredients were carrieout on second, third, fourth and fifth day at least three to five times a day followed by proper covering of the pot. After fifth day, slender bubbling was noticed with clear liquid floating on top and turbid milky slurry at the bottom, again the ingredients are mixed well followed by closing the lid. On eighth or ninth day, the mixture will separate into two main layers, a yellowish clear liquor on the top and a thick rice slurry layer at the bottom. The brewing can be decided as complete if no longer sparkling was noticed. The contents are strained for three to four times by discarding the sludge. The filtrate will be *Makgeolli* (See Figure 3. for snapshots of *Makgeolli* and *Soju*) and ready for traditional serving (Maangchi, 2020).

Figure 1. Photograph of straining of *Dongdongju* liquor. © Photo-credit: Ganesh Shimoga.

2.3 Microorganisms in Nuruk

Depending on the *Nuruk* samples, various types of microbial stains exist. Since the main ingredient of *Nuruk* is starch, the existing microorganisms in *Nuruk* are predominantly capable of degrading beta-starch. In addition, various types of, lactic acid bacteria, yeasts, and aerobic bacteria that triggers the fermentation process (Lee et al., 2017a; Jung & Chung 2017; Shin et al., 2017; Sugiyama et al., 2019). Kim et al. (2014a) isolated and reported some filamentous fungi and yeasts from a variety of *Nuruk* samples, briefly outlined in Figure 4.

We can find a plentiful of examples where bacteria, yeasts and molds are involved in the fermentation process by imparting unique exotic taste, which is of cultural importance. The metabolic process used by many microorganisms (such as bacteria and yeasts), are constantly exploited by humans in numerous industrial and agricultural applications (Lee et al., 2017b; Lee & Kim, 2017). Many of the microbes used in fermentation are considered as 'probiotics' and consuming such products linked to boost the immune system by procuring health benefits. Unlike regular yeasts, the shapes of *Saccharomycopsis fibuligera* and *Pichia kudriavzevii* are dysplastic in nature and more specifically elongated fibrous structures. These strains place a vital role in

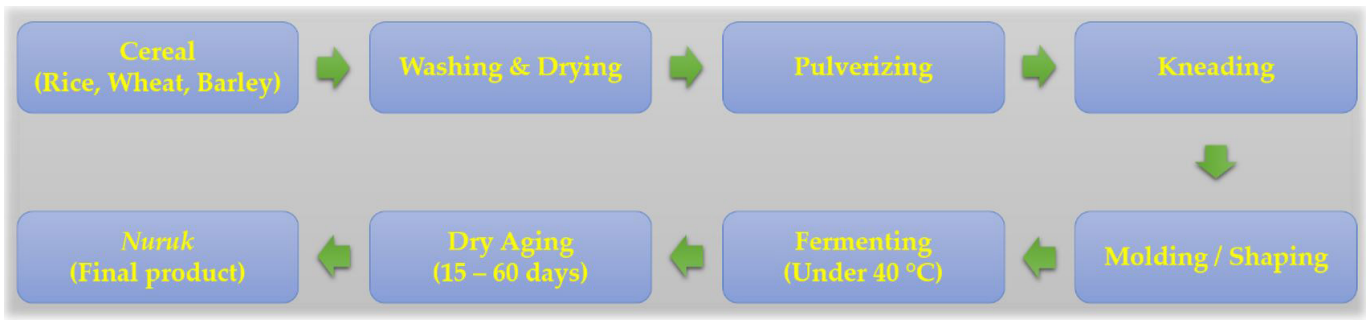

Figure 2. Flowchart representing *Nuruk* production. Adapted with permission from (Lee & Kim 2017; Shin et al., 2017).

Figure 3. Photographs of (a) traditional *Makgeolli*, and (b) traditional way of receiving *Soju*. © Photo-credit: Ganesh Shimoga.

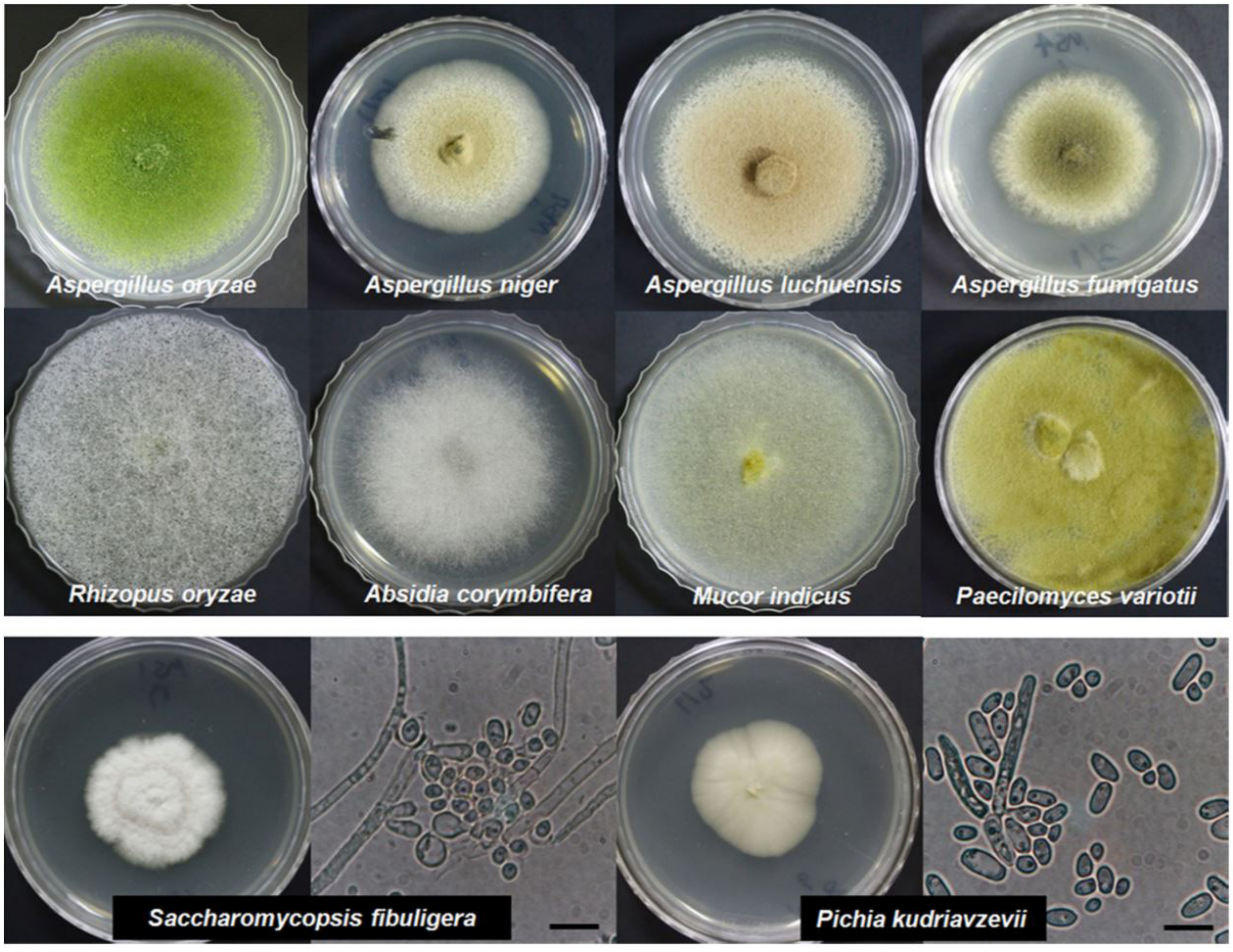

Figure 4. Partial list of filamentous fungi and yeasts isolated from various *Nuruk* samples. (Scale bar = 5 μm), Adapted with permission from Kim et al. (2014b), The Korean Society of Mycology.

alcohol production via simultaneous saccharification process. *Aspergillus luchuensis* and *Aspergillus oryzae* (also known as kōji mold), is a filamentous fungus, typically used in saccharify rice, sweet potato, and barley in eastern tradition. Mucor indicus shows its high capability to ferment pentoses and hexoses from complex lignocellulosic materials to produce ethanol. It was found that the strains of *Rhizopus oryzae* produce carbohydrate-digesting enzymes along with organic acids, ethanol and some useful esters, which can be useful in food industries. *Aspergillus fumigatus* and *Paecilomyces variotii* is a fast growing microfungi

(that can grow efficiently under a variety of environmental conditions), which shows beneficial effects on human health as an emerging agent of opportunistic disease, particularly to boost the immune system (Kim et al., 2014b; Jang et al., 2014). Recently, Kim et al. (2019). isolated a novel rod shaped Gram-stain-positive *Paenibacillus nuruki* sp. Nov anaerobic bacterium from *Nuruk* which has sequence similarities with *Paenibacillus kyungheensis*, isolated from magnolia flowers by Siddiqi et al. (2015). These newly isolated bacteria from *Nuruk* is believed to have a promising future in agro-based industries. During the process of brewing *Makgeolli*, there will be a rapid and dynamic changes in the population of bacterial community especially during first two days of fermentation process. However, the fungal community growth was significantly unchanged during brewing. As the population growth of bacterial genera *Pediococcus, Weissella*, *Lactobacillus and Enterococcus*, categorized as lactic acid bacteria increases, the pH of *Makgeolli* gradually decreases in later stages of brewing (Chai et al., 2015).

3 Composition of *Makgeolli*

Despite of microorganisms and lactic acid bacteria isolation, researchers have detected various benign chemicals, flavonoids, biogenic amines, bioactive and volatile compounds from various *Makgeolli* samples using different spectroscopic techniques. With low alcoholic content of around 6%, *Makgeolli* is believed to have probiotic, containing 100-500 times more *Lactobacillus* bacteria than yogurt, exhibiting antioxidant, anti-cancer, anti-inflammatory, anti-aging, anti-colic properties by reducing bad cholesterol levels and increasing immune and circulatory systems (Nile, 2015; Park et al., 2015). The components present in *Makgeolli* with favorable and unfavorable aspects are presented in Table 1.

3.1 Volatile components

By adopting gas chromatography-mass spectrometry (GC-MS) and GC-olfactometry (GC-O) techniques, Park et al. (2013), investigated and detected 5 different alcohols, 3 carboxylic acids and 3 carboxylic ester based volatile compounds. These compounds are believed to be responsible for specific odor from pasteurized and unpasteurized *Makgeolli* during storage period of 30 days. The chemical structures with its typical odor notes are presented in Figure 5. During fermentation process, due to catabolism processes the branched amino acids such as leucine and isoleucine converted to 3-methylbutanoic acid and 2-methylbutanoic acid, which imparts cheesy and fermented odor to *Makgeolli*. Sometimes, because of methionine metabolism of wild yeasts can impart this off-flavor to the *Makgeolli* due to the release of 3-(Methylthio)-1-propanol for longer duration of storage (Park et al., 2013; Seow et al., 2010).

By adopting solid-phase microextraction technique, Jung et al., (2014) analyzed 45 major volatile compounds using gas chromatography from 12 various commercial *Makgeolli* samples. The analyzed volatile compounds include, 33-esters, 8-alcohols, 1-aldehyde, 1-acid, 1-phenol and 1-terpene compounds attributing for its sensory, aroma and color. The list of volatile compounds other than esters from *Makgeolli* analyzed by Jung et al., (2014) was presented in Figure 6. The authors precisely carryout the identification of volatile compounds by comparing various information, including retention index, NIST library search, spectra and elemental composition by using the MassLynx 4.0 and ChromaLynx software (Waters Corp.). The authors also documented sensory evaluation of the 12 commercial *Makgeolli* samples, to judge its quality/taste perceptiveness. The results revealed that, the quality and typical flavor of *Makgeolli* was greatly influenced by the odor active ester compounds and detected terpene, phenol, aldehyde and carboxylic acid present in *Makgeolli* (Jung et al., 2014; Park et al., 2007).

3.2 Biogenic amines

Due to amination/transamination reactions of aldehydes and ketones and/or decarboxylation of amino acids produce important class of nitrogenous compounds namely, biogenic amines. The microbial decarboxylation of amino acids trigger the generation of enzymes, which eventually produce biogenic amines in fermented food and beverages. Although, biogenic amines are considered as a food hazard, within the permissible low concentrations, these can play several crutial biological roles especially in regulating physiological functions such as the growth, controlled blood pressure and nerve sensitiveness etc (Erdag et al., 2018; Özogul & Özogul, 2019). Furthermore, biogenic amines play a vital role as a nitrogen source and helps to regulate the hormones, alkaloids proteins and nucleic acids levels in the body. To be precise, biogenic amines prominently interacts with gastrointestinal microbiota and convert them to useful bioactive amino compounds. These active amine moiety can interact with many cellular macromolecules such as DNA, RNA, and proteins, conferring them to promote cell proliferation, signal transduction, and membrane stabilization (Gomez-Gomez et al., 2018).

Kim et al. (2011), observed and analyzed eight essential biogenic amines from High-performance liquid chromatography (HPLC) technique. The authors carefully studied the constituents of *Makgeolli* and documented that only putrescine content was in low and permissible during 30 days of storage period under 4 °C. However, at 20 °C, the amount of biogenic amines were drastically increased at higher temperature due to the pathogenic microbial activity. The eight essential biogenic amines reported by authors are histamine, tryptamine, phenylethylamine, tyramine, putrescine, cadaverine, spermidine and spermine (Kim et al., 2011). Evidently, the chill and fresh *Makgeolli* is a moderate source of biogenic amines, and it is recommended to cherish with nutritional food to acquire satisfactory health benefits.

3.3 Bioactive compounds

Bioactive compounds are considered as secondary metabolites that impart health benefits on living organisms. Many bioactive compounds including terpenoids, carotenoids, phenolics, phytosterols, and glucosinolates and others are testified to exhibit antioxidant, immunomodulatory, anti-osteoporotic, antihypertensive, antimicrobial, antidiabetic, and anticancer properties. The phenolic bioactive compound, especially resveratrol (3,5,4′-trihydroxystilbene), found in grape skins, peanuts, and some herbal roots show promising cardio protective and anti-inflammatory properties (Weiskirchen & Weiskirchen, 2016; Gerogiannaki-Christopoulou et al., 2006). To enrich the flavor

Table 1. Favorable and unfavorable aspect of components present in *Makgeolli*.

Components	Favorable aspects	Unfavorable aspects	Reference
Volatile compounds: (Alcohols, Carboxylic esters, Carboxylic acids)	Imparts particular aroma to *Makgeolli* depending on the chemical characteristics and concentrations of the constituent (Cheesy, Malt, Fermented, Floral, Honey, etc.)	(i) Butanoic acid gives cheesy unplesant odour to *Makgeolli.* (ii) Release of 3-(Methylthio)-1-propanol from methionine metabolism of wild yeasts can impart undesirable-flavor to *Makgeolli.*	Park et al. (2013)
Biogenic amines: (Histamine, Tryptamine, Phenylethylamine, Tyramine, Putrescine, Cadaverine, Spermidine and Spermine)	Putrescine, spermidine, and spermine play an important role in cell growth. During the storage period of 30 days at 4 °C, detection of putrescine was observed in low levels.	(i) Putrescine and tyramine were detected in high concentrations on the third day of storage at 20 °C. (ii) The concentration of tyramine increased rapidly during 5th day of storage at 20 °C.	Kim et al. (2011)
Bioactive phenolic compounds: (Piceid and Resveratrol) †	(i) The quality of resveratrol-enriched rice wine was unaltered during four weeks of storage peroid under normal refrigeration temperatures (4 °C). (ii) The resveratrol-enriched rice wine had enhanced antioxidant and radical scavenging activity.	Further studies are necessary on composition of *Makgeolli* under ambient conditions.	Yang et al. (2019)
Bioactive compounds: (Farnesol, Squalene, 4-vinylguaiacol and 2,4-di-tert-butylphenol)	Farnesol, squalene and 2,4-di-tert-butylphenol exhibits antifungal, antitumar, anti-cancer and anti-inflammatory activities.	4-vinylguaiacol was found exceptionally in *Makgeolli* and beer at higher concentrations than in wine, which impart undesirable pungent clove herbaceous aroma.	Lee et al. (2018)
Aroma active compounds: (Short chain alcohols, esters, acids, aldehydes, terpenes etc.)	Imparts characteristic pleasant flavor to *Makgeolli*. Depending on the chemical characteristics and concentrations of the constituent.	The metabolite profiling of *Saccharomyces cerevisiae* in *Makgeolli* results in the formation of 3-(Methylthio)-1-propanol, due to the thiol functionality it has the characteristic unpleasant oniony-vegetable odor.	Wei et al. (2018) Holt et al. (2019) & Etschmann et al. (2008)
Microorganisms: (Bacteria, yeasts, fungi) ϕ	(i) The major lactic acid bacteria identified in *Makgeolli* are *Lactobacillus* sp. (ii) Depending on the storage temperature and time length of *Makgeolli* production, other lactic acid bacteria such as *Leuconostoc*, *Pediococcus* and *Enterococcus* sp. are present. (iii) Some bacterial strains such as *Pediococcus acidilactici* and *Pediococcus pentosaceus* showed significant bile acid tolerance and cell adhesion capabilities signposting probiotic nature.	Further studies are necessary on composition of *Makgeolli* under ambient conditions.	Nile. (2015) Kim et al. (2014b) & Park et al. (2015)
β-Carotene [A]:	(i) Optimum addition of carrot powder was 12%. Which imparts anti-cancer and anti-inflammatory properties. (ii) β-Carotene content was gradually increased with increased alcohol content by the addition of carrot powder. (iii) Sugar content was dropped during fermentation than compare to unflavored *Makgeolli*.	Prolongated fermentation process due to the variation of sugar contents with slight orange color.	Park et al. (2017)
L-Carnitine [B]:	The fermented buckwheat *Makgeolli* promoted health benefit by boosting body's metabolism, also made effective alcohol production (2.8% – 8.4%) compared to common buckwheat *Makgeolli*.	Pre-fermentation technique of buckwheat seed by *Rhizopus oligosporus* prior to *Makgeolli* brewing to enhance the antioxidant activity.	Park et al. (2018)
Ginsenosides [C]:	Ginsenosides have been found to have both antimicrobial and antifungal properties. This red ginseng *Makgeolli* is rich in organic acid, free sugars, and ginsenoside. The total content of ginsenoside was 2.47 mg/mL.	The total acid content and pH value increased after organic acid was produced during fermentation. Red ginseng *Makgeolli* is highly acidic and sour.	Lee et al. (2015)

† Present in rice wine fermented with 5% *Polygonum cuspidatum* root powder; ϕ Present in the *Nuruk* (an amylase enzyme) – One of the source ingredients for *Makgoelli;* [A] *Makgoelli* brewing with carrot powder; [B] Rhizopus oligosporus fermented buckwheat containing 18.7 mg/kg of L-carnitine were utilized to brew L-carnitine fortified *Makgeolli* with rice. [C] *Makgoelli* brewing with red ginseng starch.

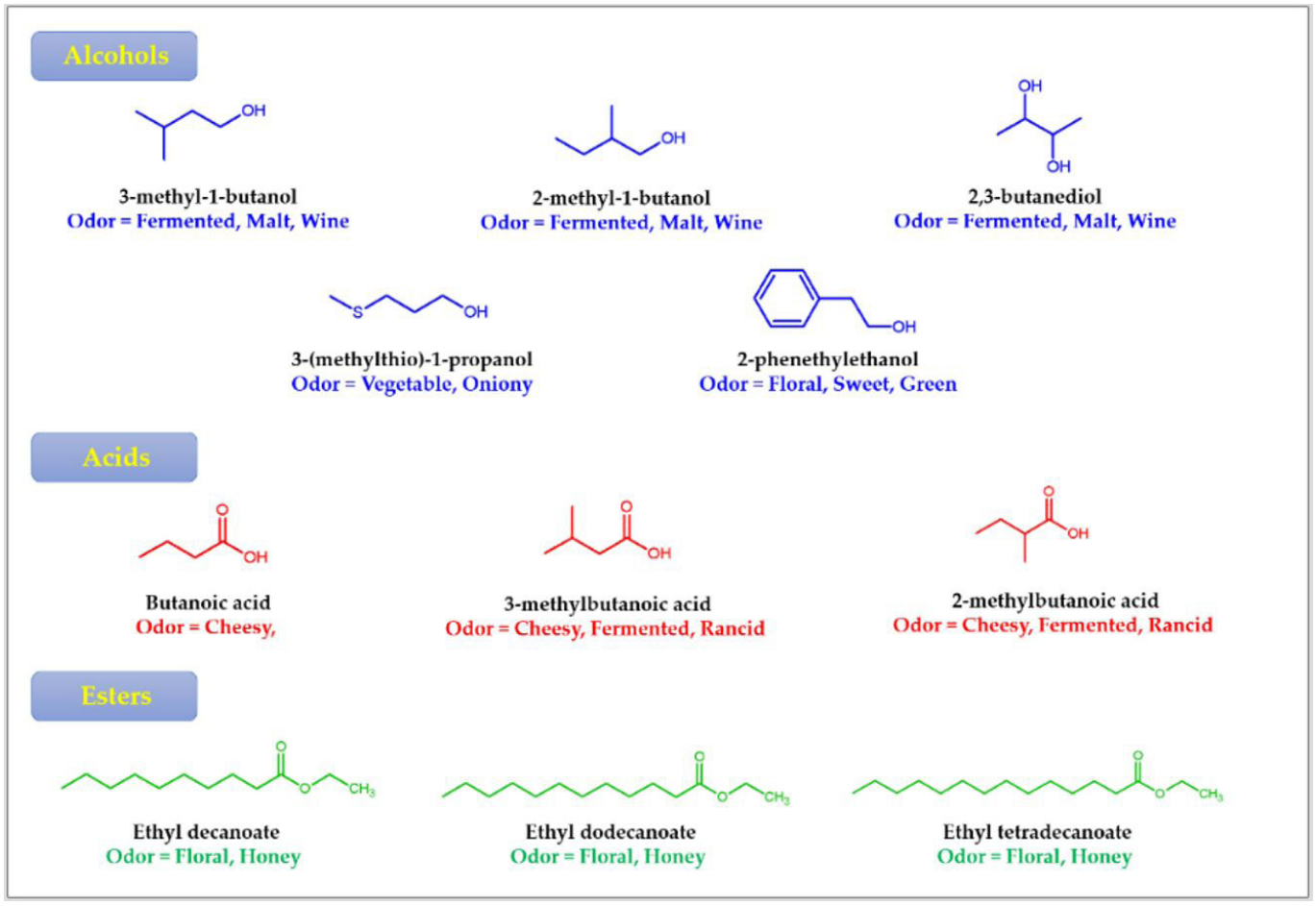

Figure 5. Chemical structures of eleven volatile compounds isolated from *Makgeolli*, Adapted with permission from Park et al. (2013), MDPI.

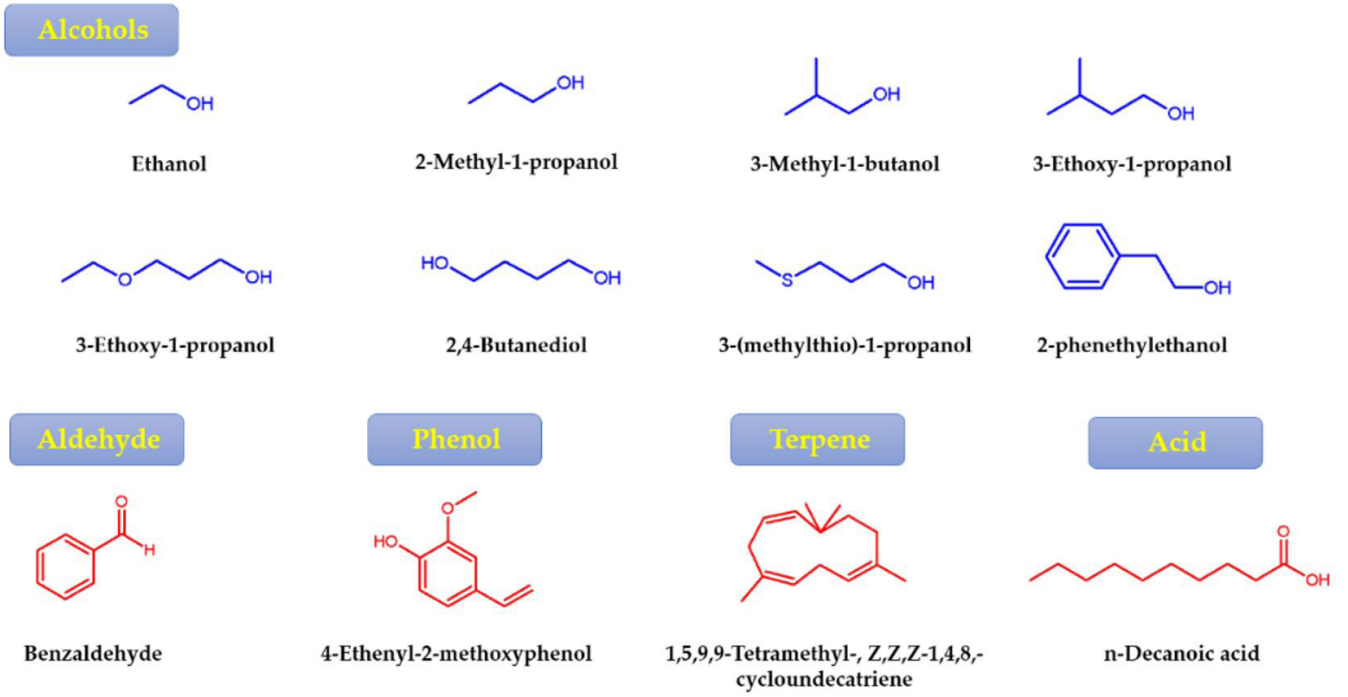

Figure 6. Chemical structures of alcohols, aldehyde, phenol, terpene and carboxylic acid compounds analyzed from commercial *Makgeolli* by Jung et al. (2014), Adapted with permission from Elsevier.

and health benefits of rice wine, Yang et al.(2019) bioprocessed the production of resveratrol-enriched rice wine by incorporating piceid and resveratrol from *Polygonum cuspidatum* roots (For chemical structures of resveratrol(3,5,4'-trihydroxystilbene) and trans-Piceid, see Figure 7). The authors documented the conversion of piceid to resveratrol by β-glucosidase enzyme during fermentation. The enriched rice wine showed enhanced antioxidant properties with significantly stronger 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, which eventually improves the storage expendabilities.

By solvent extraction coupled with gas chromatography mass spectrometry (GC-MS) technique, Lee et al. (2018) identified four important bioactive compounds in *Makgeolli* viz. farnesol, squalene, 4-vinylguaiacol and 2,4-di-tert-butylphenol (For chemical structures, see Figure 8). The authors newly identified the compound 4-vinylguaiacol (belongs to pyranoanthocyanin category) in *Makgeolli* which is most commonly found in beers, responsible for its pungent clove herbaceous aroma. In addition, farnesol and squalene found in *Makgeolli* reportedly exhibits anti-cancer and anti-inflammatory. However, 2,4-di-tert-butylphenol known for its predominant antioxidative activity (Yoon et al., 2006).

3.4 Lactic acid bacteria

In the current scenario, the beneficial probiotic properties of lactic acid bacteria are greatly emphasized. Practically viable probiotic microorganisms positively confer health benefits to the host, mainly by improving the intestinal microbiota (Hemarajata & Versalovic 2013; Zhang et al., 2019). Recent investigations of probiotics in regulating immunological, respiratory, and gastrointestinal functions to control the inflammatory bowel disease, constipation, and colon cancer has been scientifically evaluated (Yan & Polk 2020; Walker et al., 2006). The therapeutic potential of lactic acid bacteria is depends on numerous factors (Sharma et al., 2012). The main survival issues of lactic acid bacteria is their ability to survive in harsh pH of gastrointestinal tract and its capability to proliferate in the large intestine. Several studies have reported the selection criteria for potent lactic acid bacteria and its role in the production of fermented dairy, meat, fruit, vegetable, bakery products (Bintsis., 2018; Jagadeesh., 2015).

Probiotic dairy products are considered much attention due to its emerging research on health benefits. Despite of dairy products, many fermented fruit beverages with lactic acid bacteria strain can have a promising focus on health care (Szutowska., 2020;

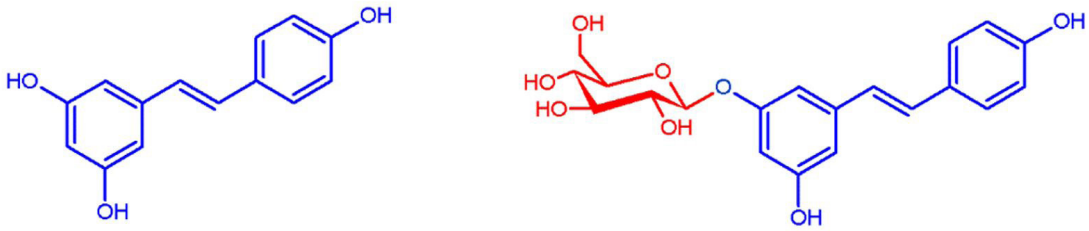

Figure 7. Chemical structures of bioactive resveratrol(3,5,4′-trihydroxystilbene) and *trans*-Piceid.

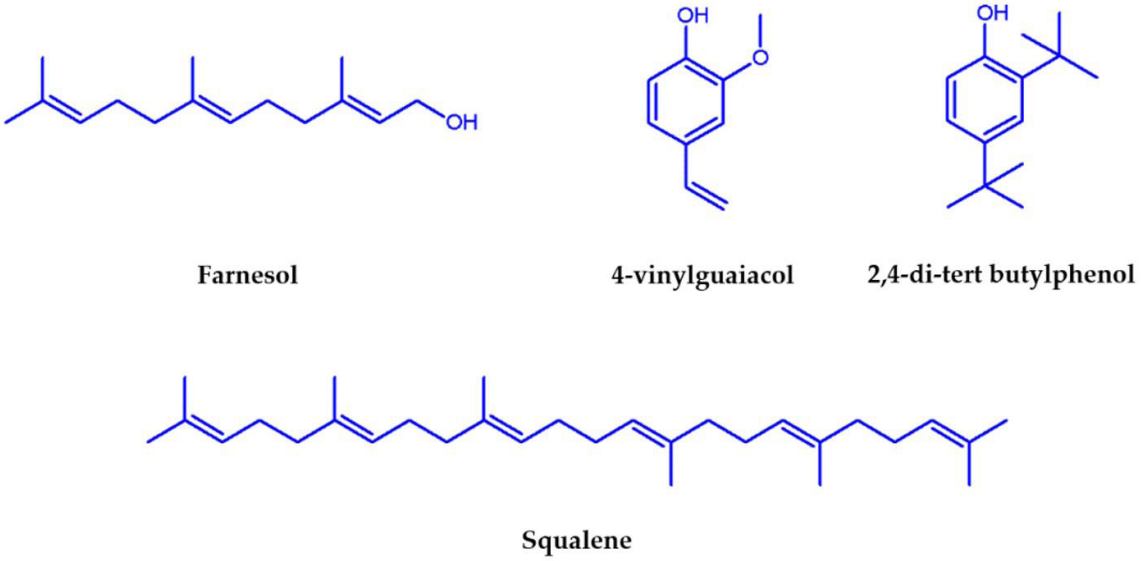

Figure 8. Chemical structures of four bioactive compounds isolated from *Makgeolli* by Lee et al. (2018).

Mousavi et al., 2011). Park et al.(2015) isolated 17 different lactic acid bacterial strains from *Makgeolli* and examined their health benificiality. The authors identified eight *Pediococcus acidilactici* strains, six *Pediococcus pentosaceus* strains, two *Lactobacillus curvatus* strains, and one *Lactobacillus curstorum* strain. With minor exceptions, all the bacterial strains produced remarkable nitric oxide production indicating to have immunomodulatory effects. Some *Pediococcus acidilactici* and *Pediococcus pentosaceus* strains showed significant bile acid tolerance and cell adhesion capabilities signposting probiotic nature of bacterial strains, useful in food industry. Thus, *Makgeolli* helps to increase the beneficial bacterial content, like *Bacteroidetes*, by surpassing harmful bacteria, such as *Firmicutes*. The moderate *Makgeolli* consumption beneficially improve the intestinal health and can be utilized in probiotics industry (Nile., 2015; Park et al., 2015).

3.5 Aroma-active components in Makgeolli

Aroma-active chemical substances in alcoholic beverages are the collective group of flavor imparting compounds, which convene aroma to the fermented beverages. Many short chain alcohols, esters, acids, aldehydes, terpenes etc. have been recognized as flavor active compounds in alcoholic beverages (Wei et al., 2018; Holt et al., 2019). Amyl alcohols, especially 3-methyl-1-butanol and 2-methyl-1-butanol are the prominent odor imparting chemicals, usually noticed in many fermented alcoholic beverages made of cereal. They divulge malt-like fermented odor to *Makgeolli* (Park et al., 2013). The fermentation process of fruits and grains, generally produce 2,3-butanediol, which has a sweet aromatic malt-like fermented fragrance (Ehsani et al., 2009). The metabolite profiling of *Saccharomyces cerevisiae* in *Makgeolli* results 3-(Methylthio)-1-propanol, due to the thiol functionality it has the characteristic oniony-vegetable odor (Etschmann et al., 2008).

The presence of aromatic 2-phenethylethanol, which is primarily found in the extract of rose, orange blossom, and other fragrant flowering plants give pleasant floral-sweet odor. 2-phenethylethanol is also recognized as an auto-antibiotic produced by the pathogenic yeast called *Candida albicans* (Morales & Hogan, 2010). The aliphatic acids butanioc acid, 3-methylbutanoic acid and 2-methylbutanoic acid reportedly present in *Makgeolli* gives acrid cheesy rancid taste. Whereas the aliphatic esters compunds, such as ethyl decanoate, ethyl dodecanoate and ethyl tetradecanoate conveys sweet floral honey type aroma to *Makgeolli* (Imark et al., 2000; Heinonen et al., 1998). The aromatic ester compounds, such as ethyl benzoate, ethyl phenyl acetate and 2-phenethyl acetate reported by Jung et al. (2014) has a characteristic pleasant odor described as floral-fruity, sweet, reminiscent of tropical flowers. These compounds are also observed as essential oils of plant part of various species. The distinctive aroma of aliphatic esters in *Makgeolli* depends majorly on the concentration and perception threshold of individual aroma-active compounds (Verstrepen et al., 2003; Conner et al., 1994).

4 Flavor varieties in *Makgeolli* and Health Benefits

Commercially, many brewing companies produce *Makgeolli* in variety of flavors such as banana, peach, green grapes etc. including original (unflavoured) flavor. Many research works are also documented by incorporating bitter melon, carrot, blueberries, ginseng roots etc. and studied the composition, biochemical properties and variation in microbial community. Park et al. (2017) studied that, brewing *Makgeolli* with carrot powder will prolong the fermentation duration and reduce the sugar level. The carrot imparts β-carotene and other functional materials to *Makgeolli* with anti-cancer and anti-inflammatory properties. Cho et al. (2016) suggested the preparation of rice *Nuruk* with bitter melon powder, remarkably improve the beneficial *Bacteroidetes* by dimishing pathogenic *Firmicutes*. *Makgeolli* derived from these *Nuruk* have higher content of soluble bioactive phenolic compounds and markedly increase the antioxidant characteristics.

Glucose is the major free sugar detected in banana *Makgeolli*. During the fermentation process, after 6th day of fermentation significant decrease in the glucose content was observed. In addition to glucose and fructose, maltose were also utilized by yeast to generate alcohols, and the reduction of these sugars impart a specific taste to *Makgeolli* with mineral and vitamin nutrients (Kim et al., 2013). Park et al. (2018) reported L-carnitine fortified *Makgeolli* using fermented buckwheat. During *Makgeolli* brewing, increasing contents of L-carnitine and biogenic flavonoids in buckwheat promote the health benefits and effectively increase the alcohol production. Lee et al.(2016) reported inhibitory effects of 70% ethanol extract of *Makgeolli* against human breast cancer cells. Dealcoholized *Makgeolli* exhibited anti-angiogenic effect without cytotoxicity and useful for the prevention of cancer cell growth. These findings afford new mechanistic insights on *Makgeolli*, as therapeutic agent.

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