



Understanding the marketability of Korean rice wine (*makgeolli*) in  
New Zealand using sensory and physicochemical methods

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## Thesis Abstract

Physicochemical and sensory information is critical to understanding the physical properties of food products. When this information is not available, then it would be difficult to establish a market opportunity for the food product as manufacturers and researchers cannot predict whether the food product will be accepted or rejected from the marketplace. In this thesis, physicochemical principles and sensory evaluations were used to understand the properties of *makgeolli* and their different processing methods. *Makgeolli* is a traditional rice alcoholic beverage that originated in Korea. Four methods of preparing *makgeolli* were investigated in this thesis, as their material e.g., fermentation starter (*nuruk*, traditional Korean fermentation starter), rice (either glutinous rice and/or non-glutinous rice) and time of fermentation varied. Interestingly, *makgeolli* uses simultaneous saccharification and fermentation for the brewing process meaning starch hydrolysis and alcoholic fermentation occur concurrently within the same vessel. The four methods of producing *makgeolli* include (1) single-stage simultaneous saccharification and fermentation of glutinous rice with *nuruk* – a Korean starter culture (1SF-N), single-stage fermentation with *nuruk* and yeast (1SF-YN), two-stage fermentation (2SF) and three-stage fermentation (3SF).

Study 1, physicochemical properties such as alcohol content, pH, colour, mineral content, proximate composition, antioxidant activity, total phenolic content, sugar, free amino acid, and organic acid profile were used to examine the four different *makgeolli* processing methods. Results indicate 1SF-N *makgeolli* sample had the highest alcohol, crude protein, antioxidant activity, total phenolic and free amino acids content while the 2SF *makgeolli* sample had the highest concentration of glucose and maltose. In addition to chemical analysis, sensory evaluation using polarised projective mapping (PPM) with sweetness (using sucrose), sourness (using citric acid), and bitterness (using quinine) as references or ‘poles’ that participants can compare the *makgeolli* samples against when placing the *makgeolli* samples on the A3 piece of paper. Although 1SF-N *makgeolli* sample had the most physicochemical features such as high concentrations of antioxidants, total phenolic content and free amino acids, it was the least liked *makgeolli* sample. In comparison, 2SF *makgeolli* sample was the most overall liked likely due to the higher sugar content compared to the other *makgeolli* samples.

In study 2, chemical analysis using solid-phase microextraction coupled with gas chromatography-mass spectrometry (SPME-GC-MS) to identify the different volatile compounds present in the four

*makgeolli* samples. In total, 45 volatile compounds were identified and the majority of compounds found of interest in the *makgeolli* samples were esters (25 compounds) and alcohol (10 compounds). Principle component analysis (PCA) was employed to determine the interactions of volatile compounds in the *makgeolli* samples. In terms of volatile compounds that are well represented in the PCA graph, limonene (citrus-like flavour), ethyl pentanoate, and hexanal (green/grass-like flavour) contributed the most for Dimension 1. For Dimension 2 on the PCA graph, 2-ethoxy-2-methyl-propane, 2-methyl-1-propanol, and isobutyl acetate were the three highest volatile compounds that contributed the most. Two sensory experiments were carried out simultaneously using Check-All-That-Apply (CATA) and Just-About-Right (JAR) were also included in this study. One hundred and twenty-nine participants (n = 68 female participants) took part in the study. Twenty terms were used for CATA, and among the 20 terms, 14 terms reached statistical significance between the four *makgeolli* samples. For JAR, seven attributes were evaluated and a high proportion of participants indicated that sourness was too much in three of the four *makgeolli* samples.

In study 3, product categorisation of *makgeolli* was investigated and characterised among beer and wine samples. Two separate sensory studies were conducted with projective mapping with ultra-flash profiling (PM with UFP) completed first then polarised sensory positioning (PSP). A collective total of 159 participants took part in the study with 68 participants in PM with UFP and 91 in PSP. Previous research indicates that *makgeolli* shared similar traits to semi-sweet white or rose wine, however, results from both sensory experiments indicate *makgeolli* had unique sensory traits and attributes, therefore, *makgeolli* should be categorised or marketed differently.

In study 4, two sensory experiments were conducted to understand how the environment affects the participant's attitudes, behaviour, and perception while consuming *makgeolli* in New Zealand. Experiment 1 (n = 60) was carried out in a laboratory setting using the evoked context method to simulate a context scenario while Experiment 2 (n = 113) was carried out in physical environments including a laboratory, an Asian restaurant, and participant's home. Both experiments indicate that context appropriateness was an important factor while consuming the *makgeolli* beverage and different context scenarios or physical environments did not change participant's overall liking of *makgeolli*. In summary, context appropriateness

may be an important factor to consider in the consumer's decision-making process and should be considered as part of hedonic testing or acceptance testing on food products.

Overall, this thesis provides insightful information regarding to physicochemical and sensory information on the different processing methods of *makgeolli*. In terms of the practicality of the research, manufacturers and researchers have basic physicochemical information about the different *makgeolli* samples. Further experimentation should be considered such as shelf-life and packaging, and additional research on microbial diversity and growth would be beneficial. For sensory analysis and evaluation, *makgeolli* was examined in different environments which provides a comprehensive view into how *makgeolli* is perceived among participants (e.g., home, laboratory, and restaurant environments). Considering the current economic environment and consumer behaviour changes, large-scale production and commercialisation of *makgeolli* in New Zealand is not advisable.

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## **Attestation of authorship**

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor used artificial intelligence tools or generative artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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# Chapters 1. Introduction

## 1.1 A brief history of *makgeolli*

Different cultures have specific alcoholic beverages that represent their geography and cultural identity. For example, in Western societies, wine (fermented by grapes) is integral to French and Italian culture, while beer is closely associated with British culture. In East Asian countries, the predominant ingredient for fermentation and producing alcoholic beverages is rice (*Oryza sativa L.*). Traditionally, rice wine is a fermented beverage commonly consumed in East and Southeast Asian countries including China, Japan, and Korea. In China, rice wine is known as *mijiu* (varieties of *mijiu* include *huangju* and *baijiu*), in Japan rice wine is known as sake, and a specific example of rice wine for Korea is *makgeolli*.

Research from pottery has indicated that fermentation culture was found as early as 8000 – 5000 B.C with fruits and honey on the Korean peninsula (Lee, 2022). By the Three Kingdoms period between 1<sup>st</sup> century B.C and 7<sup>th</sup> century A.D., alcoholic beverages fermented with grains such as rice became popular (Lee, 1996). During the Three Kingdoms period, the rice wine-making process was refined and new techniques were introduced, however, many of the different rice wines were not documented and there is no record of how the rice wines were made (Lee, 1996).

Lee (1996) wrote it was in the first half of the Koryo dynasty (918 – 1392 A.D) that *makgeolli* and *cheongju* (a refined version of *makgeolli*) were included in the wine-making process. Other names that *makgeolli* include *takju* (meaning “opaque wine”) and *makkoli* (an anglicised version of *makgeolli*; *makgeolli* used hereafter). Lee (1996) noted it was during this period that alcoholic beverages were fermented in multiple steps to enhance the flavour and alcoholic content. Most of the names of Korean rice wines can trace their origins back to the Koryo dynasty (Lee, 1996). After the Koryo dynasty was succeeded by the Joseon dynasty (1392 – 1897 AD), techniques of rice wine-making were further refined, glutinous rice was introduced in the rice wine-making process and multiple fermentation stages were favoured over single-stage fermentation (Lee, 1996). It was cited that during the Joseon dynasty, Korea had over 300 alcoholic beverage varieties with alcoholic beverages consisting of distilled liquor, medicinal (herb) flavoured wine, fruit wine, and mixed varieties (Lee, 2022).

After the Japanese annexation of the Korean Peninsula, alcohol was not allowed to be produced at home after the introduction of a tax on liquor law (1907) and the liquor law (1916) was imposed to standardise the categorisation of rice wine produced in Korea (Lee, 2022; Lee, 1996). The standardisation of rice wine in Korea was divided into three categories: *yakju* (referred to as filtered wine), *takju* (cloudy wine where *makgeolli* falls within this category) and soju (distilled wine) (Lee, 2022). The 20<sup>th</sup> century was somewhat restrictive in the production of *makgeolli* as rice was a scarce commodity and wheat was substituted for wine production (Lee, 2022).

## **1.2 Modern view of *makgeolli***

The majority of foreign press commonly cite *makgeolli* having sweet and tardiness in taste, and white-cloudiness in appearance (Lee & Lves, 2022; Macdonald, 2017), this is an interesting contrast to beer and wine which is mainly consumed in Western markets. In addition, some foreign press discuss the health properties of *makgeolli* such as having high amounts of lactic acid bacteria (Macdonald, 2017) while some discuss the cultural connection between Korean culture and the alcoholic beverage (Lee & Lves, 2022). Although *makgeolli* is a relatively new product in Western markets, *makgeolli* as a product has seen growth in production and export. For production, South Korea had at least 961 companies registered in making *makgeolli* in 2020 compared to 931 in 2019 (Lee & Lves, 2022). For export, one of the largest *makgeolli* exporters in South Korea reported a growth in sales, which broke the USD 10 million mark (Watman, 2023). In an article written by Watman (2023), Watman showed that entrepreneurs have developed *makgeolli* products specifically for the North American market under the product name 'Makku'. There is a growing commercial interest in the production, exportation, and consumption of *makgeolli* in the Western market.

## **1.3 *Makgeolli* research and research gap**

Currently, research on *makgeolli* has indicated that this alcoholic beverage contains bioactive compounds that are beneficial to human health. These bioactive compounds include farnesol and squalene (Lee et al., 2018), 1,4-dihydroxy-2-naphthoic acid (a bifidogenic growth stimulator) (Eom et al., 2012), and high total phenol content (Bae et al., 2010). Other research has explored the chemical, microbial, and sensory

differences in pasteurising *makgeolli* (Lee et al., 2022; M. G. Lee et al., 2016; Park et al., 2013), adding additional food products in the fermentation process of making *makgeolli* such as black garlic extract (Jeong, 2011) and liquorice root (*Glycyrrhiza Uralensis fisher*) (Li et al., 2022).

In terms of sensory evaluation of Korean rice wine, the majority of available research in the English language is not specific to *makgeolli* (i.e., either *makgeolli* were examined with other Korean rice wine products or the researcher was not specific on the Korean rice wine type or *makgeolli* was absent from the study) and the study was mostly conducted in South Korea. For example, researchers have indicated that they conducted sensory evaluations for *yakju* (Lee et al., 2007; Lee, Kwak, Jung, et al., 2021; Lee, Kwak, Kim, et al., 2021), *cheongju* (Byeon et al., 2023), and *makgeolli* (Jung et al., 2014; Kim & Kim, 2015). Jung et al. (2014) used descriptive sensory analysis and Kim and Kim (2015) used *makgeolli* for sensory method development.

This limits our understanding of the sensory perception of *makgeolli* from a Western consumers perspective. Therefore, unable to optimise the *makgeolli* product to cater for consumers in Western markets such as Europe, North America, and Australasia. Therefore, knowledge and information availability on *makgeolli* is limited to the few research articles that are published in international research journals in the English language.

#### **1.4 Research motivation**

The rationale of this research is to extend our knowledge about *makgeolli* and how Western consumers perceive foreign and ethnic alcoholic beverages that are not commonly available in the market. As stated in the **Section 1.3 Makgeolli research and research gap**, the majority of the research disseminated on *makgeolli* is in South Korean research journals and is written in the Korean language. Therefore, researchers who are not fluent in Korean would find *makgeolli* research to be limited. In light of this situation, research on *makgeolli* should be explored as there is evidence that foreign markets and consumers are interested in this alcoholic beverage.

This research aims to assist food scientists, food industries, and market researchers in developing an exploratory understanding of rice wine (specifically *makgeolli*) in the New Zealand market. In addition, rice

wine poses a market potential in Western markets due to its processing method where animal products are not used in the rice wine making process. For example, traditional wine processing methods may use fining agents such as casein, albumin, gelatine and isinglass to increase the clarity of the wine. The process of making *makgeolli* does not require a fining agent as the appearance of *makgeolli* is opaque and cloudy-white. Therefore, *makgeolli* is more suitable for vegans and vegetarian consumers.

Different methods of making *makgeolli* have been reported by different researchers, examples include Jeon et al. (2010); Jeong (2011); Kim et al. (2013). However, these researchers are focused on new product development rather than examining the sensory evaluation of *makgeolli* itself. This information is important because different processing methods of *makgeolli* are likely to affect the sensory attributes perceived by the consumer. This research is to document the different processing methods and to identify which processing methods of *makgeolli* are preferred by New Zealand consumers. Furthermore, documenting the sensory attributes of different *makgeolli* processing methods will aid new product development as researchers can create products that are suitable to the consumers that they are trying to target. This PhD research will include two components, the physicochemical analysis and sensory evaluation to answer the research objectives.

### **1.5 Aims and objectives**

The overall aim of this thesis research was to first identify the different processing methods of making *makgeolli* and to understand the effect of processing on the physicochemical properties *makgeolli*. In addition, the study will examine how Western consumers (specifically New Zealand consumers) perceive *makgeolli* using different sensory evaluation methods within the alcoholic beverage market.

Specific objectives of thesis research include:

- To explore whether New Zealand consumers can discriminate/differentiate different types of *makgeolli* (Chapters 3, 4 and 5).
- To understand the chemical properties of different *makgeolli* according to their different method of production (Chapters 3 and 4).

- To compare the flavour and sensory attributes of different *makgeolli* samples using chemical analysis and sensory evaluation (Chapter 4)
- To understand the consumer acceptance of *makgeolli* among New Zealand consumers (Chapter 4, 5, and 6).

The majority of the objectives will be embedded in different chapters of this thesis and will be answered according to the experiments carried out. Due to the structure of the thesis, experimental chapters will include different aspects and research objectives as illustrated in the bullet points above. For example, **Chapter 3** and **Chapter 4** incorporate both physicochemical experiments and sensory evaluation to (1) determine whether New Zealand consumers can discriminate/differentiate different types of *makgeolli* based on their different processing methods, and (2) use chemical analysis to identify different chemical properties of the *makgeolli* sample. Physicochemical experiments carried out in **Chapter 3** include antioxidant activity, amino acid, alcohol content, pH, organic acid and sugar analysis and **Chapter 4** specifically investigates the volatile compounds of the different *makgeolli* samples using solid-phase microextraction coupled with gas chromatography-mass spectrometry (SPME-GC-MS). For sensory evaluation methods, polarised projective mapping (PPM) was used in **Chapter 3** and Check-all-that-apply (CATA) and just-about-right (JAR) scales were used to evaluate sensory attributes and the degree of their intensity in **Chapter 4**. For **Chapter 5** the sensory evaluation methods used were projective mapping with ultra-flash profiling (PM with UFP) and polarised sensory positioning (PSP) to determine whether New Zealand consumers categorise *makgeolli* in the beer or wine categories. For **Chapter 6**, moods and emotions were examined among New Zealand consumers to determine in which location (e.g., restaurant or home setting) is the most appropriate place to consume *makgeolli*.

## 1.6 Overview of the thesis

This research thesis will consist of seven chapters, with four experimental chapters. The four experimental chapters (**Chapters 3, 4, 5 and 6**) will include an introduction of the experimental design and research gap, methods and materials used, results and discussion and also a summary. **Chapter 7** will conclude this research thesis with future implications and recommendations identified from this study.

### Chapter 1. Introduction

A brief historical overall of *makgeolli*, research rationale, research objectives and description of the thesis research.

### Chapter 2. Literature Review

Understanding the key ingredients used for processing *makgeolli* such as rice (glutinous and non-glutinous rice) and *nuruk* (traditional Korean fermentation starter). An overall of the different experiments carried out on Korean rice wine and *makgeolli* such as health properties, sensory evaluation, and new product development using available literature in the English language.

### Chapter 3. Characterisation of Korean rice wine (*makgeolli*) prepared by different processing methods

**Chapter 3** explores the different *makgeolli* making processes (n = 4). Characterisation of *makgeolli* using chemical analysis such as antioxidant activity, alcohol content, proximate composition, sugar, amino acid, and organic acid analysis. The sensory evaluation used to characterise *makgeolli* includes polarised projective mapping and overall liking. This chapter was published in the research journal *Current Research in Food Science*.

#### **Chapter 4. Identifying sensory attributes of Korean rice wine (*makgeolli*) using sensory evaluation and chemical analysis**

**Chapter 4** identifies the sensory attributes of the different *makgeolli* processing methods using Check-all-that-apply (CATA) and Just-about-right (JAR) methods. Additionally, SPME-GC-MS was used to identify volatile compounds of the different *makgeolli* samples. This chapter was published in the *Journal of Food Science*.

#### **Chapter 5. Product categorisation of Korean rice wine (*makgeolli*) compared to beer and wine using sensory evaluation methods**

**Chapter 5** investigates whether *makgeolli* should be positioned as a beer or wine product within the consumer market using projective mapping with ultra-flash profiling and polarised sensory positioning (PSP). This chapter was published in the *Journal of Sensory Studies*.

#### **Chapter 6. Determining the appropriate location for consuming Korean rice wine (*makgeolli*) in New Zealand**

**Chapter 6** explores whether different locations are likely to affect the consumers' behaviour and perception of consuming *makgeolli*. In addition, moods and emotions were also measured. This chapter was published in the *International Journal of Gastronomy and Food Science*.

#### **Chapter 7. Overall conclusion and future implications**

Finally, this chapter will conclude the findings and research implications of this PhD research.

## Chapters 2. Literature review

This chapter presents an overview of the ingredients associated with the process of making *makgeolli* and the sensory attributes of rice and *makgeolli*. The main ingredients used to make *makgeolli* include glutinous and non-glutinous rice, and *nuruk* (traditional Korean fermentation starter). Currently, there are different methods of processing *makgeolli* and this literature review aims to provide information regarding these ingredients such as their physiochemical, microbial, and volatile properties. The structure of this chapter is as follows: (1) an overview of rice and its associated properties, (2) an overview of *nuruk* and its associated properties, and (3) an overview of *makgeolli* and its associated properties including physiochemical and sensory information.

### 2.1 Rice (*Oryza sativa* L.) – the main ingredient for making *makgeolli*

Rice (*Oryza sativa* L.) is one of the most important crops in the world since half of the world's population consumes rice as part of their diet (Mohidem et al., 2022). The two main rice species of *Oryza sativa* L. genus varieties that are commonly cultivated include the long-grained indica variety mostly grown in tropical and subtropical Asia, the short/medium grained japonica variety mostly grown in temperate regions such as Japan (Mohidem et al., 2022). Currently, 80% of the rice produced is indica, 15% is japonica, and the remaining percentage of rice produced in the world is classified into other categories (Bautista & Counce, 2020). Rice is a semiaquatic plant grown in at least 95 countries around the world (Bautista & Counce, 2020). Interestingly, rice can be grown in either dryland or aquatic environments, however, the majority of rice is grown in aquatic environments (Bautista & Counce, 2020). Researchers have reported that rice can be harvested two to three times per year in irrigated lowland systems (Muthayya et al., 2014).

Although rice is consumed widely in the world, researchers have noted rice tends to be a poor source of vitamins and minerals, especially after the milling process due to the vitamins and minerals predominately located in the outer layers of the raw rice grain (Muthayya et al., 2014). Brown rice (e.g., rice with bran) tends to have higher dietary fibre, vitamins and minerals, especially B vitamins including thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), pyridoxine (B6) and Biotin (B7) (Mohidem et al., 2022).

### **2.1.1 Glutinous rice (*Oryza sativa* var. *glutinosa*)**

Glutinous rice (*Oryza sativa* var. *glutinosa*) also known as sticky rice, waxy rice, or sweet rice is another variety of rice that is commonly consumed in Asia. Food products that are made from glutinous rice include Asian desserts, rice wine, rice cakes and more (Kang et al., 2010). The key differences between glutinous rice and rice (*Oryza sativa* L.) which is often referred to as non-glutinous rice is the amylose and amylopectin ratio, where glutinous rice has no to very low amylose (0 – 2%) and high amounts of amylopectin (Kang et al., 2010). However, it is also important to note that glutinous rice can also come from indica and japonica varieties (Choi et al., 1999). From Choi et al's (1999) research on glutinous rice, they reported that both indica and japonica are distinguishable using 11 physicochemical and structural parameters on a principal component analysis while javanica (a subcategory of japonica) samples somewhat resemble both indica and japonica characteristics. In terms of sensory attributes, researchers cite texture (e.g., chewiness or stickiness) as one of the important components in the quality of glutinous rice followed by aroma (Ali & Hashim, 2024).

### **2.1.2 Rice structure and physicochemical components**

When the raw rice grain is harvested, the raw rice grain contains approximately 20% husk also known as the hull, 10% bran, and the milled rice kernel or commonly referred to as white rice (70%) (Bautista & Counce, 2020). The rice plant must undergo drying and milling before consumption as the husk and bran may not be pleasant for human consumption as the husk and bran are fibrous. Muthayya et al. (2014) noted that the moisture content of the rice grain before processing is 20% and is dried down to approximately 14% so it can be safely stored. The milling process first removes the husk by rubber rollers to produce brown rice (e.g., rice that contains bran) (Bautista & Counce, 2020). Depending on the market and consumer preference, brown rice is then further processed to produce white rice by removing the bran using methods of abrasion or friction (Bautista & Counce, 2020).

The milled rice kernel or white rice consists of starch, which is mostly amylopectin, a smaller amount of protein, and also amylose (Bautista & Counce, 2020). Amylose is a linear molecule that consists of  $\alpha$ -1, 4-linked glucose chains while amylopectin is a branched molecule consists around 5%  $\alpha$ -1, 6 branch linkages (Reed et al., 2013). There is great emphasis placed on the ratio between amylose and amylopectin as it determines the overall structure, appearance, and eating quality of the milled rice kernel (Mohidem et al.,

2022; Zhang et al., 2021). In terms of the approximate ratio between amylose and amylopectin in milled rice kernel, it is 18% and 82% respectively (Zhang et al., 2021). Additionally, milled rice kernel can be classified into five categories based on the amylose content these categories include waxy (also known as glutinous rice) (0 - 2%), very low (2 – 10%), low (10 - 20%), intermediate (20 – 25%), and high (25 – 33%) (Zhang et al., 2021). Bautista and Counce (2020) noted that quality components of the milled rice kernel are often judged by the per cent of chalk (e.g., the opaque portion of the rice structure that is not transparent), protein content, amylose content, cooking properties and gelatinisation characteristics.

### **2.1.3 Rice processing: washing and soaking**

The practical feature of washing rice is to remove milling dust, oils and also broken rice particulates (Yu et al., 2017). The washing process removes 60-80% of the total surface lipids and also reduces free fatty acids (Monsoor & Proctor, 2002). The free fatty acid is linked to off-flavour and lipid oxidation in rice, therefore improving the flavour after washing the rice (Monsoor & Proctor, 2002). Interestingly, the washing process does not affect the textural aspects of the rice granules. Li et al. (2019) explained that stickiness and hardness are determined by the amylose and amylopectin ratio and are not significantly changed during the washing process. Another issue that has been raised by consumers is the presence of heavy metals such as arsenic in rice which is toxic to human health (Davis et al., 2017; Navas-Acien & Nachman, 2013). The rice-washing process significantly reduces the concentration of arsenic, other activities such as rice soaking or cooking were not statistically significant (Liu et al., 2018).

Rice soaked in excess water is a common practice before cooking rice in East Asian countries such as South Korea and Japan (Yu et al., 2017). The soaking time range is 30 min to 5 h depending on the researcher and experiment (Das et al., 2006; Lakshmi et al., 2007). Like the washing process, soaking allows sugar, soluble proteins and non-starch-bound lipids to leach out (Chiang & Yeh, 2002). The soaking procedure allows the rice granules to swell and expand during cooking, which allows the complete gelatinisation process in the rice (Yu et al., 2017). Buggenhout et al. (2014) note that insufficient soaking of moisture for rice causes granule breakage during the cooking process. If the soaking process is not adequate, the central part of the grain may not fully gelatinise in the cooking process which causes the rice grain to be hard (Buggenhout et al., 2014). In addition, the soaking process also increases the cooking kinetics which reduces the cooking time (Chakkaravarthi et al., 2008). For example, Das et al. (2006) showed that pre-

soaking reduced rice cooking time from 25 min to 23 using the electric rice cooker, 29 min to 25 min using a pressure cooker and 24 min to 20 min using a natural gas stove. Researchers also demonstrated that pre-soaking rice is more energy efficient in different cooking utilises such as microwaves, rice cookers, and pressure cookers (Das et al., 2006; Lakshmi et al., 2007).

#### **2.1.4 Rice processing: different cooking methods**

The cooking process of rice is not straightforward due to cultural and consumer preferences of the different rice varieties e.g., different consumers may prefer rice with either high or low amylose content. Additionally, the amount of water used for cooking rice also changes the final formation of the rice grain as excess water absorption may cause excessive damage to the rice structure causing the rice to be less desirable for consumption (Tamura, 2023). The two common methods of cooking rice include the limited water method (LWM) where the water-to-rice ratio is fixed and the excess water method (EWM) (Tamura et al., 2021). Tamura (2023) also stated that other methods of cooking rice include frying in oil, cooking with water, steaming, and baking. Cooking rice under pressure is another method that is becoming more popular (Yu et al., 2017).

The LWM (sometimes referred to as the absorption method) is a commonly used method in households with a rice cooker (Yu et al., 2017). The rice is cooked when the amount of predetermined amount of water is fully absorbed by the rice. The ratio proposed by Juliano and Perez (1983) was based on the amylose content of the rice. For example, for each unit of rice, 1.3 times of water for waxy rice (a.k.a., glutinous rice) should be used, 1.7 times of water for rice with 12 – 20% of amylose, 1.9 times of water for rice with 20 – 25% of amylose, and 2.1 times of water for rice with a >25% of amylose (Juliano & Perez, 1983). Similar to Juliano and Perez (1983), Chakkaravarthi et al. (2008) suggested the rice-water ratio for LWM between 1:1.5 and 1:2.5 depending on the amylose content.

The EWM uses excess water to boil the rice until it is cooked, the ratio between rice to water is 1:10 and 1:20 (Chakkaravarthi et al., 2008). However, the researchers did point out that consumers in developing countries tend to use less rice to water ratio (Chakkaravarthi et al., 2008). To determine whether the rice is cooked thoroughly using the EWM, rice grains are periodically sampled to evaluate their core (Yu et al., 2017). The core of the rice grain should not show a starchy core (e.g., the core should be translucent) (Yu et al., 2017).

Another process that is often used in rice cooking is steaming, however, there are different methods of steaming rice. For example, Lina and Min (2022) described the steaming process as similar to LWM where rice is placed in an aluminium container with a certain amount of rice-to-water ratio and is steamed with a lid sealed tightly. In comparison, Thuengtung et al. (2019); Thuengtung and Ogawa (2020) used a different steaming method where the rice is first soaked, drained and put in a vessel suspended above the amount of boiling water. This method of cooking rice was used in a number of studies associated with making *makgeolli*, these studies include Ahn and Kim (2020); Choi et al. (2014); S. Kim et al. (2015); Park et al. (2024).

### **2.1.5 Rice aroma and flavour**

One of the first volatile compounds associated with rice was 2-acetyl-1-pyrroline (2-AP) which is often described as having popcorn-like aroma (Champagne, 2008). Since the discovery of 2-AP, additional volatile compounds have been identified in cooked rice such as 2-pentylfuran (known for a beany aroma), decanal (known for soapy aroma) and (*E,E*)-deca-2,4-dienal (known for a fatty aroma) but 2-AP still remains a volatile compound that is associated with rice (Champagne, 2008). Researchers have reported volatile compound changes over time due to lipid oxidation, such as hexanal (known for a grassy aroma) and 2-pentylfuran (known for a bean aroma) contributed more towards the flavour of fresh milled rice and 2-nonenal (known for a rancid flavour) and octanal (known for a fatty aroma) contributed more to the overall flavour of milled rice when long-term storage occurred (Lam & Proctor, 2003).

For sensory attributes of rice, descriptive testing is commonly used to determine the aroma, flavour, taste, appearance, and texture of rice in different stages of the milling, cooking, and storage process (Champagne, 2008). In a study conducted by Piggott et al. (1991), they developed rice lexicons including fragrant, pungent, sour, smooth, sweet, sulphur-like, muddy, earthy, bread-like, hay-like, buttery, nutty, coconut, oily grassy, mouldy and musty for their descriptive analysis on rice. Other researchers have also developed rice lexicons as part of their sensory study, and the terms were very similar to Piggott et al.'s (1991) study. For example, Pramudya and Seo (2018) developed a set of rice lexicon for evaluating the sensory attributes of rice consumed in different temperature conditions including 30 °C, 40 °C, 50 °C, 60 °C and 70 °C using the Check-All-That-Apply the (CATA) method. The rice lexicons were placed in different categories including appearance (e.g., glossy grains, loose grains, plumpness, and white), aroma by sniffing

(e.g., dairy, earthy, floral, hay-like, metallic, nutty, popcorn, rancid, and sulphur), taste/flavour by consumption (e.g., bitter, dairy, earthy, floral, grainy, grassy, hay-like, metallic, nutty, popcorn, rancid, salty, sour, sweet, and wet cardboard), and texture by consumption (e.g., chewy, firm, loose particles, moistness of grains, soft, and sticky) (Pramudya & Seo, 2018). In Pramudya and Seo's (2018) study, 13 attributes were significantly different among the five serving temperatures examined.

## 2.2 *Nuruk*

### 2.2.1 *Nuruk*: a brief overview of the traditional Korean fermentation starter

*Nuruk* is a traditional fermentation starter that is commonly used in Korea for making alcoholic beverages with cereal bases as their sugar source (Lee & Kim, 2017). Although Korean alcoholic beverages have used different types of fermentation starter over the years such as *koji* (a.k.a., Japanese fermentation starter), the traditional method is to use *nuruk* for making *makgeolli* as researchers have found *makgeolli* made from *nuruk* tends to be more superior in microbial activity (Cha et al., 2023).

*Nuruk* differs from the other fermentation starters in Asia such as *qu* in China and *koji* in Japan because *nuruk* contains an abundance of fungi (e.g., *Aspergillus* spp, *Eurotium* spp.), yeast (e.g., *Saccharomyces* spp, and *Pichia* spp), and bacteria (e.g., *Bacillus* spp, *Pediococcus* spp, and *Lactobacillus* spp) which makes the sensory attributes and flavour of Korean rice wine unique (Lee et al., 2017; Song et al., 2013). The enzymes found in *nuruk* including  $\alpha$ -amylase,  $\beta$ -amylase, glucoamylase, protease, and  $\beta$ -glucanase break down the starch and aid the fermentation process (Lee et al., 2017). Compared to wine and beer, rice wine including *makgeolli* undergoes saccharification and fermentation simultaneously, this is because the organisms breakdown the starch to glucose, and then ethanol and carbon dioxide are produced during fermentation (Nile, 2015).

From historical documents, it was believed that *nuruk* was first used in the Three Kingdoms period and *nuruk* had different names including *guk* up until the 1918 and *gokja* after 1918 (Lee & Kim, 2017). However, the name *nuruk* remained popular and is still used today.

### 2.2.2 The process and production of making *nuruk*

The ingredients used to make *nuruk* is location dependent as different regions of Korea have different methods of making *nuruk*. Common ingredients to make *nuruk* include rice and wheat (Nile, 2015), barley is also another common ingredient (Lee & Kim, 2017). It is also common to use other ingredients in the *nuruk* making process, such as researchers incorporating glasswort (*Salicornia herbacea* L.) into *nuruk* (Jeon et al., 2010). In Lee et al.'s (2017) study, they noticed *nuruk* made with barley had flavour profiles similar to beer that has a bitter-sweet taste, while *nuruk* made with glutinous rice and non-glutinous rice had a stronger sweet taste. The process of producing *nuruk* is best illustrated by Lee and Kim (2017) who describe the different steps including washing, drying, grinding, kneading, fermentation, and ageing. **Figure 2.1** illustrates the *nuruk* making process written by Lee and Kim (2017), however, it is important to note that different regions throughout Korea have different methods of making *nuruk*, the general procedure of making *nuruk* includes the drying process, the shape of the kneaded dough, and ingredients (Lee & Kim, 2017; Nile, 2015).

**Figure 2.1** The process of making *nuruk*. Adapted from: Lee and Kim (2017)

In addition to the different methods of processing *nuruk*, there are two categories of *nuruk*. The two categories include *ddeok-nuruk* which is made of a lump of grain powder and *heuchim-nuruk* which is made of cereal grains (Lee & Kim, 2017). The key difference between the *nuruk* classification depends on the location of the microorganism. For *ddeok-nuruk*, microorganisms including yeast, fungi, and bacteria are found inside the lump which provides a stronger and richer flavour in the fermentation process while *heuchim-nuruk*, the microorganisms are found on the surface of the fermentation starter which tends to be lighter in flavour and less complex (Lee & Kim, 2017).

### 2.2.3 *Nuruk* quality

From *nuruk* research, it is commonly accepted the quality of *nuruk* is not correlated with saccharification and fermentation power but instead the overall complexity of taste and flavour of the alcoholic beverage (Lee et al., 2017). The term saccharification power refers to the amount of soluble starch being enzymatically converted to simple sugars such as glucose for further processes like fermentation (Lee et al., 2017). When *nuruk* exhibits off-odour or an absence of epiphytic mould spores, this is regarded as inferior (Lee et al., 2017). From Lee et al.'s (2017), they reported that saccharification power was significantly correlated with  $\alpha$ -amylase,  $\beta$ -amylase, and glucoamylase activity.

### 2.2.4 Microbial activities of *nuruk*

As discussed in the previous section, methods of making *nuruk* vary depending on the region in Korea. These regional differences also impact on the microflora profiles of *nuruk* as reported by Song et al. (2013). In Song et al.'s (2013) article, they collected 42 *nuruk* samples from various regions of Korea and identified that not all *nuruk* samples had *Aspergillus oryzae* (the most commonly used mould for saccharification in rice wine processing). Surprisingly, only 18 out of the 42 *nuruk* samples contained *Saccharomyces cerevisiae*, the most commonly used yeast for alcohol fermentation (Song et al., 2013). From Song et al.'s (2013) study, both *Bacillus amyloliquefaciens* and *B. subtilis* were the most commonly found bacterial strains among the *nuruk* samples. The results from Song et al. (2013) indicate that both saccharification and fermentation were likely to be performed by different microbes depending on the regional *nuruk*. **Table 2.1** is a summary of the average cell number of total bacteria, fungi, yeast, and lactic acid bacteria found in *nuruk* from different provinces in Korea. Other researchers have found similar results to Song et al. (2013) as *Aspergillus oryzae* were found in many *nuruk* samples but not all. In this study, Yang et al. (2011) identified *Lichtheimia* and *Aspergillus* in 84% of *nuruk* samples, with *Lichtheimia ramosa* and *Aspergillus oryzae* being the most commonly found species. The findings from both Song et al. (2013) and Yang et al. (2011) show location is likely to play a role in the microbial profile of *nuruk*.

**Table 2.1.** Information about the average viable cell number of total bacteria, fungi, yeast, and lactic acid bacteria found in *nuruk* from difference provinces in Korea.

Note: The units used in **Table 2.1** is log CFU/10g. All experiments were conducted in triplicate with mean  $\pm$  standard deviation being presented, the letter beside the mean  $\pm$  standard deviation indicate the level of statistical significance between different provinces. Information from Song et al. (2013).

### 2.3 Overview of rice wine (*sake*, *huangjiu*, and *makgeolli*)

Rice wine is consumed throughout the world, predominately in the Asian continent with examples including Japanese rice wine (*sake*) (Akaike et al., 2020; Okuda, 2019), Chinese rice wine (sometimes referred to as yellow wine, *huangjiu*) (G.-M. Chen et al., 2021), and Korean rice wine (*makgeolli*) (H.-R. Kang et al., 2016).

All rice wine undergoes simultaneous saccharification and fermentation, where starch hydrolysis and alcoholic fermentation occur at the same time (Cai et al., 2018; Cha et al., 2023; Okuda, 2019). However, the difference between the varieties of rice wine depends on the rice species and the fermentation starter used in the fermentation process. For example, *huangjiu* and *makgeolli* tend to be brewed with glutinous rice while *sake* tends to use non-glutinous rice for fermentation (Okuda, 2019). Compared to *huangjiu* and *makgeolli*, rice cultivars used in Japanese rice winemaking are more selective as 65% of rice wine produced in Japan is rice produced from Yamadanishiki, Gohyakumangoku, and Miyamanishiki (Okuda, 2019). Okuda (2019) explains Yamadanishiki cultivar is valued among sake brewers due to its low level of protein, however, the relationship between the physicochemical properties and sensory attributes between the three

rice cultivars are not well understood. In addition to different rice cultivars used for rice wine brewing, the fermentation starter varies.

For *sake*, the key fermentation starter is *koji* (Akaike et al., 2020), *huangjiu* uses *qu* (G.-M. Chen et al., 2021), and *makgeolli* uses *nuruk* (Lee et al., 2017). The fermentation starter somewhat dictates the microbial communities within the rice wine. For example, *sake* tends to have less microbial activities because *koji* tends to be purified and predominately contain *Aspergillus oryzae* (Akaike et al., 2020). Both *makgeolli* and *huangjiu* show more microbial activity, for example, G.-M. Chen et al. (2021) noted that *huangjiu* contained bacteria such as *Lactobacillus*, *Leuconostoc*, and *Bacillus*, and fungi such as *Weissella*, *Saccharomyces*, *Rhizopus*, *Aspergillus*, and *Candida* were present in the rice wine. For *makgeolli*, a range of fungi and bacteria have been identified including fungi such as *Saccharomyces cerevisiae*, *Aspergillus tubingensis*, *Candida glabrata*, and *Aspergillus niger*; for bacteria, the examples include *Lactobacillus crustorum* and *Lactobacillus brevis* (Kim et al., 2012). Interestingly, one defining feature of *makgeolli* is the high lactic acid bacteria (Nile, 2015) but this trait is considered undesirable for *sake* and can be considered as spoiled (Akaike et al., 2020).

In terms of aroma and flavour between the different rice wines, H.-R. Kang et al. (2016) used SPME-GC/MS to analyse the volatile compounds of *makgeolli*, *sake*, and *yakju* (another variety of Korean rice wine). From Kang et al.'s (2016) study, it was evident that *makgeolli* had a great variety of volatile compounds including esters such as ethyl ethanoate (known for its fruity aroma), 3-methylbutyl ethanoate (known for its banana aroma), ethyl decanoate (known for its sweet fruity and berry like aroma), and 2-phenylethyl acetate (known for its rose and honey aroma) compared to *sake* and *yakju*. H.-R. Kang et al. (2016) commented that *makgeolli* tend to have fruity and flower aromas compared to the other rice wines, from statistical analysis using partial least squares discriminant analysis, *makgeolli*, *sake*, and *yakju* were grouped differently based on the contents of the volatile compounds. In a study carried out by Xia et al. (2023), they identified 36 volatile compounds in their *huangjiu* samples. The 36 volatile compounds include 13 esters, eight alcohols, four aldehydes, one phenol, one acid, one ketone, one ether, and seven other unclassified compounds (Xia et al., 2023). From their study, esters were the most abundant volatile compound with ethyl tetradecanoic and ethyl hexadecenoic being present in all stages of the fermentation process (Xia et al., 2023). A review written by G.-M. Chen et al. (2021), noted regional differences were

observed in the *huanjiu* made from Jiangxi, Guangxi, Shaoxing, Jiangsu, Shanghai, Shangdong, Fujian, Guangdong, Shanxi, Anhui, and Liaoning provinces where esters including ethyl acetate, ethyl 2-hydroxypropanoate (known for creamy and fruity, similar to coconut scent), ethyl hexanoate (known for fruity aroma, similar to apple peel), ethyl phenylacetate (known for a sweet aroma, similar to honey and floral), 2-phenylethyl acetate (known for rose and honey aroma), ethyl benzoate (known for a sweet aroma, similar to grape or black current), diethyl butanedioate (known for having an alcoholic aroma, similar to whiskey and brandy), alcohol including 2-methylpropan-1-ol (known for having a banana aroma), acetaldehyde, furfural, and naphthalene were present (G.-M. Chen et al., 2021).

### **2.3.1 Physicochemical components of Makgeolli**

In this section, the physicochemical components of *makgeolli* including antioxidants, amino acids, and organic acids will be discussed.

#### **2.3.1.1 Antioxidant research on *makgeolli***

Among the chemical tests used to evaluate antioxidant activities, 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity and 2, 2-azino-bis-(2-ethylbenzothiazoline-6-sulfonic) acid (ABTS) radical cation scavenging activity were used the most in *makgeolli* studies. From Bae et al.'s (2012) study, they evaluated the antioxidants of six *makgeolli* samples and one white wine. The results indicate *makgeolli* tend to have lower antioxidant activity based on DPPH and ABTS scavenging activity, however, some *makgeolli* samples tends to have higher total polyphenol content using the Folin-Ciocalteu method (Bae et al., 2010). In terms of incorporating some ingredients into *makgeolli*, there are clear evidence that it improved the antioxidant levels of the alcoholic beverage. Incorporation of specific ingredients into *makgeolli* were reported to improve consumer acceptance such as blueberry and black rice (M.-O. Kim et al., 2015) and eastern prickly pear (*Opuntia humifusa* Raf.) (Choi et al., 2018). For quinoa (*Chenopodium quinoa willd*), incorporating this ingredient into *makgeolli* improved the antioxidant levels, however, no statistical significance was observed for overall acceptance (Jeon et al., 2023).

#### **2.3.1.2 Amino acids and organic acid research on *makgeolli***

Amino acids play a vital role in alcoholic beverage production because they influence the aroma and taste of the final product. In addition, amino acids may also affect the ageing process as the time, temperature, and sediment amount found in *makgeolli* are likely to change their quality during storage (Choi

et al., 2019; Kim et al., 2023). In general, the addition of fermentation starters to rice aids the breakdown of proteins in rice into free amino acids by the bacterial and fungal proteases (Seo et al., 2016). It is important to note, that the free amino acids also contribute to the complex sensory attributes such as umami, sweet, bitter, and astringency in rice wine (Liu et al., 2022). Similar to amino acids, organic acids can also influence the taste and flavour of rice wine. During fermentation, large amounts of sugar are converted to organic acids by carbohydrate metabolism (Liu et al., 2022). Organic acids provide sourness within the rice wine and also provide colour to the beverage (Liu et al., 2022). Organic acids also reduce the diversity of microorganisms in the rice wine which in some cases inhibits the growth of pathogenic bacteria providing food safety for the wine (Liu et al., 2022). In terms of research availability on both amino acids and organic acids on *makgeolli*, the studies available are relatively limited in the English literature.

In Kang et al.'s (2014b) study, they investigated the correlation between initial amino acid profiles in *makgeolli* and whether it was a predictor of forming major aromatic compounds such as fusel alcohols, acetate esters, and ethyl esters of fatty acids in the finished product. From their results, Kang et al. (2014b) concluded that fusel alcohols and acetate esters were positively correlated with the amino acid profiles from the *makgeolli* mash (a product with combined fermentation starter, cooked rice, and water that did not undergo fermentation) amino acid profile. However, ethyl esters such as ethyl hexanoate, ethyl octanoate, and ethyl decanoate were poorly correlated with the  $R^2$  range from 0.17 to 0.40 (Kang et al., 2014b). From this study, Kang et al. (2014b) showed a relationship between amino acids in the initial product and how it affects the aroma and flavour, once fermentation is completed. The volatile compounds that showed high correlation include 2-methylpropan-1-ol (known for the sweet and fruity smell), 3-methylbutan-1-ol (known for a banana scent), 2-methyl butanol, 2-methylpropyl acetate (known for fruity aroma, similar to pears and raspberries), 3-methylbutyl acetate (known for fruity aroma, similar to bananas and pears), 2-methylbutyl acetate (known for fruity aroma, similar to apples and pears), and 2-phenylethyl acetate (known for fruity aroma, similar to raspberries) in the *makgeolli* products (Kang et al., 2014b).

In a different study, Song et al. (2022) investigated the differences between commercial *makgeolli* and traditional *makgeolli* (called *gayangju*, traditional *makgeolli* hereafter) by measuring amino acids, volatile compounds, and microbial growth. The key difference between commercial *makgeolli* and traditional *makgeolli* that Song et al. (2022) highlighted was that traditional *makgeolli* uses *nuruk* for

saccharification and fermentation, while commercial *makgeolli* rely on extracted yeast and enzymes for the same process. Additionally, Song et al. (2022) also investigated how periods of fermentation and storage (e.g., 40 days of fermentation and an additional 28 days of storage). For the saccharification and fermentation to take place, glucoamylase,  $\alpha$ -amylase, and *Saccharomyces cerevisiae* were added to the cooked rice (Song et al., 2022). From the study, it was evident that the traditional *makgeolli* had a higher and more diverse amino acid profile. Song et al. (2022) noted that some amino acids such as aspartic acid (associated with flavours of richness) were two times greater in the traditional *makgeolli* than the commercial *makgeolli*. Other amino acids that are associated with sweetness such as threonine, serine, and alanine were at least 1.5 to 2-fold higher in the traditional *makgeolli* compared to the commercial *makgeolli* (Song et al., 2022).

In a recently published article by Tak et al. (2024), they examined the organic acids, amino acids, and fatty acids of three Korean rice wines including *makgeolli*, *yakju*, and traditional-*soju*. The results from the study indicate that organic acids varied, depending on the Korean rice wine. For example, *makgeolli* had higher concentration levels of pyruvic acid and glucuronic acid, *yakju* had high amounts of succinic acid and lactic acid, and traditional-*soju* had high amounts of malonic acid, malic acid, tartaric acid, and gluconic acid (Tak et al., 2024). For the three amino acids (e.g., alanine, phenylalanine, and leucine) and the five fatty acids (e.g., *cis*-9-octadecanoic acid, octadecanoic acid, decanoic acid, nonanoic acid, and octanoic acid) were most abundant in *makgeolli* compared to *yakju* and traditional-*soju* (Tak et al., 2024). Tak et al. (2024) commented the differences in organic acids, amino acids, and fatty acids are likely to be attributed to the distillation process and filtration method.

### **2.3.2 Volatile compounds found in *makgeolli***

As discussed in the previous sections, the aroma and flavour of rice wine are influenced by many factors including the metabolism of sugar and the breakdown of proteins into free amino acids. Although many factors can influence the metabolism of the sugar and proteins such as temperature, time, and environment, researchers have emphasised on the importance of saccharification and fermentation agents used in the process of making *makgeolli*. For example, Seo et al. (2016) demonstrated the selection of yeast (e.g., fermentation agent) is a critical step in the development of aroma and flavour for *makgeolli* as the metabolomics including sugar, amino acids, and polyols differs significantly in the *makgeollis* made by

either *Saccharomyces bayanus*, *Saccharomyces cerevisiae*, and *Saccharomyces coreanus*. In a different study, Cha et al. (2023) showed disparities in the microbial and metabolic profiles based on the saccharification agent used in making *makgeolli* between *nuruk* and *koji*. The results from Cha et al.'s (2023) study indicate *makgeolli* made from *koji* had lower overall microbial diversity compared to *makgeolli* made from *nuruk*. This can be attributed to the fact that manufacturers of *nuruk* encourage colony growth of other microbes while *koji* only contains a select few microbes specifically *Aspergillus oryzae*. In addition, the concentration of organic acids and sugars tends to be higher in *makgeolli* made from *nuruk*, however, sensory evaluation data was not included in this study (Cha et al., 2023).

One of the key studies that is often cited is Jung et al.'s (2014) study on the chemical and sensory profiles of *makgeolli* using descriptive analysis, chemical, and volatile compounds for volatile and sensory research on *makgeolli*. This study allowed researchers to establish a correlation between volatile compounds and sensory attributes on *makgeolli* as volatile compounds and sensory attributes were quantified. In Jung et al.'s (2014) study, 45 major volatile compounds were identified consisting of 33 esters, 8 alcohols, 1 aldehyde, 1 acid, 1 phenol, and 1 terpene. Between 28 and 35 volatile compounds were found in each of the 12 *makgeolli* samples examined (Jung et al., 2014). The most abundant volatile compounds found in Jung et al.'s (2014) study were 2-phenylethanol (known for having a floral and rose-like aroma) and ethanol, while 10 esters were predominant in the *makgeolli* samples including ethyl decanoate (known for a sweet and apple-like aroma), ethyl (Z)-octadec-9-enoate (known for a sweet aroma, similar to ripe fruits), ethyl octanoate (known for a sweet aroma, similar to pineapple-like notes), 2-pethethyl acetate (known for sweet aroma similar to rose and honey), ethyl acetate (known for sweet, fruity aroma, similar to pears and banana), 3-methylbut-1-yl ethanoate (known for sweet and fruity aroma, similar to banana), Ethyl hexadecanoate, ethyl 9,12-Octadecadienoate, Ethyl dedecanoate, and Ethyl tetradecanoate. In terms of the volatile compounds and physicochemical properties that correlated well with sensory attributes examined via descriptive analysis, these properties including Ethyl octanoate, Ethyl dedecanoate, ethanol, 2-Methyl-1-propanol, 2-Phenethyl acetate, *b*-value (Hunter analysis, *b*-value for colour analysis), total acidity, Ethyl heptanoate, and Ethyl octanoate (Jung et al., 2014). The correlated sensory attributes will be discussed in the following section in the sensory attributes of *makgeolli*.

In the next few paragraphs, volatile compounds were examined in different aspects of *makgeolli* processing. These processing features include pasteurisation (Park et al., 2013), the use of different saccharification and fermentation agents (Choi et al., 2024; Park et al., 2014; Song et al., 2022), and additional ingredients such as banana (Kim et al., 2013) and black extracts (Jeong, 2011).

In Park et al.'s (2013) study, they investigated the volatile compound differences between pasteurised and unpasteurised *makgeolli*. Many *makgeolli* products in the market are sold either pasteurised or unpasteurised, due to its unique feature of containing lactic acid bacteria that is perceived to be beneficial to human health (Nile, 2015). However, *makgeolli* also contains microbes such as *Micrococcus*, *Bacillus*, *Aerobacter*, and *Pseudomonas* spp., which can lead to spoilage (Park et al., 2013). In this study, Park et al. (2013) fermented two batches of *makgeolli* (one being pasteurised and the other not) and stored for 30 days at 4 °C. A total of 11 volatile compounds were identified including 3-methyl-butanol (banana or pear-like aroma), 2-methyl-1-butanol, 2,3-butanediol, butanoic acid (rancid or cheesy aroma), 3-methylbutanoic acid, 2-methylbutanoic acid, 3-(methylthio)-1-propanol, 2-phenylethanol (floral-like or rose-like aroma), ethyl decanoate (fruity and sweet aroma, similar to apple or pears), ethyl dodecanoate, and ethyl tetradecanoate (Park et al., 2013). Although no statistical significance was observed in the initial storage time for both pasteurised and unpasteurised *makgeollis*, the volatile compounds from the unpasteurised *makgeolli* increased significantly (Park et al., 2013).

In terms of the differences between commercial *makgeolli* and traditional *makgeolli*, Song et al. (2022) investigated the similarities and differences in the volatiles identified between the two different processing methods. The commercial *makgeolli* was processed using glucoamylase,  $\alpha$ -amylase, and *Saccharomyces cerevisiae* for saccharification and fermentation, while traditional *makgeolli* used *nuruk*. As discussed in the previous section, the traditional *makgeolli* had a higher concentration and more diverse amino acid profile. In terms of the volatile compounds, the most significant volatile compound was 2-methyl-1-butanol (known to have a fruity aroma and a characteristic of strong alcoholic beverages) (Song et al., 2022). Other volatile compounds that increased or saw significant changes over the ageing process of the traditional *makgeolli* include 2,3-butanediol (known for having a sweet aroma), 3-methyl-1-butanol, ethyl tetradecanoate (known for having sweet, fruity, creamy, waxy, and also coconut-like notes), ethyl decanoate (known for having a fruity aroma, similar to grape or brandy), ethyl dodecanoate (known for having a sweet,

fruity, and waxy aroma), butanoic acid (known for having rancid, sour and vomit-like aroma similar to rancid butter or cheese), 3-methylbutanoic acid, 2-methylbutanoic acid, 2-methyl-1-propanol, ethyl acetate (known for having a pear or nail polish remover aroma), ethyl caprylate (known for having a fruit, sweet, and aromas similar to apples), 2-phenylethanol (known for having a floral and rose-like aroma), and 3-methylbutyl acetate (known for having a banana aroma) (Song et al., 2022).

In some amino acids and organic acids experiments associated with *makgeolli*, additional ingredients have been added such as banana (Kim et al., 2013), black garlic (*Allium sativum*) (Jeong, 2011), wheat-rice mixture (Park et al., 2014) to the fermentation process. Active volatile compound studies were carried out to determine whether additional ingredients improved the flavour and aroma of the *makgeolli*. For example, Kim et al. (2013) compared traditional *makgeolli* and *makgeolli* supplemented with banana, and 39 volatile compounds were detected with ethyl acetate (known for having sweet and fruity aroma, similar to pears or bananas) being the major ester for both the traditional *makgeolli* and *makgeolli* supplemented with banana samples. In terms of the major volatile compound derived from alcohol, both samples varied with 3-methylbutanol being the major alcohol volatile compound for traditional *makgeolli*; 2-methyl-1-propanol for *makgeolli* supplemented with banana (Kim et al., 2013). In a different study, Jeong (2011) examined whether the incorporation of black garlic into *makgeolli* improved the physicochemical and microbial properties of the alcoholic beverage, experiments included pH, organic acid, free sugar, total activity, and total soluble solid content, colour, and total viable cells for lactic acid bacteria and yeast were examined. In addition, active volatile compounds were assessed using GC-MS. From Jeong et al.'s (2011) study, the volatile compound with the highest peak for *makgeolli* samples (with and without garlic) was ethyl acetate. Interestingly, 2-methyl-1-propanol was also found in *makgeolli* with garlic similar to the *makgeolli* with banana but low in traditional *makgeolli* (Jeong, 2011; Kim et al., 2013). Lastly, Park et al. (2014) conducted a two factorial study where they examined different yeast (including *Saccharomycopsis fibuligera* CJN1020, *Pichia jadinii* CJN1287, and *Saccharomyces cerevisiae* CJN1514) and carbohydrate source (including white rice and a combination carbohydrate source of white rice, brown rice and wheat, referred to as WBW hereafter). From the study, Park et al. (2014) identified 40 volatile compounds including 11 alcohols, 20 esters, 2 carbonyls, 4 hydrocarbons, and 3 non-classified groups. Not surprisingly, WBW samples tend to have more volatile compounds due to the different carbohydrate sources incorporated in the processing

method of making *makgeolli* (Park et al., 2014). In addition, 3-methylbutan-1-ol (known for a banana scent), and benzeneethanol were detected in both white rice *makgeolli* and WBW *makgeolli* (Park et al., 2014).

### **2.3.3 Sensory research on *makgeolli***

This final section of the literature review will be divided into two parts, the first part is a brief overview of sensory evaluation and the second part is about the sensory research conducted on *makgeolli* that is published in the English literature.

#### **2.3.3.1 Brief overall of sensory evaluation**

Firstly, sensory evaluation is a scientific method that is used to evoke, measure, analyse, and interpret information from individuals perceived through the sense of sight, smell, touch, taste, and hearing (Lawless & Heymann, 2010). Therefore, sensory evaluation uses the basic physical principles of psychophysics to establish how humans respond to physical stimuli (Lawless & Heymann, 2010).

In terms of the experiments and tests carried out in sensory evaluation, these can be classified into three main classes including difference (a.k.a., discrimination) testing, descriptive testing, and affective testing (Lawless & Heymann, 2010). Both discrimination and descriptive testing are analytic tests which means participants are selected based on their knowledge and good sensory acuteness to the characteristics of the product such as taste, smell, and texture (Lawless & Heymann, 2010). Difference testing is the simplest class of sensory methods because it is about establishing whether perceptible differences exist between two types of products (Lawless & Heymann, 2010).

For descriptive testing, this sensory method is to profile a product on its sensory characteristics (Murray et al., 2001). Generally speaking, the analytic test requires participants to undergo a certain level of training or product knowledge before taking part in descriptive testing (Murray et al., 2001). However, descriptive testing is often described as laborious and resource-intensive for the participants and the researcher who is carrying out this sensory method (Valentin et al., 2012). Alternatives such as ‘check-all-that-apply’ (CATA), flash profiling, free sorting task, projective mapping (sometimes called napping®), polarised sensory positioning, and pivot profile® have been developed to conventional descriptive testing such as descriptive analysis which is more cost-effective and less time-consuming (Valentin et al., 2012).

Lastly, affective testing attempts to quantify the degree of liking of a product (Lawless & Heymann, 2010). The sensory methods used to establish the degree of liking vary from preference testing (selecting one product out of a group of products) or hedonic testing (e.g., rating products on a 9-point scale).

### **2.3.3.2 Sensory research on *makgeolli* in the English literature**

From available research on the sensory evaluation of *makgeolli*, the majority of the studies conducted were acceptance tests (a subcategory of affective testing) where consumers were asked to what degree they liked or disliked a typical *makgeolli* sample. These studies include *makgeolli* brewed with licorice (*Glycyrrhiza uralensis* Fisher) (Li et al., 2022), *makgeolli* brewed with blueberry and black rice (M.-O. Kim et al., 2015), and *makgeolli* brewed with prickly pear (*Opuntia humifusa* Raf.) (Choi et al., 2018).

Studies that focus on other sensory evaluation methods excluding acceptance tests on *makgeolli* are very limited in the English language. For example, three studies conducted by Jung et al. (2014); Kang et al. (2014a) and Kim and Kim (2015) explicitly state *makgeolli* in their title and different sensory evaluation methods were used. Jung et al. (2014) carried out descriptive analysis in their study, while Kang et al. (2014a) evaluated the basic taste (e.g., sweetness, sourness, bitterness, umami, and saltiness) on a 7-point scale. In another study, Kim and Kim (2015) measured biometric information such as brainwaves while participants consumed *makgeolli*.

As discussed in the previous section, Jung et al. (2014) investigated the physicochemical properties of *makgeolli* and used descriptive analysis to evaluate 22 sensory attributes of the 12 *makgeolli* samples. As part of the descriptive analysis process, Jung et al. (2014) trained 10 panellists with six 1 hr training sessions were held to establish the 22 sensory attributes, definitions and overall panel etiquette. From the study, Jung et al. (2014) found a strong correlation between sensory attributes and physicochemical properties of *makgeolli*, these sensory attributes include appearance (e.g., whiteness, yellowness, turbidity, and bubbles), aroma (e.g., sour, sweetness, fruitiness, roasted cereal, yeast, mouldiness), flavour (e.g., sweet, sour, roasted cereal), mouth feel (e.g., mouth feel, astringency, full body, and carbonation). For the volatile compounds and physicochemical properties that were strongly correlated to sensory attributes for *makgeolli* please refer to **Section 2.3.2**.

In a different study conducted by Kang et al. (2014a), Kang et al. (2014a) evaluated whether readings from the electronic tongue ( $\alpha$ -Astree2 E-tongue) correlated well with sensory evaluation and the amino acid/fatty acid profiles of each *makgeolli*. Kang et al. (2014a) used descriptive testing to determine the sweetness, sourness, saltiness, umami, and bitterness of each *makgeolli*, by panellists scoring each taste on a 7-point scale. Reference solutions such as fructose, citric acid, sodium chloride, monosodium glutamate, and caffeine were consumed and were used as a frame of reference while scoring the taste intensity on the 7-point scale (Kang et al., 2014a). From the study, the electronic tongue correlated well with sensory evaluation information apart from bitterness (Kang et al., 2014a).

## Chapters 3. Characterisation of Korean rice wine (*makgeolli*) prepared by different processing methods

### 3.1 Prelude

Chapter 3, *Characterisation of Korean rice wine (makgeolli) prepared by different processing methods* examines the different processing methods of making *makgeolli* in scientific literature. Although this alcoholic beverage has a long history with Korean culture, many studies use different methods of producing *makgeolli*, therefore it is difficult for researchers and manufacturers to optimise, develop, or tailor *makgeolli* to the consumers' taste. Therefore, it is important to understand and identify the different methods of *makgeolli*, especially its chemical and sensory properties. Currently, there are four uniquely different ways of producing *makgeolli* that were identified for this research. The four ways of producing *makgeolli* include (1) single-stage saccharification and fermentation process with *nuruk* (traditional Korean fermentation starter culture) only (1SF-N), (2) single-stage saccharification and fermentation process with yeast and *nuruk* (1SF-YN), (3) two-stage saccharification and fermentation process with a combination of non-glutinous and glutinous rice as the carbohydrate source (2SF), and (4) three-stage saccharification and fermentation process with a combination of non-glutinous and glutinous rice (3SF).

This chapter is divided into two parts. First, to determine the physicochemical properties of *makgeolli* such as amino acid, sugar, organic acids, antioxidants, pH, ethanol, mineral content, and proximate composition. Second, to understand participants' perception of *makgeolli* by using polarised projective mapping with sweetness (e.g., sucrose solution), sourness (e.g., citric acid solution), and bitterness (e.g., quinine solution) as references or 'poles' for comparison. The results indicate that 1SF-N had the highest alcohol content (13% ABV), antioxidant, and free amino acid due to the high amount of *nuruk* used for saccharification and fermentation. However, 1SF-N is perceived as the least liked *makgeolli* sample. In comparison, 2SF had the highest concentration of glucose and maltose and is the most liked *makgeolli*. Sweetness is likely to be a determining factor for consumers' liking towards *makgeolli* and sourness should be reduced.

### 3.2 Introduction

*Makgeolli*, also known as Korean turbid rice wine, is a traditional Korean alcoholic beverage made from fermentation of glutinous rice with a starter culture called *nuruk* (S. Kim et al., 2015; Lee et al., 2015; Son et al., 2018). The beverage can be described as a whitish to yellowish opaque liquid with a sweet fruity aroma, slightly bitter, alcoholic, and sour taste. Most commercial *makgeollis* have an alcohol content of about 6–8% by volume and a pH between 3.6 and 4.4 (Jung et al., 2014). *Nuruk* is a traditional Korean rice wine starter culture made by grinding wheat, barley and rice followed by the addition of water to proliferate microorganism growth. The microbes in the *nuruk* depend on the grain source and the fermentation environment, hence the microbial community can vary significantly between products (Kwon & Sohn, 2012). However, the main microbes essential for the fermentation of *makgeolli* are *Saccharomyces cerevisiae*, *Aspergillus* spp, *Lactobacillus* spp, *Rhizopus* spp, and *Penicillium* spp. The  $\alpha$ -amylase,  $\beta$ -amylase, glucoamylase enzymes produced by *Aspergillus* spp and *Rhizopus* spp are responsible for the saccharification of rice starch. *Saccharomyces cerevisiae* are responsible for converting the sugars into alcohol and fruity esters while the *Lactobacillus* spp creates a tarty flavour in *makgeolli* (Lee et al., 2007).

Previous studies have mainly focused on the metabolites, volatiles, and microbial profiles from a single stage fermented (1SF) *makgeolli* (Jeon et al., 2010; Kim et al., 2013; Lee et al., 2013). This is the most common *makgeolli* fermentation process and involves washing and soaking of the glutinous rice, followed by draining and steaming. Next, the rice is cooled to 25 °C and mixed with water, *nuruk* and additional yeast (*S. cerevisiae*) to initiate the fermentation process. After seven days of fermentation at room temperature, the mixture is filtered and bottled to give the final *makgeolli* product. There are other *makgeolli* processing routes that have been reported such as a two-stage (2SF) (Kang et al., 2014a; S. Kim et al., 2015) and a three-stage fermented (3SF) *makgeolli* (Nile, 2015). The reasons for using multiple stage fermentations however were not stated and are not immediately obvious. The most apparent advantages of 1SF over 2SF and 3SF are the lower production time and the lower energy input. As mentioned earlier, 1SF *makgeolli* only requires seven days of fermentation but 2SF and 3SF *makgeolli* processes would require 10 and 12 days of fermentation respectively and require more processing steps. In summary, the 2SF and 3SF *makgeolli* products have been studied to a much lesser extent in terms of their chemical, nutritional, physicochemical, and sensory properties. Therefore, this study will investigate whether 2SF and 3SF may offer advantages

over the 1SF process when producing *makgeolli*. As *makgeolli* becomes a more globally accepted beverage, it is of interest to determine the sensory preferences of other non-Korean consumers. A study of United States consumers found that a sweeter Korean rice wine was preferred (Kwak et al., 2015).

This work is divided into two parts. The first part aims at filling the knowledge gap by comparing and investigating the antioxidant activity, total phenolic content, amino acid profile, sugar profile, organic acid profile, mineral content, and the major physicochemical properties of *makgeolli* products made using 1SF, 2SF and 3SF processing routes. The second part involves the use of the polarised projective mapping (PPM) technique for sensory evaluation to show how New Zealand consumers in particular perceive *makgeolli*, as little is known about consumers' perception of this beverage outside of Korea.

This mixed method approach is novel to food science because most food studies focus on either food chemistry or sensory science. When the two different fields of food science are combined, sensory acceptance tests are typically used to establish the overall liking of the food product. These tests do not necessarily further improve our understanding of how food products are perceived unless other sensory science tests such as discrimination or descriptive testing are utilised.

The significance of this study will allow the rice wine industry and brewers to select the most suitable processing route to produce a *makgeolli* with desirable attributes for non-Koreans and it also contributes to the evaluation of a relatively new method (polarised projective mapping) in the field of food sensory research (Ares et al., 2013; De Saldamando et al., 2015; Horita et al., 2017; Wilson et al., 2018) by applying the technique to holistic evaluations and perceptions of *makgeolli*.

### **3.3 Materials and method**

#### **3.3.1 Materials**

##### **3.3.1.1 Makgeolli materials**

Glutinous rice (*Oryza sativa* var. *glutinosa*), short grain non-glutinous rice (*Oryza sativa* subsp. *japonica*) and wheat based-*nuruk* were sourced from Wang Ltd., Korea. Safale US-05 dry ale yeast was sourced from Fermentis, S.I. Lesaffre, France.

### 3.3.1.2 Chemicals and reagents

Trolox, 2,4,6-Tris(2-pyridyl)-s-triazine (TPTZ), neocuproine, gallic acid, Folin-Ciocalteu reagent, methanol, pyruvic acid, malonic acid, fumaric acid, citric acid, dry acetonitrile, phenol, D4-alanine, amino acid standard, pyridine and multielement standard solution for microwave plasma atomic emission spectroscopy (MP-AES) were purchased from Sigma-Aldrich, US. Malic acid, sucrose, D(+)galactose anhydrous and D(+)maltose were sourced from British Drug Houses (BDH) Chemicals Limited, UK. Iron (III) chloride, succinic acid, ascorbic acid, and anhydrous sodium sulphate were bought from Scharlab, Spain. Petroleum ether (analytical grade, 60–80 °C), hydrochloric acid (37%), sulphuric acid (97%), ammonium acetate, ammonium heptamolybdate, nitric acid (68%), formic acid, glacial acetic acid, acetonitrile, boric acid, potassium sulphate, sodium bicarbonate, sodium hydroxide, sodium carbonate and copper(II) sulphate were purchased from Thermo Fisher Scientific, US. Monopotassium phosphate was purchased from Interchem, NZ. Copper(II) chloride was purchased from VWR International, US. Methyl chloroformate were obtained from Merck, US. Absolute ethanol was obtained from Pauling Industries Limited, New Zealand. Chloroform was bought from Acros Organics, Spain. D(+)glucose anhydrous was purchased from Biolab limited, Australia. Borate was sourced from Pure Science Ltd., New Zealand. AccQ-Tag™ reagent for amino acids analysis was purchased from Apollo Scientific Ltd., UK. All chemicals were reagent grade.

### 3.3.2 Preparation of *makgeolli*

Preparation of single-stage fermented (1SF-N) *makgeolli* with *nuruk* involved weighing 2 kg of glutinous rice, followed by washing until the water ran clear (Jeon et al., 2010). The rice was soaked for 3 h, then drained for 1 h before subjecting to steaming for 120 min. The rice was then cooled to 25 °C followed by mixing with 3 L of de-ionised (DI) water and 500 g of ground *nuruk*. The mixture was fermented at 25 °C for 7 days. The resulting *makgeolli* (around 2 L) was filtered, bottled, and stored in a fridge at 4 °C until further analysis. Samples are analysed within three days from production.

Single-stage fermented yeast and *nuruk* (1SF-YN) *makgeolli* was made by the method reported by Kim et al. (2013). The preparation was similar to 1SF-N *makgeolli* with some modifications. The modifications were 40 g of ground *nuruk* and 11 g of dry yeast were used. The purpose of the yeast was to substitute a significant portion of the *nuruk*.

Preparation of two-stage fermented (2SF) *makgeolli* involved the same washing and draining process as 1SF-YN but also included the addition of a fermentation base (Kang et al., 2014b). The base was prepared by milling 400 g of non-glutinous rice into a fine powder using a blender (Russell Hobbs, UK). The resulting powder was mixed with 1.25 L of DI water and cooked for 15 min and cooled to 25 °C, followed by addition of 200 g of ground *nuruk* and then left to ferment for 1 day at 25 °C. This was used as a fermentation base for the next stage. Two kilograms of glutinous rice were washed, drained, and steamed in the same fashion as preparing for 1SF. One litre of the fermentation base was mixed with 1.5 L of DI water and steamed glutinous rice followed by 7-day fermentation at 25 °C.

Preparation of three-stage fermented (3SF) *makgeolli* followed the same procedure as 2SF except the fermentation base was fermented twice. For example, 1 L of the fermented non-glutinous base was added into another 400 g of washed, drained, milled and cooked non-glutinous rice. This was left to ferment without adding *nuruk* for 1 day at 25 °C and subsequently this second fermentation base was added to the steamed glutinous rice for the main fermentation. A summary of the preparation of these four styles of *makgeolli* are depicted in and all the *makgeolli* samples were prepared in quadruplicate for analysis.

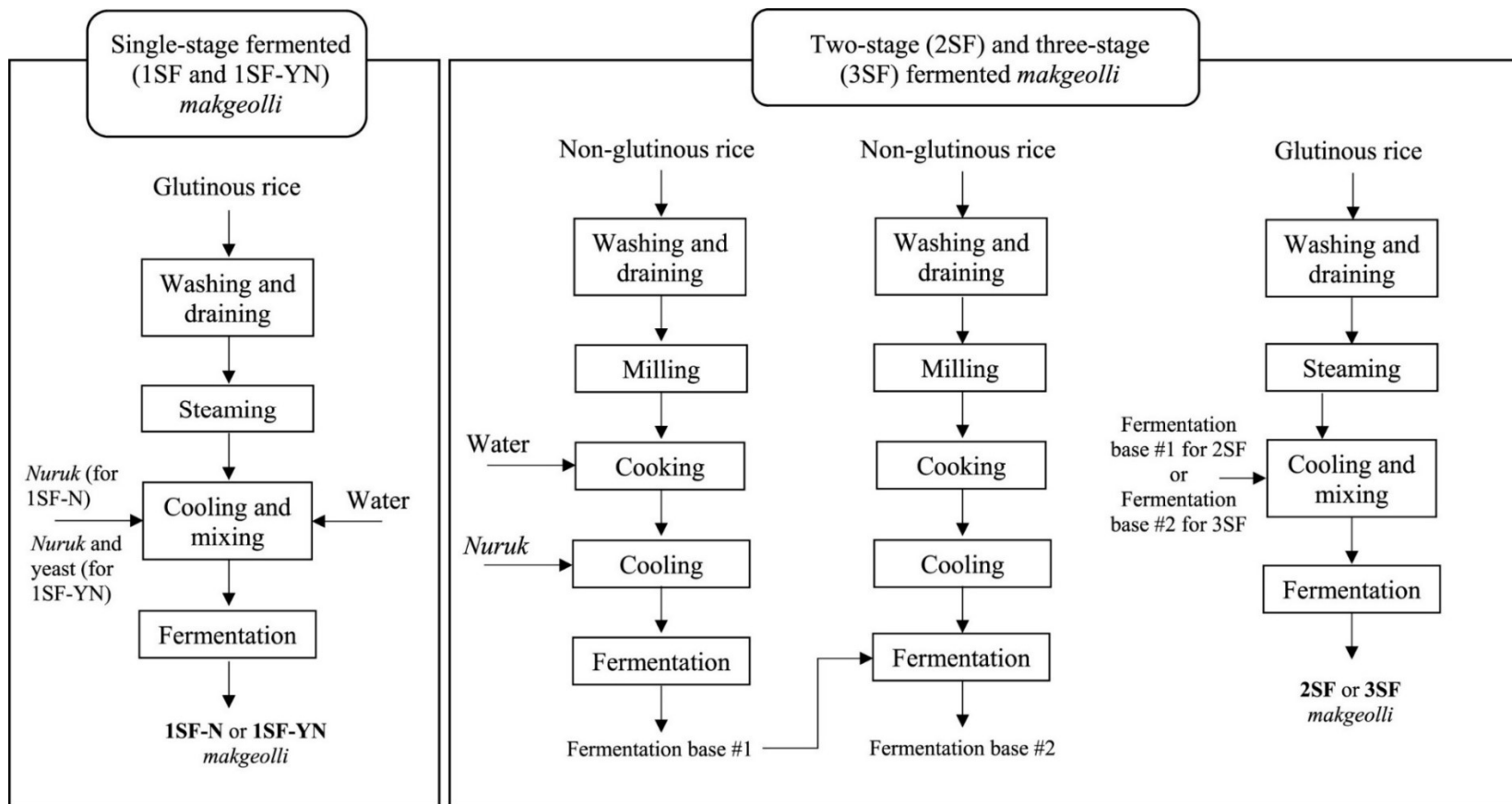


Figure 3.1 Process flow diagram showing four methods of making *makgeolli*.

From Wong, Muchangi, et al. (2023).

### 3.3.3 Proximate, alcohol, acetic acid, pH, minerals and colour analysis

Standard Association of Official Analytical Chemist (AOAC) methods were used to analyse for ash (method 942.05) (Thiex, Novotny, et al., 2019), protein (method 954.01) (Bicsak, 2020) and lipid (method 920.39) (Thiex, Anderson, et al., 2019) in the *makgeolli* samples. The AOAC method 925.09 for moisture content was not used because oven drying would caramelize the carbohydrates and give inconsistent results. Instead, the *makgeolli* samples were freeze-dried in a Christ® Alpha 2–4 LSC Plus freeze dryer (Germany) for 5 days to determine the moisture content. Total carbohydrate was determined using the sulphuric acid-phenol method described by (Chow & Landhäusser, 2004).

The concentration of ethanol and acetic acid were measured by GC/FID using a Shimadzu GC-2010 Plus gas chromatograph (Shimadzu, Japan) equipped with a split/splitless injector, a flame ionisation detector (FID) and fitted with an Agilent Durabond – Fatwax Ultra Inert column which has 30 m length x 0.25 mm i. d. x 0.25 µm film thickness (Agilent, USA). The alcohol concentration was reported in percentage alcohol by volume (ABV).

Colour determination was performed using the protocol of (Tangsriang et al., 2019). The equipment used for analysis was a Hunter lab ColorFlex 45/0 V1.80 spectrophotometer (HunterLab, Virginia, USA). Colour values were given as CIE L\* (light/dark), a\*(+red/-green) and b\* (+yellow/-blue).

Minerals analysis was done according to the principle of (Poitevin, 2019). After digesting with concentrated nitric acid in a microwave digester (Anton Paar Multiwave GO Plus, Austria) and dilution, the samples were analysed with an Agilent Technologies 4200 microwave plasma atomic emission spectrometer (USA). The pH was measured using an Oakton pH 700 Bench Meter (Oakton Instruments, USA).

### 3.3.4 Antioxidant capacity and total phenolic content

Three different antioxidant assays were carried out on the *makgeolli* samples to check for false positives/negatives. All the *makgeolli* samples were diluted by a factor of 10 before analysis and all the antioxidant results were expressed in mg Trolox equivalent (TE) per L of *makgeolli* through comparison to a standard curve.

The *phosphomolydenum* (*phospho.*) assay was performed as outlined by (Ivanišová et al., 2016). One mL of diluted *makgeolli* sample was mixed with 2.8 mL  $\text{KH}_2\text{PO}_4$  (0.1 M), 6 mL  $\text{H}_2\text{SO}_4$  (1 M), 0.4 mL

(NH<sub>4</sub>)<sub>6</sub>Mo<sub>7</sub>O<sub>24</sub> (0.1 M) and 0.8 mL of distilled water in a glass vial. Once vortexed, the samples were incubated at 90 °C for 120 min. The samples were rapidly cooled in an ice water bath, then the absorbance measured at 700 nm.

The ferric-ion reducing antioxidant power (FRAP) assay involved the following procedure according to (Benzie & Strain, 1996). 0.1 mL of diluted *makgeolli* was mixed with 2 mL of FRAP reagent and 0.9 mL of distilled water and then left to react for 5 min at ambient temperature. The absorbance of the samples was measured at 593 nm.

The *cupric reducing antioxidant capacity (CUPRAC) assay* is described by (Özyürek et al., 2011) with slight modifications. One mL of diluted *makgeolli* was added to 1 mL CuCl<sub>2</sub> (0.01 M), 1 mL of NH<sub>4</sub>Ac (1 M), 1 mL of neocuproine (0.0075 M) and 0.1 mL of distilled water. The solution was left to react for 5 min at ambient temperature and its absorbance was measured at 450 nm.

The *Folin-Ciocalteu (FC) total phenolic assay* was carried out according to the method reported in Singleton et al. (1999) with slight modifications. Ten-fold diluted *makgeolli* with distilled water (1 mL) was mixed with 500 µL of FC reagent in a glass vial and left to react for 5 min at ambient temperature. Twenty percent (m/v) Na<sub>2</sub>CO<sub>3</sub> (1.5 mL) was then added to the solution and vortexed for 10 s. The glass vial was left to react for 2 h in the dark. The absorbance was measured at 765 nm. Total phenolic content was expressed in mg gallic acid equivalents (GAE)/L *makgeolli*.

### **3.3.5 Sugar analysis by high performance liquid chromatography coupled with evaporative light scattering detector (HPLC-ELSD)**

Glucose, galactose, and maltose were used as the calibration sugar standards. An adaptation of a procedure by (Chessum et al., 2022), was used. Briefly, the 1SF-N, 1SF-YN and 3SF *makgeolli* samples were diluted tenfold using ultrapure water. For the 2SF *makgeolli* sample, a 25-fold dilution was performed. The diluted *makgeolli* samples (3 mL) and 60 µL of xylitol (internal standard) were mixed with 3 mL of chloroform to create a monophasic liquid. The solution was vortexed at medium speed for 30 s. The solution was then centrifuged at 1300×g for 10 min. The bottom chloroform part was discarded. This process was repeated two more times. One millilitre of the upper aqueous part was then drawn out and centrifuged at 1300×g at 4 °C for 10 min before HPLC analysis. A Shimadzu-10 A Auto Injector (Shimadzu Corporation,

Japan) coupled to a Shimadzu LC-10ATVP pump were used for the liquid chromatography analysis. Separation of sugars was achieved using a Luna® Omega 3 µm SUGAR 100 A 250 × 4.6 mm LC Column (Phenomenex, USA). The mobile phase was 80% Acetonitrile – 20% Milli-Q water, isocratic dilution. Injection volume was 5 mL at a flow rate of 0.5 mL/min. An Agilent 385-ELSD detector (Agilent Technologies, USA) was used for the detection of compounds. Instrument grade nitrogen gas (BOC) controlled by an Agilent N2-14-K727 nitrogen gas generator was set at a flow rate of 1.2 mL/min. The evaporator temperature was 80 °C, and the nebuliser temperature was 50 °C.

### **3.3.6 Organic acids analysis by methyl chloroformate (MCF) Derivatisation**

All the standards and samples were frozen using liquid nitrogen before freeze-drying overnight in a freeze-dryer (Virtis SP Scientific Advantage Pro, USA). Derivatisation with methyl chloroformate (MCF) was done according to the protocol of Smart et al. (2010) with d4-alanine as the internal standard. An Agilent 7890 B gas chromatograph coupled to an Agilent 5975 B single quadrupole mass spectrometer (Agilent, USA) and a Gerstel multipurpose autosampler (Gerstel, Germany) were used for gas chromatography – mass spectrometry analysis. Briefly, 1 µL of each sample was injected into a 4 mm glass splitless inlet packed with deactivated glass wool. The inlet temperature as 290 °C; the column flow was 1.0 mL/min; and the initial average linear velocity was 35 cm/s. Purge flow was set at 25 mL/min, 1 min after injection. The column used was a fused silica DB-1701 30 m × 0.25 mm x 0.25 µm stationary phase (86% dimethylpolysiloxane, 14% cyanopropyl phenyl) Agilent column (Agilent technologies, USA). The carrier gas used was instrument grade (99.99%, BOC) helium gas. GC oven temperature was set as follows: The temperature was raised to 45 °C and held for 2 min, then increased at a rate of 9 °C/min to 180 °C and held at this temperature for 5 min. The temperature was again increased by 40 °C/min to 220 °C where it was held for 5 min. The temperature was increased again at a rate of 40 °C/min to 240 °C and held for 11.5 min. The temperature was finally ramped up by 40 °C/min to 280 °C and held for 10 min. The transfer line to the mass spectrometric detector was maintained at 250 °C, the source at 230 °C and the quadrupole at 150 °C. The detector was turned on 5.5 min into the run. The detector was run in positive-ion, electron-impact ionisation mode, at 70eV electron energy. MassHunter software (version b.07.01 sp1; build 7.1.524.1), was used to interpret the data. Identification of compounds was performed by comparing the results to the National Institute of Spectral library (NIST, version 2.2; build Jun 10, 2014).

### 3.3.7 Amino acid analysis by AccQ·Tag™ method

The AccQ·Tag™ method for detecting amino acids, calibration standards and sample preparation were performed according to Salazar et al. (2012). Amino acids were analysed in an Agilent 1260 Infinity Quaternary LC System (USA). The system consisted of the following components: 1260 quaternary pump, 1260 infinity automatic liquid sampler, 1260 infinity thermostatted column compartment, and 1260 infinity diode array detector, connected to a 6420 triple quadrupole liquid chromatograph-mass spectrometry detector system with electrospray ionisation source. Separation of amino acids was achieved with a Kinetex® 1.7 µm Evo C18 100 A 2.1 × 150mm liquid chromatograph column. The stationary phase was C18 with trimethylsilyl end-capping while the solid phase was a core-shell organo-silica with ethane cross-linking. The column was operated at 25 °C. Mobile phase A was 0.1% formic acid in MilliQ water. Mobile phase B was 0.1% formic acid in acetonitrile. The flow rate was set at 0.225 mL/min. The mass spectrometer ionisation source conditions were as follows: capillary voltage of 4 kV, drying gas temperature of 300 °C, drying gas flow of 10 L/min and nebuliser pressure of 30 psi. The positive ion mode was performed with multiple reaction monitoring (MRM) for quantitative analysis. MassHunter software, (version b.09.00/build 9.0.647.0) was used for analysis. Identification of compounds was done by comparing results to the National Institute of Spectral library (NIST, version 2.2; build Jun 10, 2014).

### 3.3.8 Sensory evaluation of makgeolli using polarise projective mapping (PPM)

#### 3.3.8.1 Participant recruitment and sociodemographic

The sensory experiment was carried out in Auckland, New Zealand and participants were recruited by friends and staff members of AUT University. Due to the ongoing situation of COVID-19 in Auckland, New Zealand between late 2021 and early 2022, the sensory experiment shifted from a laboratory setting to a take-home test in form of sensory test kits (refer to **Appendix A**). This method was used to minimise the potential spread of COVID-19 among the participants and to adhere to health and safety policies. The criteria that participants must fulfilled before partaking in the sensory experiment included reading through the information sheet, being over the legal age of 18 for consuming alcohol, not suffering from food allergies such as wheat, rice, and alcohol, not operating heavy machinery or driving within 2 h of completing the experiment, and not being pregnant or trying to conceive a child.

Sixty-two participants took part in the sensory experiment with an even split between males and female. For ethnicity, the largest group that participated was Chinese (40.0%), followed by Korean (20.0%), New Zealand European (12.90%), Indian (6.5%), Sri Lankan (6.5%), and other ethnicities which consist of individuals of Latin American, Middle eastern, Pacific Islander, Vietnamese and more (14.1%). 33.9% of the participants were between the ages of 21–29 years, followed by 29.0% aged between 30 and 39 years, 14.5% aged 40–49 years, and 22.6% were over the age of 50 years.

### 3.3.8.2 Sensory materials

The test kit included a set of seven 50 mL solutions, a questionnaire, instructions with photos, a consent form, a pen, and a large plastic bag 27 cm × 33 cm (Armada, New Zealand). Sensory test kits were sent out to the participants and collected by the researcher. The seven solutions consisted of three pole solutions including R1 (sucrose 10 g/L – sweet), R2 (citric acid 2 g/L – sour), R3 (quinine 6 mg/L – bitter) and the four *makgeolli* samples (1SF-N, 1SF-YN, 2SF, and 3SF). Fifty millilitres of pole solutions and samples were placed in sealed 70 mL sterile leakproof plastic containers (Citotest, China). The pole solutions were labelled with R1, R2, and R3 while the *makgeolli* samples were labelled with three-randomised digits. The test kits were stored at 4°C and the participants head to conduct the sensory test within three days after receiving the package.

### 3.3.8.3 Polarised projective mapping (PPM) sensory procedures and questionnaire

The sensory experiment included four components. Firstly, participants were tasked to complete the PPM experiment and then followed this by indicating their degree of liking on a 100 mm bi-polar line scale of the poles and the *makgeolli* samples. Secondly, participants were then asked about their subjective and objective knowledge of wine. Lastly, sociodemographic data including gender, age, ethnicity, and frequency of consuming alcohol were collected.

The three-pole solutions were placed 25 cm apart in a triangle formation on an A3 piece of paper (refer to **Appendix B**). Using the bottom left corner (landscape position) of the A3 piece of paper as a reference point, the coordinates of the three-pole solutions are placed on three fixed points either  $X1 = 25.6$  cm and  $Y1 = 21.0$  cm,  $X2 = 4.0$  cm and  $Y2 = 8.6$  cm, and  $X3 = 4.0$  cm and  $Y3 = 33.5$  cm. The triangle formation enabled the participants to place the four different *makgeolli* samples within the triangle space.

Participants were asked to sample and remember the taste, flavour, and smell of the pole solutions (e.g., R1, R2, and R3) and then were asked to consume the *makgeolli* samples in no specific order and arrange the *makgeolli* samples on the A3 paper using the three poles as a guide. Participants were instructed to arrange the *makgeolli* samples and poles closer to each other if the subjects believe the sensory attributes were similar, while *makgeolli* samples and poles that were not similar were placed further apart. On the instruction sheet and questionnaire, participants were told that there were no right or wrong answers, and the placement of the *makgeolli* was based on their sensory perception and to use their own criteria for the *makgeolli* arrangement.

### **3.3.9 Statistical analysis**

#### **3.3.9.1 Statistical analysis and chemical data**

Statistical analysis was performed using R (version 3.6.2). The Shapiro test was carried out to check for normality of the data;  $p$ -value  $>0.05$  demonstrated that data was normally distributed. Correlation of normally distributed data was performed using the Pearson correlation coefficient. Kendall correlation coefficient was used for data not normally distributed. A  $p$ -value  $<0.05$  meant the two variables under investigation were statistically significantly correlated. Only the data sets meeting these criteria ( $p$ -value  $<0.05$ ) were reported in this study. One-way analysis of variance (ANOVA) and Tukey honest significant difference (Tukey HSD) tests were also performed to check for significant differences ( $p$ -value  $<0.05$ ) between the sample mean values.

#### **3.3.9.2 Statistical analysis on sensory data**

The statistical analysis of the PPM experiment and degree of liking was separated into three parts: overall, male and female. Using the left bottom corner as a reference, all seven solutions including poles and *makgeollis* were manually measured for their X and Y coordinates. The coordinates of each subject were then recorded on a table with two columns for each pole and sample, representing X and Y coordinates on the excel spreadsheet. Once all the coordinates are established, multifactor analysis (MFA) was used to analyse the PPM data.

One-way ANOVA was used to establish whether there were statistical differences in hedonic liking between the poles and *makgeolli* samples for overall, male, and female. Two-way ANOVA was used to see

whether the hedonic liking of poles and *makgeollis* were affected by gender. Results were considered statistically significant on liking when the associated *p*-value was <0.05. R software version was used for statistical analysis, R version 4.1.3. FactoMineR and factoextra packages were used for MFA, and Agricola packages were used for the Tukey HSD posthoc test in both one-way and two-way ANOVA.

### 3.4 Results and discussion

#### 3.4.1 Proximate analysis and physicochemical properties of *makgeolli*

The proximate composition, alcohol, pH, colour, and mineral content of the *makgeolli* samples are shown in **Table 3.1**. Reports on proximate composition of *makgeolli* are scarce in the literature with only one study by Park et al. (2015). Park et al. (2015) reported that their *makgeolli* products in general have an average of 92.7% moisture, 3.8–4.38% total carbohydrate and 2.5–3.0% total protein. These values were different to the results from this study due to the different rice used for making their *makgeolli* samples. Park et al. (2015) used two non-glutinous japonica rice cultivars *Seolgaeng* and *Sindongjin* whereas the *makgeolli* samples from this study were produced using glutinous rice. Therefore, it is expected that the moisture content would be lower at 78–84% and the carbohydrate would be higher at 12–20% although the initial water to grain ratio for making these *makgeolli* samples was roughly the same as used by Park et al. (2015)

The 1SF-N *makgeolli* had the highest protein content because of the comparatively high concentration of *nuruk* used for the fermentation process. J.-E. Kang et al. (2016) conducted a proximate analysis on *nuruk* and found that the crude protein in wheat-based *nuruk* can vary between 12% and 14%. The pH values of the *makgeolli* samples in this study were within the expected range of 3.4–4.5 as reported by other research groups (Jung et al., 2014; Lee et al., 2013; Park et al., 2015).

The alcohol content for the 1SF-N *makgeolli* was the highest at 13.0% ABV and was assumed to be due to the large amount of *nuruk* used for the simultaneous saccharification and fermentation (SSF) step. This alcohol level is similar to alcohol levels reported by (Park et al., 2015) (14–18% alcohol) but higher than 6–7% levels reported for *makgeolli* by Kim et al. (2013). As the *nuruk* contains fungi that produces amyolytic enzymes for the saccharification process and yeasts that facilitate alcohol production (Bal et al., 2014), the 1SF-N fermentation process is expected to be more efficient in generating alcohol. The 3SF

*makgeolli* also has a high alcohol content (12.6%) because of the double pre-fermentation step to produce a starter base that may also contain high numbers of microbes for the main fermentation. The 1SF-YN *makgeolli* has the lowest alcohol content at 4.52%. This result was expected even though this sample had added yeast it has the lowest amount of *nuruk* used during the SSF step.

Phosphorus was observed to have the highest concentration in the four types of *makgeolli* tested. Calcium, potassium, sodium, and magnesium were observed to be in moderate concentrations. The lowest concentration of minerals observed in the four *makgeolli* samples were zinc, silicon, copper, and manganese (**Table 3.2**). All these minerals are important for the microbial activity (Freire et al., 2017) during fermentation of *makgeolli* samples.

In terms of colour 1SF-N *makgeolli* was observed to be the darkest ( $L^* = 61.3$ ), reddest ( $a^* = 0.495$ ) and yellowest ( $b^* = 10.91$ ) among the four *makgeolli* samples. This is due to the high tannic content in the *nuruk* (Jeon et al., 2010) resulting in a strong brownish hue in the *makgeolli*. The redness ( $a^*$  values) were low in the other *makgeolli* samples ( $< -1.28$ ), whereas the yellowness ( $b^*$  values) were in the range between - 1.06 and 6.35.

**Table 3.1** Proximate composition, alcohol content, pH, colour, mineral content in *makgeolli* made from different processing routes.

Sample	<u>Proximate composition (% wet basis)</u>						<u>Colour</u>			
	Moisture	Total carbohydrate	Total protein	Ash	Lipid	Alcohol (%ABV)	pH	<i>L</i> *	<i>a</i> *	<i>b</i> *
1SF-N	82.37 ± 1.22 <sup>a</sup>	12.55 ± 1.43 <sup>a</sup>	4.89 ± 0.17 <sup>a</sup>	0.29 ± 0.05 <sup>a</sup>	0.06 ± 0.05 <sup>a</sup>	13.0 ± 0.5 <sup>a</sup>	3.73 ± 0.03 <sup>a</sup>	61.3 ± 0.4 <sup>a</sup>	0.495 ± 0.1 <sup>a</sup>	10.91 ± 0.1 <sup>a</sup>
1SF-YN	84.31 ± 1.51 <sup>a</sup>	14.17 ± 1.34 <sup>a</sup>	1.35 ± 0.34 <sup>b</sup>	0.06 ± 0.06 <sup>b</sup>	0.11 ± 0.04 <sup>a</sup>	4.5 ± 0.4 <sup>b</sup>	3.42 ± 0.05 <sup>b</sup>	42.4 ± 0.1 <sup>b</sup>	-1.92 ± 0.1 <sup>b</sup>	-1.06 ± 0.4 <sup>b</sup>
2SF	78.10 ± 2.10 <sup>b</sup>	20.43 ± 2.34 <sup>b</sup>	1.42 ± 0.25 <sup>b</sup>	0.09 ± 0.04 <sup>b</sup>	0.06 ± 0.07 <sup>a</sup>	7.8 ± 0.4 <sup>c</sup>	3.62 ± 0.03 <sup>c</sup>	56.9 ± 2.0 <sup>c</sup>	-1.29 ± 0.2 <sup>c</sup>	6.35 ± 0.5 <sup>c</sup>
3SF	84.47 ± 1.78 <sup>a</sup>	13.55 ± 1.61 <sup>a</sup>	1.74 ± 0.41 <sup>b</sup>	0.08 ± 0.07 <sup>b</sup>	0.15 ± 0.06 <sup>a</sup>	12.6 ± 0.5 <sup>d</sup>	4.14 ± 0.12 <sup>d</sup>	58.4 ± 1.4 <sup>c</sup>	-1.28 ± 0.2 <sup>c</sup>	3.99 ± 0.2 <sup>d</sup>
<u>Mineral content in mg/L</u>										
	<b>P</b>	<b>Zn</b>	<b>Si</b>	<b>Ca</b>	<b>Cu</b>	<b>K</b>	<b>Mg</b>	<b>Mn</b>	<b>Fe</b>	<b>Na</b>
1SF-N	10.61 ± 0.44 <sup>a</sup>	0.43 ± 0.16 <sup>a</sup>	1.07 ± 0.28 <sup>a</sup>	2.47 ± 1.10 <sup>a</sup>	0.27 ± 0.15 <sup>a</sup>	11.61 ± 1.84 <sup>a</sup>	2.45 ± 0.37 <sup>a</sup>	0.56 ± 0.01 <sup>a</sup>	1.24 ± 0.52 <sup>a</sup>	1.28 ± 0.18 <sup>a</sup>
1SF-YN	19.61 ± 3.98 <sup>b</sup>	0.31 ± 0.07 <sup>b</sup>	0.94 ± 0.39 <sup>b</sup>	2.33 ± 0.55 <sup>b</sup>	0.18 ± 0.04 <sup>b</sup>	5.24 ± 0.78 <sup>b</sup>	0.75 ± 0.04 <sup>b</sup>	0.49 ± 0.02 <sup>b</sup>	0.76 ± 0.10 <sup>b</sup>	2.00 ± 0.71 <sup>b</sup>
2SF	21.03 ± 4.54 <sup>c</sup>	0.27 ± 0.01 <sup>c</sup>	0.23 ± 0.19 <sup>c</sup>	1.80 ± 0.16 <sup>c</sup>	0.18 ± 0.03 <sup>b</sup>	7.30 ± 1.22 <sup>c</sup>	1.45 ± 0.13 <sup>c</sup>	0.50 ± 0.02 <sup>c</sup>	0.55 ± 0.08 <sup>c</sup>	1.49 ± 0.31 <sup>c</sup>
3SF	26.83 ± 2.13 <sup>d</sup>	0.31 ± 0.01 <sup>d</sup>	0.11 ± 0.14 <sup>d</sup>	2.22 ± 0.45 <sup>c</sup>	0.13 ± 0.05 <sup>d</sup>	7.17 ± 1.67 <sup>c</sup>	1.22 ± 0.23 <sup>c</sup>	0.52 ± 0.01 <sup>c</sup>	0.60 ± 0.17 <sup>c</sup>	1.42 ± 0.18 <sup>c</sup>

Results are expressed as the mean ± standard deviation (n = 4). Values with different a – d superscript letters in the same column differ significantly (p < 0.05) as determined by Tukey test.

The total phenolic content (TPC) of the *makgeolli* samples from this study were in general higher than those reported in commercially available *makgeolli* samples in Korea (**Table 3.2**). Bae et al. (2010) reported that the TPC in commercial *makgeolli* products ranged between 100 and 250 mg GAE/L. The TPC of the *makgeolli* samples from this study ranged between 300 and 400 mg GAE/L with the exception of 1SF-N which had 621 mg GAE/L. This elevated TPC value was because of 1SF-N sample had the highest amount of *nuruk* incorporated into the fermentation process and is similar to the TPC values of 600–1400 mg GAE/L reported by Lee (2020). As mentioned earlier, *nuruk* is a starter culture predominately made of ground wheat and barley which are known to contain sizable amounts of phenolic compounds such as ferulic acid, syringic acid, p-hydroxybenzoic acid, p-coumaric acid and hydroxycinnamic acids (Hernández et al., 2011; Quinde-Axtell & Baik, 2006). Interestingly, the TPC of these rice wines were much lower than red grape wines but higher than white grape wines which have been reported to have TPC values of 1200–2500 mg GAE/L and 150–300 mg GAE/L respectively (De Beer et al., 2003; Lingua et al., 2016).

All the *makgeolli* samples exhibited some antioxidant activity with 1SF-N giving the highest activity. It is known that dietary phenolic compounds are effective antioxidants (Rice-Evans et al., 1997). Therefore, the high phenolic content in *nuruk* is presumed to be responsible for the high antioxidant activity in the 1SF-N sample. The phospho. antioxidant assay resulted in the highest antioxidant activity values of the three assays used in this study. This was not surprising as the three assays all measure different aspects of antioxidant activity. Also, the phospho. assay can overestimate antioxidant activity if there are other non-phenolic reducing agents such as reducing sugars and certain amino acids present in the sample (Munteanu & Apetrei, 2021). For the FRAP and CUPRAC assays, there were no significant differences in antioxidant activity among the 1SF-YN, 2SF and 3SF samples. The results from the FRAP assay in this study were comparable with reported literature values (Lee et al., 2022). However, since this is the first time the CUPRAC assay has been applied to *makgeolli*, any comparison to reported literature is difficult. In general, the antioxidant activity from the three essays showed similar a pattern to the TPC values, this is in agreement with Lee (2020). Interestingly, the antioxidant activity of *makgeolli* (0.24–0.65 g TE/L) were much lower than red wines (1.72–3.8g TE/L) using FRAP assay as comparison (Kondrashov et al., 2009).

**Table 3.2** Antioxidant activity and total phenolic content in makgeolli made with four different processing.

<i>Makgeolli</i> sample	Antioxidant Activity (g TE/L)			Total Phenolic Content (mg GAE/L)
	Phospho	FRAP	CUPRAC	Folin-Ciocalteu
1SF-N	3.99 ± 0.29 <sup>a</sup>	0.65 ± 0.15 <sup>a</sup>	0.48 ± 0.02 <sup>a</sup>	621 ± 9 <sup>a</sup>
1SF-YN	2.81 ± 0.25 <sup>b</sup>	0.27 ± 0.02 <sup>b</sup>	0.17 ± 0.09 <sup>b</sup>	307 ± 8 <sup>b</sup>
2SF	2.13 ± 0.20 <sup>c</sup>	0.26 ± 0.01 <sup>b</sup>	0.24 ± 0.02 <sup>b</sup>	397 ± 10 <sup>c</sup>
3SF	3.01 ± 0.22 <sup>b</sup>	0.24 ± 0.03 <sup>b</sup>	0.22 ± 0.01 <sup>b</sup>	318 ± 19 <sup>d</sup>

Results are expressed as the mean ± standard deviation (n = 4). Values with different a – d superscript letters in the same column differ significantly (p < 0.05) as determined by Tukey test. TE = Trolox equivalent. GAE = Gallic acid equivalent.

### 3.4.2 Sugars in *makgeolli*

Maltose was the most abundant sugar detected in the *makgeolli* samples from this study (**Table 3.3**), except in 1SF-N where it was not detected. This was in agreement with the observations of Son et al. (2018). The glucose concentration was, however, found to be low in all the *makgeolli* samples relative to maltose. The 2SF *makgeolli* sample was observed to contain the highest concentrations of both maltose and glucose among the tested *makgeolli* samples. This agrees with the high total carbohydrate in 2SF *makgeolli* as shown in **Table 3.1** and similar results were reported by Lee et al. (2013) who found glucose, maltose and trace amounts of fructose in their samples. The use of the first fermentation base as a starter culture to ferment the main glutinous rice may have created an ideal conditions for the hydrolysis and saccharification of the amylopectin which accounts for 99.7% of the starch in glutinous rice (Guo et al., 2015). Also, this may be the reason for the moderate alcohol content and high glucose and maltose content in 2SF *makgeolli* as the yeast did not have enough time to convert the sugars to alcohol.

**Table 3.3** Sugar content in mg/mL in the four types of *makgeolli* samples.

Sample	Glucose	Galactose	Maltose
1SF-N	5.13 ± 0.99 <sup>a</sup>	0.38 ± 0.08 <sup>a</sup>	ND
1SF-YN	4.43 ± 0.28 <sup>b</sup>	0.14 ± 0.01 <sup>b</sup>	67.70 ± 12.14 <sup>a</sup>
2SF	8.24 ± 1.77 <sup>c</sup>	0.32 ± 0.06 <sup>c</sup>	107.93 ± 13.53 <sup>b</sup>
3SF	6.10 ± 0.84 <sup>d</sup>	0.25 ± 0.01 <sup>d</sup>	11.33 ± 0.90 <sup>c</sup>

Results are expressed as the mean ± standard deviation (n = 4). Values with different a – d superscript letters in the same column differ significantly (p < 0.05) as determined by Tukey test. ND = not detected.

### 3.4.3 Organic acids in *makgeolli*

Pyruvic acid was detected in the highest amounts in the 2SF *makgeolli* followed by the 1SF-YN *makgeolli*. However, it was detected in relatively low concentrations in the 3SF and 1SF-N *makgeolli* (**Table 3.4**). Fumaric acid was not detected in any of the *makgeolli* samples which corresponded to the findings of Seo et al. (2016) It is known that pyruvic, citric and fumaric acid are intermediate products of glycolysis and the citric acid cycle (Son et al., 2018). In particular, pyruvic acid supplies energy to microbial cells through the citric acid cycle in aerobic environments. However, in an anaerobic environment such as an alcoholic fermentation, the pyruvic acid is converted to ethanol (Yu et al., 2015). Since pyruvic acid is not the end-product of fermentation, the presence of high levels of pyruvic acid in the *makgeolli* samples would depict an incomplete glycolytic and citric acid cycle in the yeast cells. Therefore, it can be inferred that the fermentation process in the 2SF *makgeolli* and 1SF-YN *makgeolli* samples was incomplete. The 1SF-N and 3SF *makgeolli* samples had low levels of pyruvic acid, indicating a more complete fermentation process, and hence the higher alcohol content.

Malic and citric acid were made by *S. cerevisiae* from glucose during fermentation. Malic acid is generated through the oxaloacetate or fumarate pathways. Citric acid is generated during conversion of sugar to alcohol by *S. cerevisiae* or during malolactic fermentation by lactic acid bacteria (Seo et al., 2016). In this study, concentrations of these two organic acids were highest in the 1SF-N *makgeolli* sample. This could therefore be indicative of the higher presence of *S. cerevisiae* from the *nuruk*. However, the concentrations of malic acid and citric acid were very low and did not vary significantly in all the other types of *makgeolli*.

Succinic acid, lactic acid and acetic acid were also produced by *S. cerevisiae* during the fermentation process (Seo et al., 2016; Son et al., 2018; Yu et al., 2015). Therefore, these organic acids could possibly be used as indicators of the efficiency of yeast metabolism. It was also discovered that succinic acid had a positive correlation to ethanol content (Seo et al., 2016). In this study, succinic acid concentration was highest in both the 1SF-N and 3SF *makgeolli* which also had the highest alcohol content.

### 3.4.4 Amino acids in *makgeolli*

Bacterial and fungal proteases from *nuruk* can break down proteins in rice and wheat into free amino acids (Seo et al., 2016). This may explain the high free amino acid content in all *makgeolli* samples (**Table 3.5**). Phenylalanine, glutamic acid, proline, and isoleucine were detected in high concentration whereas

cysteine, citrulline, and ethanol amine were very low in the four *makgeolli* samples. This observation was in accord with a report by Kang et al. (2014b). The 1SF-N *makgeolli* sample contained the highest amount of total free amino acids which corresponded to the highest crude protein content due to amount of *nuruk* used. Conversely, 1SF-YN *makgeolli* had the least concentration of total amino acids and subsequently, a low crude protein content. Although the essential and non-essential free amino acids have little to no taste (Solms, 1969), understanding the free amino acid profile of *makgeolli* is very important because the amino acids can influence the development of the aroma and taste profile of the final beverage. For example, essential amino acids can be directly assimilated by yeast under the Ehrlich pathway where they are converted into aromatic and volatile compounds such as aldehydes, fusel alcohols and fusel acids (Hazelwood et al., 2008; Kang et al., 2014b; Son et al., 2018). These compounds have significant impact on the flavour of the final *makgeolli* (Kang et al., 2014a).

In general, the non-essential amino acids were detected in high concentrations relative to the essential amino acids. Similar findings have been reported by Yu et al. (2015). Non-essential amino acids such as glycine, alanine, and serine were also assimilated by yeast. However, they could not be metabolised through the Ehrlich pathway, instead, they were converted to pyruvate. This could be further broken down into esters via the anabolic pathway (Pires et al., 2014). In the current study, the 1SF-YN *makgeolli* was observed to contain the lowest concentrations of the non-essential amino acids whereas 1SF-N *makgeolli* had the highest concentrations of the non-essential amino acids.

**Table 3.4** Organic acids in g/L in the four types of *makgeolli* samples.

Sample	Pyruvic	Malonic	Succinic	Citric	Malic	Tartaric	Lactic	Acetic	Fumaric
1SF-N	7.37 ± 0.42 <sup>a</sup>	0.02 ± 0.01 <sup>a</sup>	0.47 ± 0.03 <sup>a</sup>	0.05 ± 0.01 <sup>a</sup>	0.05 ± 0.01 <sup>a</sup>	0.06 ± 0.01 <sup>a</sup>	8.79 ± 0.15 <sup>a</sup>	0.72 ± 0.05 <sup>a</sup>	ND
1SF-YN	15.61 ± 0.99 <sup>b</sup>	0.02 ± 0.01 <sup>a</sup>	0.07 ± 0.01 <sup>b</sup>	0.01 ± 0.01 <sup>a</sup>	0.02 ± 0.01 <sup>b</sup>	0.004 ± 0.001 <sup>b</sup>	6.37 ± 0.32 <sup>b</sup>	2.23 ± 0.29 <sup>b</sup>	ND
2SF	22.58 ± 1.60 <sup>c</sup>	0.02 ± 0.01 <sup>a</sup>	0.12 ± 0.01 <sup>c</sup>	0.02 ± 0.01 <sup>a</sup>	0.02 ± 0.01 <sup>b</sup>	0.019 ± 0.001 <sup>c</sup>	11.28 ± 0.08 <sup>c</sup>	1.79 ± 0.37 <sup>c</sup>	ND
3SF	1.13 ± 0.06 <sup>d</sup>	0.02 ± 0.01 <sup>a</sup>	0.47 ± 0.02 <sup>a</sup>	0.02 ± 0.01 <sup>a</sup>	0.03 ± 0.01 <sup>c</sup>	0.005 ± 0.001 <sup>d</sup>	1.55 ± 0.08 <sup>d</sup>	0.33 ± 0.04 <sup>d</sup>	ND

Results are expressed as the mean ± standard deviation (n = 4). Values with different a – d superscript letters in the same column, differ significantly (p < 0.05) as determined by Tukey test. ND = not detected.

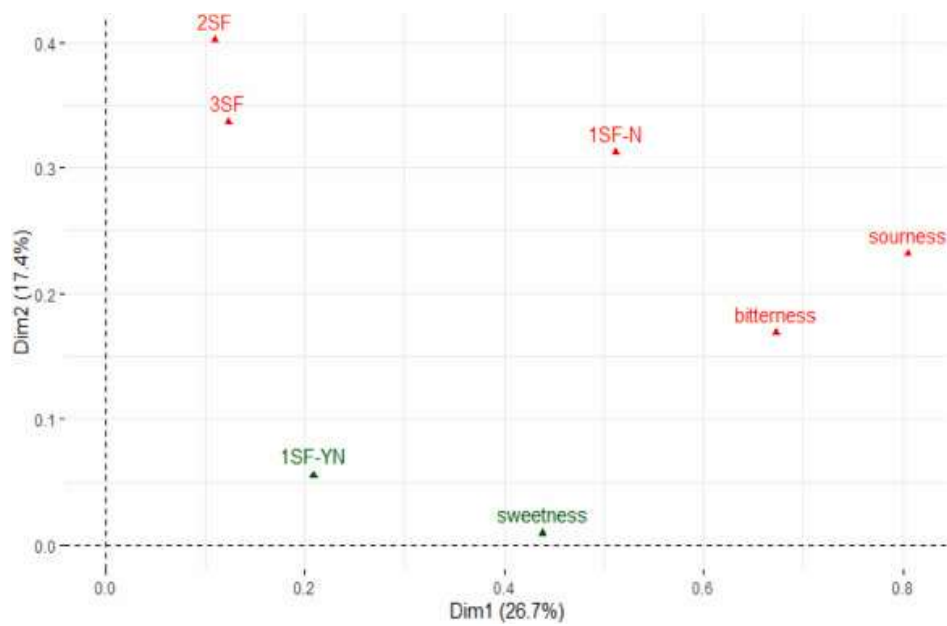
**Table 3.5** Free amino acid concentration (mg/L) in the four types of *makgeolli* samples.

<b>Essential amino acids</b>				
Amino acid	<u><i>Makgeolli</i> samples</u>			
	1SF-N	1SF-YN	2SF	3SF
Histidine	57.3 ± 3.9 <sup>a</sup>	1.9 ± 0.2 <sup>b</sup>	23.0 ± 2.5 <sup>c</sup>	46.9 ± 1.9 <sup>d</sup>
Leucine	108.2 ± 12.4 <sup>a</sup>	9.4 ± 1.5 <sup>b</sup>	55.4 ± 8.7 <sup>c</sup>	49.0 ± 1.6 <sup>d</sup>
Isoleucine	271.8 ± 31.5 <sup>a</sup>	33.2 ± 2.4 <sup>b</sup>	136.2 ± 17.3 <sup>c</sup>	117.7 ± 4.3 <sup>d</sup>
Lysine	124.9 ± 4.8 <sup>a</sup>	11.7 ± 0.3 <sup>b</sup>	82.8 ± 7.5 <sup>c</sup>	105.6 ± 9.2 <sup>d</sup>
Methionine	26.9 ± 4.5 <sup>a</sup>	4.0 ± 0.9 <sup>b</sup>	9.8 ± 5.7 <sup>c</sup>	1.7 ± 0.2 <sup>d</sup>
Phenylalanine	222.0 ± 13.1 <sup>a</sup>	51.0 ± 2.7 <sup>b</sup>	126.5 ± 15.3 <sup>c</sup>	106.2 ± 7.3 <sup>d</sup>
Threonine	59.2 ± 4.8 <sup>a</sup>	6.1 ± 0.8 <sup>b</sup>	27.8 ± 3.7 <sup>c</sup>	42.7 ± 1.5 <sup>d</sup>
Tryptophan	54.4 ± 3.4 <sup>a</sup>	15.2 ± 3.7 <sup>b</sup>	24.2 ± 6.6 <sup>c</sup>	17.4 ± 1.7 <sup>d</sup>
Valine	199.1 ± 13.8 <sup>a</sup>	31.3 ± 1.8 <sup>b</sup>	98.7 ± 14.8 <sup>c</sup>	87.1 ± 7.9 <sup>d</sup>
<b>Non-essential amino acids</b>				
Amino acid	<u><i>Makgeolli</i> samples</u>			
	1SF-N	1SF-YN	2SF	3SF
Alanine	385.8 ± 18.1 <sup>a</sup>	49.5 ± 2.0 <sup>b</sup>	178.0 ± 25.9 <sup>c</sup>	321.5 ± 21.9 <sup>d</sup>
Arginine	202.3 ± 17.8 <sup>a</sup>	36.0 ± 2.0 <sup>b</sup>	45.9 ± 3.9 <sup>c</sup>	94.7 ± 19.6 <sup>d</sup>
Aspartic acid	108.5 ± 10.1 <sup>a</sup>	12.8 ± 0.8 <sup>b</sup>	76.3 ± 11.6 <sup>c</sup>	60.1 ± 2.1 <sup>d</sup>
Citrulline	7.9 ± 0.7 <sup>a</sup>	2.9 ± 0.4 <sup>b</sup>	6.4 ± 0.3 <sup>c</sup>	2.3 ± 0.2 <sup>d</sup>
Cysteine	3.6 ± 0.2 <sup>a</sup>	ND	0.6 ± 0.0 <sup>b</sup>	0.2 ± 0.0 <sup>c</sup>
Ethanol amine	7.5 ± 0.5 <sup>a</sup>	2.0 ± 0.1 <sup>b</sup>	3.9 ± 0.2 <sup>c</sup>	6.6 ± 0.5 <sup>d</sup>
Glutamic acid	334.3 ± 41.0 <sup>a</sup>	61.4 ± 2.6 <sup>b</sup>	164.9 ± 22.2 <sup>c</sup>	92.6 ± 11.5 <sup>d</sup>
Glycine	139.7 ± 10.2 <sup>a</sup>	20.7 ± 1.2 <sup>b</sup>	59.7 ± 11.5 <sup>c</sup>	73.3 ± 3.8 <sup>d</sup>
Proline	475.0 ± 37.6 <sup>a</sup>	63.4 ± 4.4 <sup>b</sup>	193.8 ± 18.8 <sup>c</sup>	158.1 ± 12.9 <sup>d</sup>
Hydroxy-Proline	17.7 ± 1.8 <sup>a</sup>	1.9 ± 0.4 <sup>b</sup>	4.2 ± 0.1 <sup>c</sup>	4.3 ± 0.6 <sup>c</sup>
Ornithine	84.4 ± 5.7 <sup>a</sup>	1.9 ± 0.3 <sup>b</sup>	119.6 ± 10.6 <sup>c</sup>	91.4 ± 9.8 <sup>d</sup>
Serine	93.5 ± 2.6 <sup>a</sup>	10.4 ± 0.3 <sup>b</sup>	49.6 ± 8.8 <sup>c</sup>	72.0 ± 2.6 <sup>d</sup>
Tyrosine	211.1 ± 19.8 <sup>a</sup>	29.9 ± 3.9 <sup>b</sup>	92.0 ± 5.8 <sup>c</sup>	112.0 ± 7.1 <sup>d</sup>
Total amino acids	3195.1 ± 77.3 <sup>a</sup>	456.6 ± 9.3 <sup>b</sup>	1579.3 ± 54.7 <sup>c</sup>	1663.4 ± 39.6 <sup>d</sup>

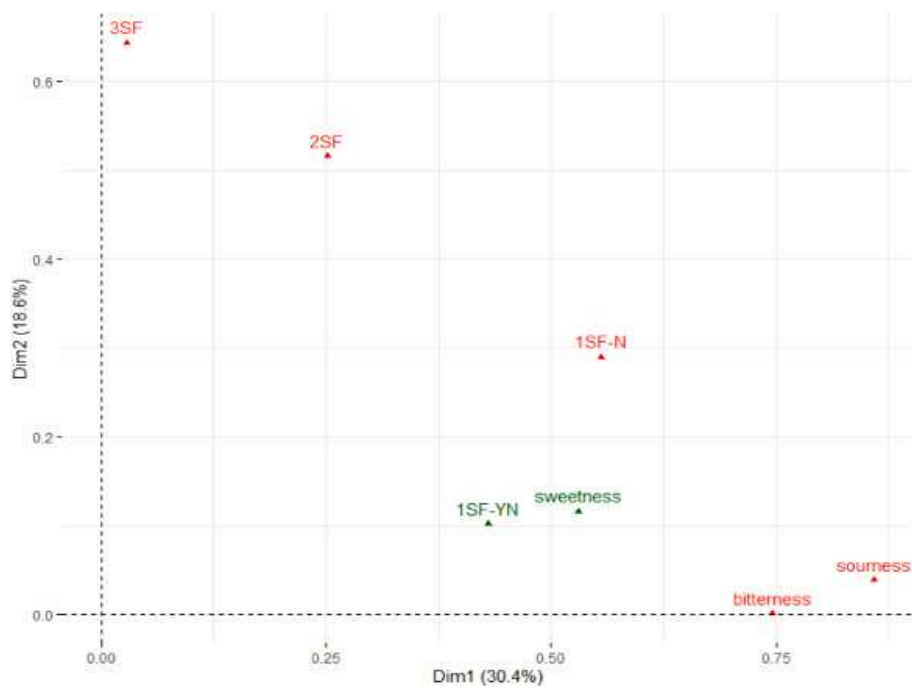
Results are expressed as the mean ± standard deviation (n = 4). Values with different a – d superscript letters in the same column, differ significantly (p < 0.05) as determined by Tukey test. ND = not detected.

### 3.4.5 Polarised projective mapping sensory results on makgeolli

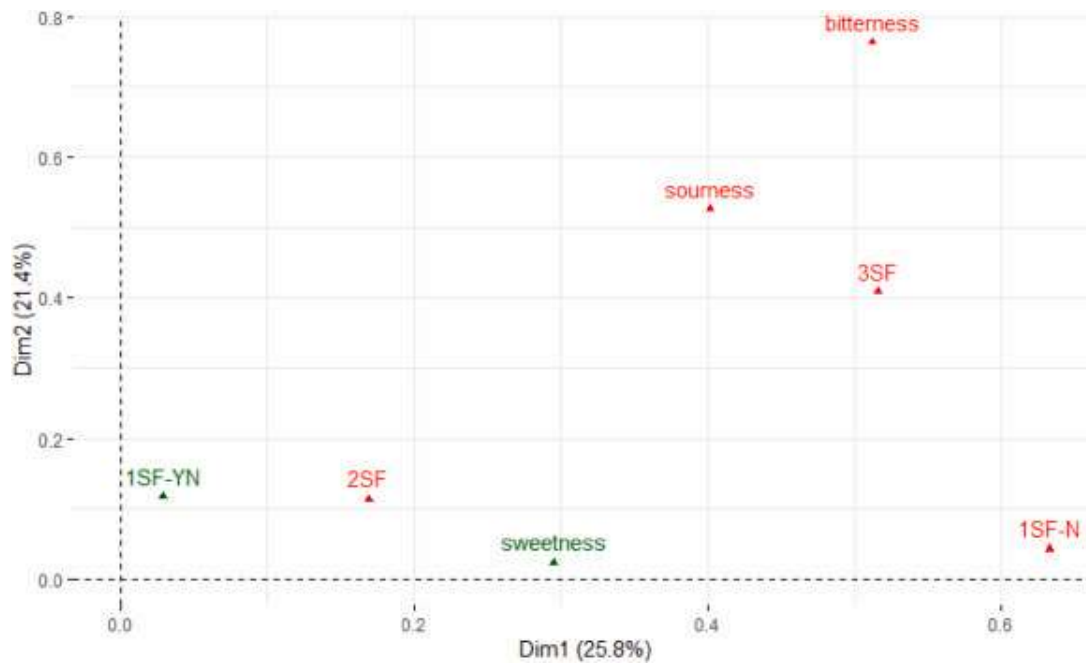
For the sensory data, multiple factor analysis (MFA) was used to arrange the complex data, including quantitative and/or qualitative information on how the variables clustered together onto the MFA maps (Pagès, 2005). The plots in **Figure 3.2**, **Figure 3.3**, and **Figure 3.4** represent the correlation between the seven solutions and dimensions on the MFA-plot map. Within each MFA-plot map, the position of each of the seven solutions shows how the three taste (such as sweet, sour, and bitter) solutions are associated with the different *makgeolli* samples. The overall MFA of the PPM data (**Figure 3.2**) explains 44.1% (Dimension 1 = 26.7%, Dimension 2 = 17.4%) of the variation of the two dimensions. For the first dimension, sourness (citric acid), bitterness (quinine), and 1SF-N were identified as active groups which defines the distance between the variables in the MFA-plot graph and contributed the most information. In comparison, three active groups (1SF-N, 2SF and 3SF) were identified and contributed the most information in dimension 2. Both 1SF-YN and sweetness were identified as supplementary data which have minimum influence in the overall MFA graph. The male MFA data (**Figure 3.3**) showed similar results compared to the overall MFA (**Figure 3.2**), with the male MFA data explaining 49.0% (Dimension 1 = 30.4%, Dimension 2 = 18.6%) of variation of the two dimensions. In contrast, the female participants' MFA (**Figure 3.4**) showed 47.2% (Dimension 1 = 25.8%, Dimension 2 = 21.4%) of variation of the two dimensions on the MFA map. Contribution of Dimension 1 and Dimension 2 differ slightly between male and female participants. For male participants, sourness (citric acid), bitterness (quinine), and 1SF-N contributes over 20% of the cut-off point in Dimension 1, while 3SF and 2SF contributes over 30% in Dimension 2. For female participants (**Figure 3.4**), 1SF-N, 3SF, and bitterness (quinine) are the three active groups for Dimension 1, while bitterness (contributing over 21.2%), sourness (citric acid), and 3SF contributes over 20% in Dimension 2.



**Figure 3.2** Overall MFA distribution of the PPM for all participants with Dimension 1 contributing 26.7% and Dimension 2 contributing 17.4%.

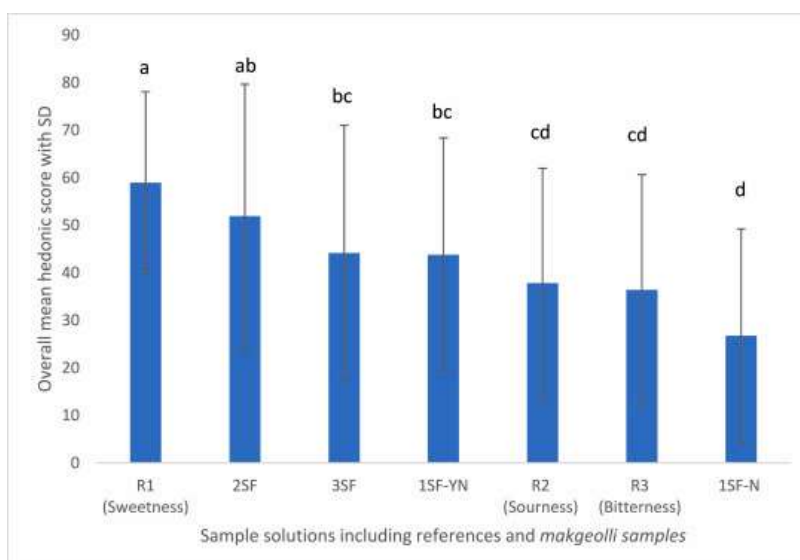


**Figure 3.3** MFA distribution of the PPM for male participants only with Dimension 1 contributing 30.4% and Dimension 2 contributing 18.6%.



**Figure 3.4** Figure 3.4. MFA distribution of the PPM for female participants only with Dimension 1 contributing 25.8% and Dimension 2 contributing 21.4%.

Analysis of variance showed a statistical significance in the overall mean hedonic rating among the reference solutions and the *makgeolli* samples ( $p < 0.001$ ) as shown in **Figure 3.5**. Sweetness was liked the most with an overall mean rating of  $59.0 \pm 19.1$  mm on a 100 mm bi-polar scale, followed by the 2SF sample with an overall mean hedonic rating of  $51.9 \pm 27.7$ . The 3SF ( $44.2 \pm 26.8$  mm) and 1SF-YN ( $43.8 \pm 24.6$  mm) samples had similar overall mean hedonic ratings in the PPM experiment and were statistically different from the sucrose solutions. On the other hand, the 1SF-N sample had the lowest overall mean hedonic rating among the seven solutions in the PPM experiment ( $26.8 \pm 22.5$  mm).



**Figure 3.5** Figure 3.5. Overall mean hedonic score of samples tested in the PPM experiment with four types of makgeolli samples (1SF-YN, 1SF-N, 2SF and 3SF), sucrose, citric acid, and quinine solution (SD = standard deviation).

In terms of gender differences between females and males, it was evident that female participants tended to score higher in the mean hedonic rating of all seven samples compared to males. However, female participants also had a higher standard deviation for most sample solutions. A statistically difference was observed for both female ( $p < 0.001$ ) and male participants ( $p < 0.001$ ) when they rated the *makgeolli* and reference solutions.

From the PPM experiment, increased fermentation time did not increase the participants mean hedonic score. The 2SF sample had a longer fermentation time than the 1SF-YN and 1SF-N by two days but it was two days shorter than the 3SF sample. The two-stage fermentation process enhanced the sweetness of the *makgeolli* sample and no significance was observed in overall liking from participants between the sweetness solution and 2SF (**Figure 3.5**). In contrast, citric acid (sourness) and quinine (bitterness) solutions were perceived as undesirable traits. It was not surprising that participants rated both citric and quinine solutions relatively low, however, it was interesting to see that the 1SF-N had the lowest mean hedonic score overall. The low mean hedonic score for sample 1SF-N is likely to be attributed to the high concentration of *nuruk* used for the 1SF-N fermentation during the seven-day process.

The current study assessed the effects of New Zealand consumer perception of *makgeolli* in an environment outside of the laboratory setting. Researchers in this field of sensory science have noted that there is a variability of overall liking for food products being assessed at home (home use test) compared to the laboratory (central location test). However, other researchers have also noted that non-laboratory settings increased the encouragement of participants when sensory experiments are being conducted (Zandstra et al., 2020). Although this current research design was limited to observing the participants' behaviour in non-laboratory settings, this study may give researchers, such as in the wine industry, and brewing industries, insight into how New Zealand consumers are likely to perceive *makgeolli* in the natural environment. It has been historically argued by sensory scientists that central location tests can reduce random biases from participants, when variables such as the laboratory layout, food sample presentation, and information and experimental protocols remain constant (Boutrolle et al., 2005). However, the COVID-19 pandemic has changed the way many sensory studies are conducted and implemented during the period of 2020 – 2022 (Varela, 2022).

In this study, we have identified the key attribute that drove the overall liking of *makgeolli* is being closely associated with sweetness. The 2SF sample was rated the highest for overall liking by both males and females, and this can be explained by the high concentration of maltose and glucose content in this sample. This result is consistent with findings demonstrated in the United States where consumers preferred their Korean rice wine to be sweeter (Kwak et al., 2015). Thus, brewers and the wine industry might consider the 2SF *makgeolli* for the New Zealand market, as the sensory characteristics were the most preferred and liking is a necessary component for product success.

Both sourness and bitterness were the main attributes that drove participants to dislike certain *makgeolli* samples in this study, and in particular the 1SF-N sample. This sample had the highest levels of malic and citric acid which explains the strong association of sourness that participants perceived from the 1SF-N sample during the PPM experiment. According to Jeon et al. (2010) malic acid is considered an undesirable compound in wine products; however, this has not been previously documented or observed in the scientific literature for *makgeolli*. Although this is a preliminary finding, future work to overcome the limitations of this study such as the relatively small sample size and the structure of the PPM experiment warrants further investigation. The high concentration of malic acid is likely to be one of the factors that

caused participants to rate the 1SF-N sample relatively low in overall liking compared to the other three *makgeolli* samples. In terms of bitterness, high phenolic content tends to cause food products to be bitter and the 1SF-N *makgeolli* sample contained considerably high TPC values when compared to the other *makgeolli* samples in the PPM study. Also, although phenolic compounds in alcoholic beverages may sometimes be desirable, Lentz (2018) noted that spoilage or burnt characteristics may be perceived as undesirable by consumers.

The novelty of this study comes in two parts. First, this study uses a mixed method approach where chemical analysis was employed to quantify the proximate composition and the concentration of the free amino acids, sugars, alcohol content, and antioxidant activity of the four different *makgeolli* processing methods. For the qualitative component, a sensory study using PPM and an A3 piece of paper was employed to categorially identify how the four *makgeolli* samples were perceived by participants according to sweetness, bitterness, and sourness on an A3 piece of paper. From this study, researchers can observe that a high concentration of maltose and glucose is likely to increase the overall liking of the food product, specifically the 2SF sample in this study. A high concentration of malic acid is not desirable in *makgeolli* which was observed with a low overall liking for the 1SF-N sample.

Second, to the best of the researcher's knowledge, this is the first time that a projective method study has been completed and executed outside of the laboratory environment with food samples. This research demonstrates that projective methods can be implemented outside the laboratory with the guidance of the researchers. However, due to the multiple ways of conducting projective methods in sensory science such as using computer software (e.g., FIZZ and RedJade) or a pen and an A3/A2 sheet, researchers in future should compare the different experimental techniques of project methods outside of the laboratory setting to get comparable results.

### 3.5 Conclusion

From the chemical analysis, results showed that the 1SF-N *makgeolli* sample had the highest alcohol content, crude protein, antioxidant activity, total phenolic content, and total free amino acid concentration of the four samples. However, in sensory testing, the 1SF-N sample was rated the lowest overall liking out of the four *makgeolli* processing methods.

Incorporating an additional fermentation step before the main fermentation was found to produce *makgeolli* with the highest-level of glucose and maltose content. Participants seem to prefer this *makgeolli* processing method (2SF). The 1SF-YN *makgeolli* sample had the lowest alcohol and total free amino acids content among the four processing methods tested. This is not surprising due to its low input of *nuruk* and yeast when producing 1SF-YN. Pyruvic, lactic, and acetic acid were the most dominant organic acids in all the *makgeolli* samples with concentrations above 1 g/L. The findings from this study will give a better understanding for rice wine brewers and researchers on how processing affects the chemical and sensory properties of *makgeolli* and how this influences consumer perceptions and overall liking. In terms of producing and launching more rice wine products in New Zealand, more research is needed to understand consumer attitudes towards purchasing rice wine for consumption and how branding, product packaging, and context of consumption might play a part in changing perceptions of the rice wine.

## Chapters 4. Identifying sensory attributes of Korean rice wine (makgeolli) using sensory evaluation and chemical analysis

### 4.1 Prelude

**Chapter 4**, *identifying sensory attributes of Korean rice wine (makgeolli) using sensory evaluation and chemical analysis* aims to quantify and establish sensory attributes unique to each of the four *makgeolli* samples made from the different processing methods. In continuation of understanding the different *makgeolli* processing methods, additional profiling methods or descriptive testing is warranted to understand the sensory attributes perceived by the participants. In the previous chapter, **Chapter 3** established physicochemical properties of the different *makgeolli* processing methods such as alcohol content, pH, colour, mineral content, proximate composition, antioxidant activity, total phenolic content, sugar analysis, free amino acid, and organic acid profile. However, the sensory attributes are yet to be examined.

This chapter is divided into two parts with both sensory evaluation and flavour science components. First, sensory evaluation was conducted on the four *makgeolli* samples using Check-All-That-Apply (CATA) and Just-about-right (JAR). CATA is a rapid sensory profiling method that allows participants to mark or check attributes that are relevant to the sample from a list of attributes organised by the researcher. In comparison, JAR evaluates whether the intensity of a certain attribute is enhancing or penalising the overall liking of the product. For the second part, volatile compounds were identified using the SPME-GC-MS. By identifying the volatile compounds emitted in the *makgeolli* samples, researchers can understand what type of flavour profiles are desired among consumers and whether a correlational relationship can be established between volatile compounds and physicochemical properties. By identifying and establishing information about sensory attributes and flavour profiles, researchers and manufacturers can enhance (or reduce) specific sensory attributes that are considered desirable (or undesirable) in *makgeolli*.

## 4.2 Introduction

Research on alcoholic beverages such as wine and beer is popular among Western scientific literature; however, ethnic beverages like *makgeolli* (Korean rice wine [KRW]) are limited. *Makgeolli* is made from glutinous rice, water, and a starter culture called *nuruk* (see **Appendix C** for more details of *nuruk*) (S. Kim et al., 2015; Lee et al., 2015; Son et al., 2018). *Nuruk* plays an important role in the overall flavour of *makgeolli* because it contains a variety of microorganisms such as bacteria, fungi, and yeast—notably, *Bacillus amyloliquefaciens*, *Bacillus subtilis*, *Enterococcus faecium*, *Pediococcus pentosaceus*, and *Lichtheimia corymbifera* were found in *nuruk* (Song et al., 2013). Compounds such as 2,3-butanediol (buttery odour), 2-cyclohexen-1-ol, phenyl ethyl alcohol (floral odour), benzyl alcohol (fruity odour), and 3-methylbutanoic acid (cheese odour) were identified in the *nuruk* samples using gas chromatography–mass spectrometry (GC–MS), which are likely contributors to the flavour profile of *makgeolli* (S.-m. Lee et al., 2016). Other rice wine studies have shown that the starter culture determines the concentration of flavour compounds such as ethyl octanoate (apple-like aroma) and phenyl ethyl alcohol (rose aroma) (L. Chen, L. Ren, et al., 2021) and varying levels of polyphenolic content (Cai et al., 2019).

In terms of flavour compounds in *makgeolli*, Jung et al. (2014) identified 45 volatile compounds using gas chromatography coupled to time-of-flight mass spectrometry. The 45 major volatile compounds include 33 esters, eight alcohols, one aldehyde, one acid, one phenol, and one terpene (Jung et al., 2014). Three esters closely perceived as having fruity flavour—ethyl decanoate (grape flavour), ethyl octanoate (floral, banana, pear, and pineapple flavour), and ethyl dodecanoate (fruity flavour)—were observed in the *makgeolli* samples (Jung et al., 2014). In another study, H.-R. Kang et al. (2016) identified high levels of ethyl esters in *makgeolli* using solid-phase microextraction (SPME) coupled with GC–MS. Fruity and flower/floral flavour compounds (ethyl acetate, isoamyl acetate, ethyl decanoate, and phenyl ethyl acetate) were observed by H.-R. Kang et al. (2016).

In recent years, there have been a few published studies on the sensory perception of KRW in Western literature. KRW is an umbrella term for alcoholic beverages that originates from Korea and the primary ingredient for fermentation is rice. Examples of KRW include but are not limited to *yakju*, *makgeolli*, *takju*, *cheongju*, and *dongdongju*. These studies include Kwak et al. (2015) investigating the

sensory attributes of KRW among consumers in the United States for their acceptability, (Heo et al., 2020) identifying specific sensory attributes of KRW such as apple and sweet taste where it was found to be positively correlated with overall consumer liking, and (Wong, Muchangi, et al., 2023) comparing different *makgeolli* products using polarised projective mapping against three basic tastes including sourness, sweetness, and bitterness.

The purpose of this study is to determine the sensory profile of *makgeolli* from different processing methods. This research is novel because there is limited research on the flavour perception of *makgeolli* and sensory preferences in non-Korean markets such as New Zealand. This study aims to contribute to the growing area of cereal alcoholic beverages such as rice wine by exploring the flavour and sensory perception of rice wine outside of Asia. The main objectives of this paper include (a) using chemical techniques (SPME–GC–MS) to identify volatiles that are currently present in different *makgeolli* processing methods, (b) understanding the sensory characteristics of *makgeolli* by New Zealand consumers using CATA, and (c) understanding the intensity of specific attributes that contributes to the overall liking of *makgeolli* and how *makgeolli* samples can be optimised to increase consumer acceptance.

### **4.3 Materials and methods**

The following section is a description of the methods and materials used in the sensory evaluation and volatile compound analysis using SPME–GC–MS experiments.

#### **4.3.1 *Makgeolli* samples**

Four different *makgeolli* processing methods were examined in the sensory evaluation and SPME–GC–MS experiment. The *makgeolli* processing methods were identified from scientific literature (Jeon et al., 2010; S. Kim et al., 2015; Nile, 2015) and the researchers used Wong, Muchangi, et al. (2023) method of producing *makgeolli* for experimentation. The *makgeolli* samples will be referred to as 1SF-N, 1SF-YN, 2SF, and 3SF in this article. All *makgeolli* samples were prepared in the Food Laboratory of Auckland University of Technology. All materials were purchased from the Auckland CBD area.

In summary, the preparation of single-stage-fermented (1SF-N) *makgeolli* with *nuruk* involved washing 2 kg of glutinous rice (Wang Ltd.) until the water ran clear (around 10 min of continuous washing) and soaking for 3 h before draining for 1 h. The glutinous rice is then steamed for 120 min and then cooled to 25°C followed by mixing with 3 L of de-ionised (DI) water and 500 g of ground *nuruk* (Wang Ltd.). The 1SF-N mixture was then fermented at 25°C for 7 days. 1SF-N samples were then filtered and stored in an amber-coloured bottle in a refrigerator at 4°C until it was used for sensory evaluation and chemical analysis (within a week).

Preparation of single-stage-fermented (1SF-YN) *makgeolli* with yeast and *nuruk* followed a similar procedure as 1SF-N; however, 500 g of ground *nuruk* was replaced with 40 g of ground *nuruk* and 11 g of dry yeast (Safale US-05 dry ale yeast, Fermentis, S.I. Lesaffre).

The preparation of two-stage-fermented (2SF) *makgeolli* deviates from 1SF-N and 1SF-YN where the fermentation base was first produced before being incorporated into the glutinous rice and DI water mixture. The fermentation base is processed by first soaking 400 g non-glutinous rice (Wang Ltd.) for 3 h and then draining for 1 h. The non-glutinous rice is then milled into a fine powder using a blender (Russell Hobbs). The non-glutinous rice powder is cooked for 15 min with 1.25 L of DI water and then cooled to 25°C before incorporating 200 g of ground *nuruk*. The fermentation base is then left to ferment for 1 day at 25°C. The fermentation base is then filtered and 1 L of the fermentation base is incorporated into the 2 kg glutinous rice mixture with 1.5 L of DI water following a similar procedure as described for 1SF-N.

Three-stage-fermented (3SF) *makgeolli* followed the same procedure as 2SF; however, the fermentation base was fermented twice. For example, the fermentation base follows the same procedure as described in 2SF; however, after 1 day, the fermentation base is filtered and 1 L of this base is added into another set of 400 g of washed, drained, milled, and cooked non-glutinous rice. The fermentation base was left to ferment without additional *nuruk* for 1 day at 25°C and this second fermentation base was added to the steamed glutinous rice for the main fermentation as described in 1SF-N.

## **4.3.2 Sensory evaluation and wine knowledge assessment**

### **4.3.2.1 Study protocol**

The sensory evaluation was presented as a questionnaire format including a 9-point hedonic category scale, Check-All-That-Apply (CATA), Just-About-Right (JAR), subjective and objective wine scale, and sociodemographic questions. A code to differentiate the participants was printed on the right-hand corner of each page of the questionnaire (seven pages of the questionnaire in total). During the sensory evaluation, an information sheet about the experiment, a consent form, and a questionnaire about the sensory evaluation were presented to the participant upon arriving at the Food Science Laboratory (AUT). Participants were instructed to answer the questions according to the order presented on the questionnaire. For each *makgeolli* sample, a randomised three-digit code was printed on the top of the first four pages of the questionnaire and participants were required to answer the questions specifically to the *makgeolli* sample with the corresponding three-digit randomised codes. The participants first answered the 9-point hedonic category scale regarding the overall liking of the *makgeolli* sample, then participants were instructed to select the CATA terms that best describe the sensory attributes of the *makgeolli* sample. Lastly, participants were instructed to use the JAR scale to evaluate the *makgeolli* sample. After completing all four *makgeolli* samples in the order instructed by the researcher, participants answered questions to the objective wine knowledge scale followed by the subjective wine knowledge scale. Sociodemographic questions were placed on the last page of the questionnaire.

### **4.3.2.2 Participants**

Participants were recruited from the Auckland city area by means of posters, social media, and word-of-mouth. Participants were screened for the following criteria: (1) the participant does not suffer from food allergies such as wheat, rice, and alcohol, (2) the participant is not pregnant or trying to conceive a child, (3) the participant is not operating heavy machinery or driving within 2 h after completing the sensory evaluation, and (4) participants being or over the legal age of 18 were allowed to take part in the sensory evaluation. Participants were invited to participate in the sensory evaluation based on their interest in the *makgeolli* study, and the information sheet states that the participant should be a regular consumer of alcoholic beverages, for example, beer and wine. Regular consumption of rice wine was not a prerequisite for participants participating in the sensory evaluation. One hundred and thirty-two participants attended the

sensory evaluation; however, three participants were removed due to the participants not being responsive or submitting an incomplete sensory evaluation. One hundred and twenty-nine participants participated in the study, with 52.7% female participants taking part in the sensory evaluation. Most of the participants were aged between 21 and 29 years old (58.9%), and the largest self-identified ethnic group in this experiment was New Zealand European (29.5%) followed by East Asian subjects (27.9%). Forty percent of participants consume rice more than once a week, followed by 28.7% of participants who consume rice at least once a week, and only 12.4% of participants seldom consume rice. Researchers used the self-prioritisation method as part of the sociodemographic questions to categorise participants into specific ethnic groups. Participants can only identify one specific ethnic group that they strongly associate themselves with (Kukutai & Callister, 2009). New Zealand Europeans are defined as individuals who have a strong affiliation with New Zealand (e.g., citizenship or cultural identity) with European ancestry. A summary of the participants' sociodemographic details is presented in **Table 4.1**. This sensory test was reviewed and approved by the AUT Ethics Committee number 19/241.

**Table 4.1.** Sociodemographic information of participants with percentage including age, gender, ethnicity, rice consumption frequency, and alcoholic consumption frequency that participated in the sensory evaluation.

Characteristics	Sample n (%)
<b>Age</b>	
18 – 20	7 (5.4%)
21 – 29	76 (58.9%)
30 – 39	23 (17.8%)
40 – 49	10 (7.8%)
50+	13 (10.1%)
<b>Gender</b>	
Male	61 (47.3%)
Female	68 (52.7%)
<b>Ethnicity</b>	
East Asian <sup>a</sup>	36 (27.9%)
European <sup>b</sup>	9 (7.0%)
Maori/Pacifika <sup>c</sup>	13 (10.0%)
Middle Eastern <sup>d</sup>	7 (5.4%)
New Zealand European <sup>e</sup>	38 (29.5%)
South Asian <sup>f</sup>	21 (16.3%)
Other <sup>g</sup>	5 (3.9%)
<b>Rice Consumption</b>	
More than once a week	52 (40.3%)
Least once a week	37 (28.7%)
Every second week	14 (10.9%)
Once a month	10 (7.7%)
Seldom	16 (12.4%)
<b>Alcohol Consumption</b>	
More than once a week	26 (20.1%)
Least once a week	32 (24.8%)
Every second week	25 (19.4%)
Once a month	46 (35.7%)

<sup>a</sup>East Asians category consist of subjects with east and south east Asian ancestry e.g., Chinese, Japanese, South Korean, Thai, Filipino, and Vietnamese.

<sup>b</sup>Europeans consist of subjects that have strong affiliation to European countries such as Greece, United Kingdom, France, Germany, and Spain that do not identify as New Zealand European.

<sup>c</sup>Maori and Pasifika category consist of subjects with Maori, Tongan, Samoan ancestry.

<sup>d</sup>Middle Eastern category consists of subjects with Iranian or Jordanian ancestry.

<sup>e</sup>New Zealand European is defined as individuals that have European ancestry but with strong affiliation with New Zealand (e.g., New Zealand citizenship).

<sup>f</sup>South Asian category consists of subjects with Indian or Sri Lankan ancestry.

<sup>g</sup>Other category consist of subjects from African, Latin American, and American ancestry.

#### 4.3.2.3 Sample presentation and sensory evaluation procedure

The sensory evaluation took place in the Food Laboratory at the AUT city campus with the temperature set at 22°C. White fluorescent light was used in the Food Laboratory, and prior knowledge or training in rice wine or alcoholic beverages such as beer or wine was not necessary. Before starting the sensory evaluation, a researcher explained the nature of the experiment and how to answer the questionnaire to the participants. Participants were instructed to consume the *makgeolli* sample one at a time following the order of the three-digit randomised codes printed on the questionnaire and answer the survey questions accordingly. A 1 min break was enforced between each sample by a timer with a counting down function and participants were asked to consume one cracker (Arnotts) and a sip of water as a palate cleanser. All samples were prepared at least 4 h before the experiment took place. A total of 15 mL of *makgeolli* was pipetted to a 30-mL transparent portion cup and was stored in the refrigerator at 4°C before the sensory evaluation.

#### 4.3.2.4 Scales and questionnaire

The sensory evaluation consists of a 9-point hedonic category scale labelled from “*dislike extremely*” to “*like extremely*” for determining the overall liking of *makgeolli*, CATA, JAR, and sociodemographic questions. Objective and subjective wine knowledge questions were also included to understand the participant's degree of knowledge, attitude, and behaviour toward wine (Ellis & Caruana, 2018; Flynn & Goldsmith, 1999; Forbes et al., 2008). The use of the objective and subjective wine knowledge scale is only for exploratory purposes and both scales are not specifically designed for rice wine. However, the researchers' intention was to see whether group clustering existed among participants and whether this would affect the taste and flavour perception of *makgeolli*. Research previously published by Kwak et al. (2015) indicates that KRW (including *makgeolli*) may have similar attributes to rosé or white wine. This is to test whether different levels of objective and subjective wine knowledge would perceive *makgeolli* differently. The objective wine knowledge questions, consisting of five questions, were taken verbatim for this study (Ellis & Caruana, 2018; Forbes et al., 2008). However, four questions from the subjective wine knowledge were used instead of the nine presented in Flynn and Goldsmith (1999). A focus group consisting of four researchers and students from the Department of Food Science and Microbiology (AUT) noted that the five other questions from the subjective wine knowledge scale were repetitive and as a result, those questions were subsequently removed from the questionnaire. Subjective wine knowledge scale required

participants to select the answer that best describes their situation on a 7-point category scale from “*disagree strongly*” to “*agree strongly*.” The four questions include (Q1) “Among my circle of friends, I’m one of the ‘experts’ on wine,” (Q2) “Compared to most other people, I know a lot about wine,” (Q3) “I am quite familiar with wine,” and (Q4) “I feel very knowledgeable about wine.” Two of the four questions—Q1 and Q2—were taken from Ellis and Caruana (2018); Flynn and Goldsmith (1999); Forbes et al. (2008).

The CATA method was selected due to its ease of use and the minimal training required for participants to yield meaningful sensory information about the food product. CATA is relatively simple to carry out as participants only need to “check” or “mark” specific sensory attributes that are relevant or perceived by the participants. CATA has been used in alcoholic beverages and the products include *Syrah* (Alencar et al., 2019), Sangiovese wine (Rinaldi et al., 2021), and *yakju* (Lee, Kwak, Kim, et al., 2021). Terms used in the CATA questionnaire were formulated by previous literature that performed descriptive sensory analysis on *makgeolli*, KRW, and rice (Jung et al., 2014; Kwak et al., 2015; Lee & Lee, 2008; Pramudya & Seo, 2018). In addition, two focus groups were convened to ascertain the most fitting terms for describing the *makgeolli* samples. Two focus groups with four participants in each were recruited from AUT, however, sociodemographic details were not collected. All participants had previous experience with sensory evaluation; however, they are not regular consumers of rice wine. Seven participants were students ( $n = 5$  from the Department of Food Science and Microbiology;  $n = 2$  from the Department of Chemistry) and one was a staff member from AUT. Four *makgeolli* samples were presented with random three-digit numbers in the focus groups, and the focus groups were set up in a semi structural format describing the *makgeolli* samples by sight, taste, flavour, and texture.

Based on the results from published literature (1) and two focus groups (2), 20 terms were selected for this study that best describe the *makgeolli* samples including apple, apricot, astringent, bitter, bubbly, cider, cream, dairy, floral, hay-like, metallic, nutty, peach, pear, rancid, sour, sweet, watery, yellow, and yeasty. During the sensory evaluation, participants were asked to review the terms listed on the CATA questionnaire to ensure their understanding of all the terms. A list of terms and their corresponding definition were provided to participants during the sensory evaluation for the CATA questionnaire. participants were

asked to select all the terms that they consider best describe the *makgeolli*. All the CATA terms were placed in a random order to reduce answering bias throughout the sensory evaluation.

The JAR scale was selected as part of this study because the JAR scale allows researchers to determine which sensory attribute should be reformulated or adjusted to increase product overall liking of *makgeolli*. Other features of the JAR scale that appealed to the researchers include (1) the ability to calculate the penalty score that identifies which specific attributes are affecting *makgeolli*'s hedonic score and (2) to quickly ascertain the perception of the intensity of specific attributes (e.g., sweetness and sourness) in *makgeolli* by the participants partaking in this study. Seven attributes including *sweetness, sourness, astringency, colour, alcohol strength, fruitiness, and smoothness* were assessed on a 5-point JAR scale (1 = *Not enough*, 3 = *Just about right*, and 5 = *Too much*). All the JAR attributes were placed in a random order to reduce answering bias on the questionnaire. Sensory terms with definitions were provided to the participants alongside CATA terms; participants were encouraged to ask the researcher if they did not understand the terms.

#### 4.3.3 Chemical analysis (SPME-GC-MS)

Headspace SPME for volatile analysis of *makgeolli* used a similar methodology reported by Diep et al. (2021). A volume of two millilitres of *makgeolli* sample was placed in each headspace vial with 0.5 g of NaCl. A total of 10 µL of internal standard (5 µL/L solution of 1,2 dichlorobenzene in ultra-purified water) was added to the headspace vial and vortexed for 30 s. The headspace vial was heated at 50°C and was incubated for 15 min at an agitator speed of 250 rpm. The SPME fibre used for this study was Supelco 50 mm/30 µm DVB/CAR/PDMS, Stableflex, 24GA Fibre Assembly (Sigma Aldrich 57,329-U). The extraction period was 25 min, and the desorption time was 5 min at a desorption temperature of 50°C. SPME volatile analysis was performed on an Agilent GC-MS system, 7890B GC and 5977B MSD, equipped with a Gerstel autosampler. The column used was an Agilent J&W DB-Wax UI column (122-7032UI) (0.25 µm film thickness, 0.25 mm ID × 30 m length). The carrier gas was helium with a constant flow rate of 1.1 mL/min. The injection was splitless, with the inlet temperature for the injection port set at 250°C. For the chromatographic conditions, the temperature was set at 40°C, held for 2 min, and raised to 240°C at the rate of 8°C/min and held for 3 min. The total run time of mass spectrometry (MS) was 30 min. The MS

conditions were set at a source temperature of 250°C and a quad temperature of 150°C, with the electron ionisation energy set at 70 eV. The total MS total ion chromatogram scanned masses range from 38 to 450 *m/z*.

To aid in the identification of unknown compounds, a series of alkane standards (C7–C30; Supelco) was run using the same GC–MS method as used in the sample analysis. The retention times for alkanes from heptane to triacontane were uploaded to the MassHunter Unknowns software program to augment the NIST14 library compound identification with retention index (RI) values. The semi polar column RI values for the NIST-identified compounds were compared with the experimentally obtained RI values. If the values were within 20 points, this was identified as a positive hit, and if not, the RI values of similar NIST matching compounds were compared to the experimentally obtained RI value to help verify a hit. Once a compound hit was obtained, the compound was added to the MassHunter Library that would be run against the entire sample set to obtain relative concentrations. The GC–MS response of the volatile compounds was normalised to the response of the internal standard. GC–MS quantification was not performed, and absolute concentration was not obtained. The SPME–GC–MS results are semiquantitative in nature as the relative concentrations were normalized against 1,2-dichlorobenzene as the internal standard. The volatile compound responses in **Table 4.3** include the mean of *makgeolli* samples in triplicate ( $n = 3$ ) and their standard deviation.

#### 4.3.4 Statistical analysis

Hierarchical cluster analysis (HCA) was employed to determine the consumer groups present in this study in combination with objective wine knowledge, subjective wine knowledge, *makgeolli* overall liking, alcoholic consumption pattern, and rice consumption pattern data. Ward's method was employed with Euclidean distances to calculate cluster groups among the participants.

Nine-point hedonic category scale of *makgeolli* overall liking was analysed by one-way analysis of variance (ANOVA) and the post hoc test was performed by Tukey's Honestly Significant Difference (HSD) test when statistically significant differences were observed. ANOVA was also performed between male and female participants for the overall liking of *makgeolli* on the 9-point hedonic category scale. Statistical significance was defined to exist at  $p < 0.05$  for the one-way ANOVA.

Each CATA term was calculated by counting the number of times participants marked the term that best describes the *makgeolli* samples. Cochran's  $Q$  test was performed to evaluate the statistical differences among the four *makgeolli* samples (1SF-N, 1SF-YN, 2SF, and 3SF). If statistical differences among the variables were observed, post hoc multiple pairwise comparisons were performed using McNemar's test. Alpha was set at 0.05 to determine statistical significance. Correspondence analysis (CA) was used to visualise the interactions between different sensory attributes of the CATA terms and *makgeolli* samples. Significant terms determined by Cochran's  $Q$  test were used in CA.

Mean drop was calculated by the mean overall liking for the JAR attribute minus the mean overall liking of “not enough” and mean overall liking of “too much” (Narayanan et al., 2014). This was performed for each attribute that was stated in **Section 4.3.2.4**. The mean drop values were then plotted against the percentage of participants giving each attribute a response that is either “not enough” or “too much” (Narayanan et al., 2014).

Principal component analysis (PCA) was conducted to understand the interactions of volatiles in the *makgeolli* samples. The volatiles were standardised using `scale.unit` function from FactoMineR package in R.

All data analyses were performed in R version 4.1.0. JAR data were analysed and visualised using “SensoMineR” (Lê & Husson, 2008) and “FactoMineR” (Lê et al., 2008). CAs were visualised using “FactoMineR.” Nonparametric analyses such as Cochran's  $Q$  test and McNemar's test were performed by “rcompanion” R package.

## **4.4 Results and discussion**

### **4.4.1 Hierarchical cluster analysis**

From the HCA, four groups were identified—Cluster 1 with 28 participants, Cluster 2 with 70 participants, Cluster 3 with eight participants, and Cluster 4 with 20 participants. Three participants were removed from HCA due to incomplete answers in sensory evaluation. Cluster 1 participants rated 2SF

( $5.6 \pm 1.9$ ) with the highest mean hedonic score, while they rated 3SF ( $3.9 \pm 2.1$ ) as the lowest among the four *makgeolli* samples. Over 75% of the participants consume rice at least once a week, and the consumption frequency of alcoholic beverages is distributed evenly between the four categories of once a month, every second week, at least once a week, and more than once a week. In Cluster 2, participants rated 1SF-YN ( $5.8 \pm 2.0$ ) the highest on the mean hedonic scale, while 1SF-N ( $4.4 \pm 1.8$ ) is rated the lowest. The majority of the participants are between the ages of 21 and 34 (80.0%), and participants tend to consume alcoholic beverages at a lower frequency compared to the three cluster groups. Cluster 3 consists of eight participants, and they rated 1SF-N ( $5.4 \pm 2.7$ ) the highest on the mean hedonic score and 2SF ( $4.1 \pm 1.9$ ) the lowest among the four *makgeolli* samples. Interestingly, Cluster 3 had the highest correct answers on the objective wine knowledge scale and scored moderately on the subjective wine knowledge scale. Cluster 4 consists of 20 participants — 1SF-YN ( $5.7 \pm 1.3$ ) scored the highest on the mean hedonic score for overall liking of the *makgeolli* and 1SF-N ( $3.3 \pm 1.6$ ) scored the lowest. Cluster 4 participants scored high on the subjective wine knowledge scale relative to the other cluster groups; however, their answers were less correct compared to Cluster 3 for objective wine knowledge.

In this study, objective wine knowledge and subjective wine knowledge were used as an exploratory technique to categorise different participants into different customer segments by employing HCA. Of course, objective wine knowledge and subjective wine knowledge cannot be directly related to rice wine and KRW. However, behavioural questions exclusively about rice wine or KRW would not yield much information in a Western context, given the limited availability and presence of rice wine products. Research from Kwak et al. (2015) indicates that Western consumers perceive KRW as belonging to the wine category. From Kwak et al. (2015) study, Western consumers tend to rate KRW samples with higher overall liking when the KRW has a higher resemblance to semi-sweet white wine. More research is needed on Western consumers' attitudes and behaviours toward rice wine as information regarding this topic is limited.

#### 4.4.2 Hedonic rating of *makgeolli* samples

Statistical differences were observed between *makgeolli* samples for the mean hedonic rating ( $p < 0.001$ ) (see **Appendix D** for the graphing of hedonic score of the four *makgeolli* samples and **Appendix E** for the one-way ANOVA results of the hedonic score of the four *makgeolli* samples). 1SF-YN was

observed to be the most liked *makgeolli* sample with an overall mean hedonic score of  $5.5 \pm 2.0$  followed by 2SF ( $5.1 \pm 2.1$ ); however, both are not statistically significant. 3SF has a hedonic score of  $4.5 \pm 2.0$ , and 1SF-N was the least liked *makgeolli* sample with a hedonic score of  $4.3 \pm 1.9$ . Both 3SF and 1SF-N were not statistically significant; however, 1SF-N is significantly different from 1SF-YN.

ANOVA showed statistical differences among genders in mean hedonic scores of the four *makgeolli* samples ( $p < 0.001$ ) (see **Appendix F** for the overall liking of *makgeolli* between genders and **Appendix G** for the ANOVA results of overall liking of *makgeolli* between male and female participants). The mean hedonic scores for male participants of *makgeolli* tend to be lower than female participants; however, female participants tend to rate overall liking of *makgeolli* with a greater range (e.g., greater standard deviation). Female participants rated the 1SF-YN sample with the highest overall mean of  $5.6 \pm 2.0$  followed by 2SF ( $5.2 \pm 2.2$ ); however, the difference was not statistically significant. 1SF-YN ( $5.5 \pm 2.0$ ) was also the highest rated among male participants followed by 2SF ( $5.0 \pm 2.0$ ). Both male and female participants rated 1SF-N as the least liked *makgeolli* with an overall hedonic rating of  $4.3 \pm 2.1$  and  $4.2 \pm 1.8$ , respectively.

The hedonic score of *makgeolli* overall liking is relatively low (e.g., the mean hedonic score of overall liking is below 6). A possible explanation of the moderate low overall liking of *makgeolli* among the participants may be the result of limited prior experience before the sensory evaluation and being unfamiliar with Korean alcoholic beverages. Studies show that previous experience with ethnic food products helps consumers to form positive expectations of the food product, consequently increasing overall liking (Choe & Hong, 2018). In terms of familiarity, evidence suggests that familiarity with the food product is often correlated with higher hedonic scores during consumer testing (Hong et al., 2014; Park et al., 2020).

#### 4.4.3 Check-All-That-Apply

Thirteen terms were cited 20% or more by participants, while 14 terms were statistically significant between *makgeolli* samples using Cochran's *Q* test. These terms include apple, apricot, astringent, bitter, bubbly, cider, creamy, dairy, hay-like, peach, sour, sweet, watery, and yellow. The most used term by subjects to describe *makgeolli* was sour. The perceived attribute of astringency by participants increased as the length of fermentation time increased in *makgeolli*. In contrast, more participants noted bubbliness as a

perceived trait in single-stage fermentation such as 1SF-YN, and this trait reduced as the length of fermentation time increased such as 2SF (11.6%) and 3SF (5.4%). **Table 4.2** shows the usage frequency and statistical significance of terms used to describe *makgeolli*. Post hoc test was performed using McNemar's test to identify terms with statistical significance at  $p < 0.05$ . There are similarities between the attributes identified in this study and those described by Kwak et al. (2015) and Lee and Lee (2008). American participants identified attributes such as apple, pear, peach, nutty, yeasty, and apricot to describe KRW (Kwak et al., 2015).

**Table 4.2** A contingency table of the fraction of consumers selecting the 20 terms from the Check-All-That-Apply questionnaire to describe *makgeolli*.

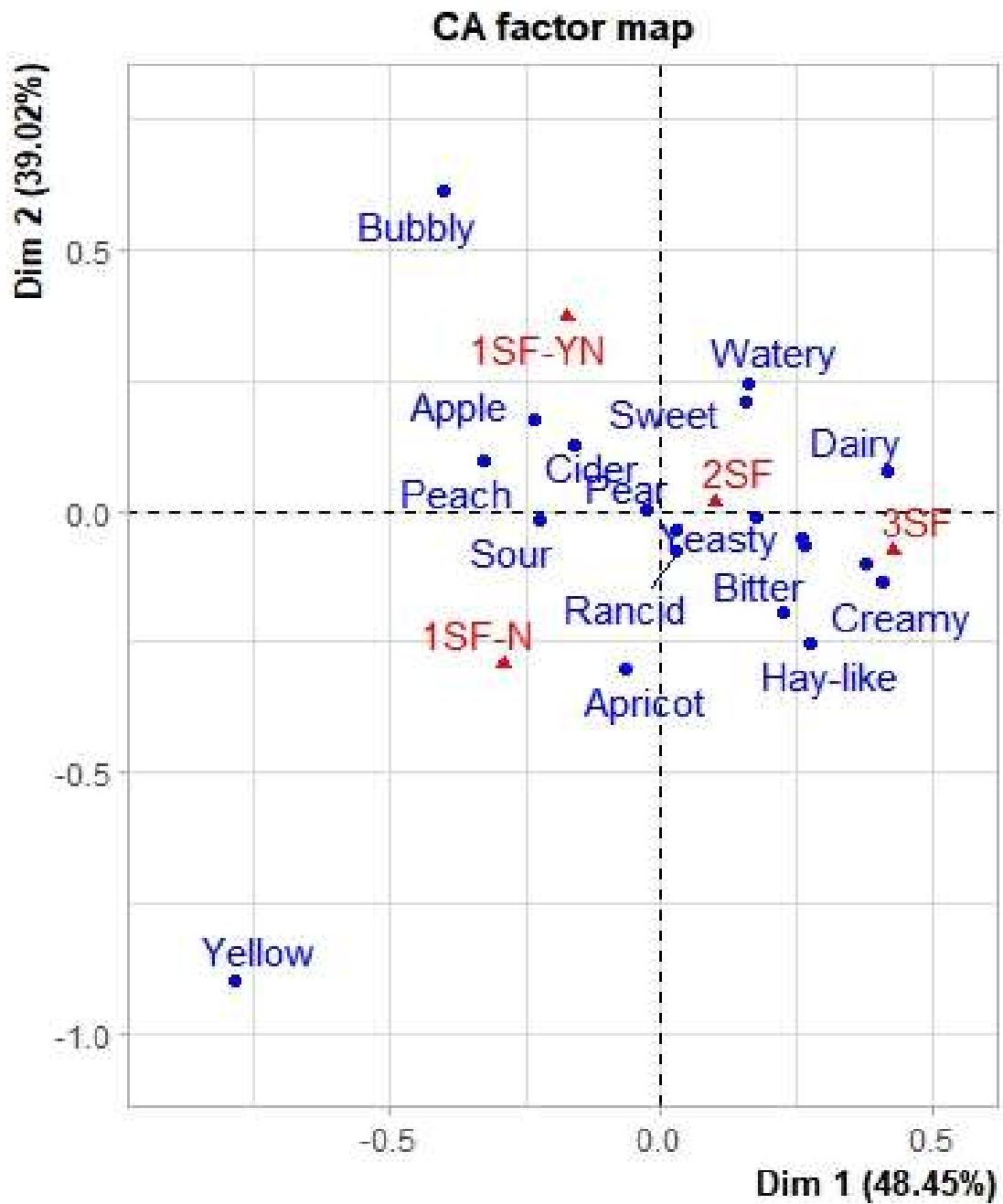
Attribute	Significance	1SF-YN	1SF-N	2SF	3SF
Apple	0.000***	0.403 <sup>a</sup>	0.326 <sup>a</sup>	0.333 <sup>a</sup>	0.132 <sup>b</sup>
Apricot	0.018*	0.07 <sup>b</sup>	0.194 <sup>a</sup>	0.132 <sup>ab</sup>	0.109 <sup>ab</sup>
Astringent	0.004**	0.217 <sup>b</sup>	0.264 <sup>ab</sup>	0.357 <sup>a</sup>	0.388 <sup>a</sup>
Bitter	0.000***	0.178 <sup>a</sup>	0.341 <sup>b</sup>	0.333 <sup>b</sup>	0.403 <sup>b</sup>
Bubbly	0.000***	0.411 <sup>b</sup>	0.147 <sup>b</sup>	0.116 <sup>a</sup>	0.054 <sup>a</sup>
Cider	0.000***	0.527 <sup>d</sup>	0.457 <sup>c</sup>	0.481 <sup>b</sup>	0.24 <sup>a</sup>
Creamy	0.000***	0.085 <sup>b</sup>	0.147 <sup>b</sup>	0.31 <sup>a</sup>	0.271 <sup>a</sup>
Dairy	0.008**	0.116 <sup>ab</sup>	0.07 <sup>b</sup>	0.163 <sup>ab</sup>	0.202 <sup>a</sup>
Floral	0.538 <sup>NS</sup>	0.054 <sup>a</sup>	0.085 <sup>a</sup>	0.062 <sup>a</sup>	0.093 <sup>a</sup>
Hay like	0.005**	0.07 <sup>a</sup>	0.155 <sup>ab</sup>	0.109 <sup>ab</sup>	0.202 <sup>b</sup>
Metallic	0.550 <sup>NS</sup>	0.085 <sup>a</sup>	0.085 <sup>a</sup>	0.07 <sup>a</sup>	0.116 <sup>a</sup>
Nutty	0.117 <sup>NS</sup>	0.054 <sup>a</sup>	0.07 <sup>a</sup>	0.101 <sup>a</sup>	0.132 <sup>a</sup>
Peach	0.027*	0.116 <sup>b</sup>	0.116 <sup>b</sup>	0.093 <sup>ab</sup>	0.031 <sup>a</sup>
Pear	0.437 <sup>NS</sup>	0.116 <sup>a</sup>	0.132 <sup>a</sup>	0.155 <sup>a</sup>	0.093 <sup>a</sup>
Rancid	0.819 <sup>NS</sup>	0.116 <sup>a</sup>	0.155 <sup>a</sup>	0.132 <sup>a</sup>	0.132 <sup>a</sup>
Sour	0.000***	0.612 <sup>b</sup>	0.775 <sup>a</sup>	0.667 <sup>ab</sup>	0.287 <sup>c</sup>
Sweet	0.018*	0.271 <sup>a</sup>	0.14 <sup>b</sup>	0.279 <sup>a</sup>	0.233 <sup>ab</sup>
Watery	0.000***	0.318 <sup>a</sup>	0.155 <sup>b</sup>	0.093 <sup>b</sup>	0.302 <sup>a</sup>
Yeasty	0.463 <sup>NS</sup>	0.31 <sup>a</sup>	0.372 <sup>a</sup>	0.372 <sup>a</sup>	0.318 <sup>a</sup>
Yellow	0.000***	0.031 <sup>a</sup>	0.403 <sup>b</sup>	0.037 <sup>a</sup>	0.031 <sup>a</sup>

Letter within each row represents a statistical difference between each sample.

<sup>NS</sup> Statistical significance was not reached, \*Statistical significance was reached at  $P < 0.05$ ,

\*\* Statistical significance was reached at  $P < 0.01$ . \*\*\* Statistical significance was reached at  $P < 0.001$ .

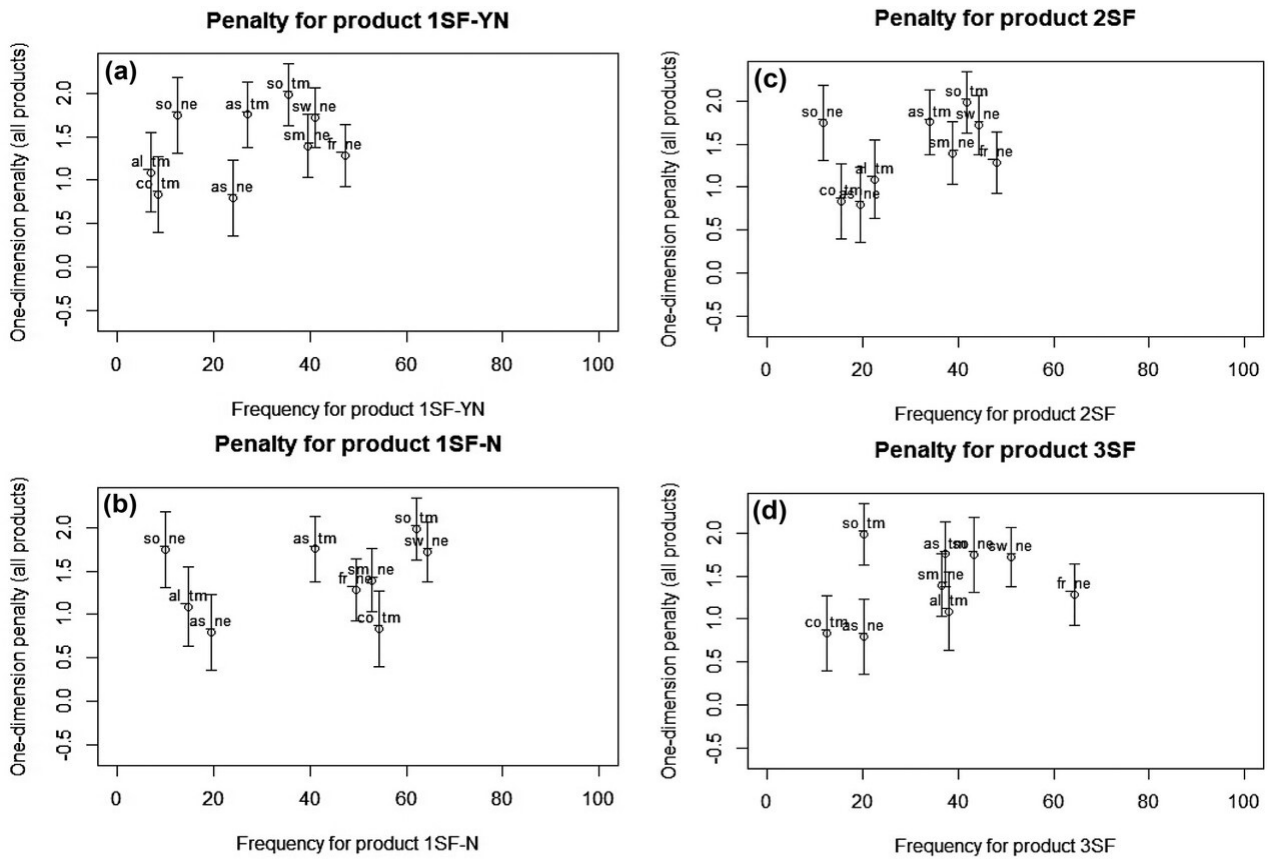
Further analysis of CATA terms was performed by using CA to visualise the association between sensory attributes and *makgeolli*, as shown in **Figure 4.1**. The CA biplot map explains 87.47% of the total variance (48.45% in the first dimension and 39.02% in the second dimension). Each *makgeolli* was distributed on each of the four quadrants of the biplot map. The first dimension was defined by fruity flavour attributes such as apple, peach, cider, apricot, and pear in the negative values, compared to textural attributes such as creamy, watery, and astringent in the positive values. The results displayed in **Figure 4.1** show that 2SF and 3SF are closely grouped together in the positive values of the first dimension, while 1SF-YN and 1SF-N are in the negative values. The differences between the *makgeolli* samples and sensory attributes in **Figure 4.1** are likely to be influenced by the processing method such as the fermentation time and starter culture. For example, 3SF had the longest fermentation time and required a three-stage fermentation process, thereby enhancing the creamy texture of the rice wine. In contrast, 1SF-YN and 1SF-N had 7 days of single-stage fermentation; therefore, the creamy texture was not properly developed. From the CA biplot map, 1SF-YN shares similar flavour attributes such as apple, peach, cider, and apricot described by Kwak et al. (2015) as favourable traits of rice wine. In comparison, 1SF-N was associated with negative sensory attributes such as bitter and sour, both of which are negative drivers of rice wine (Kwak et al., 2015).



**Figure 4.1** Correspondence analysis of the CATA terms and the cluster distribution of *makgeolli* samples.

#### 4.4.4 JAR and penalty analysis

**Figure 4.2a** summarises the penalty analysis for 1SF-YN. Overall, four attributes including too much sourness, not enough sweetness, not enough smoothness, and not enough fruitiness contributed a big part of the hedonic score in 1SF-YN. For 1SF-N, sensory attributes including too much sourness, not enough smoothness, not enough fruitiness, and too much astringency exceed the penalty of 1 as shown in **Figure 4.2b**. This indicates that reformulation should be considered for 1SF-N; however, some of the attributes tend to contradict each other with a mean drop over 1 for both too much and not enough. For example, 62% of participants cited sourness to be too much for SF-N with a mean drop score of 1.88, while 10% of participants cited sourness as not enough for 1SF-N with 1.82. Similar issues can be observed for both 2SF and 3SF as shown in **Figure 4.2c** and **Figure 4.2d**, respectively, where contradictory information was observed. For 2SF, six attributes of interest excluding colour had a mean drop score of more than 1. The contradictory results may have been caused by two factors: differing consumer groups within the participants in this study and participants not knowing an ideal product to compare *makgeolli* with or being unfamiliar with the product itself. From **section 4.4.1**, four clusters of consumer groups were identified in this study using HCA. The four consumer groups may have perceived the four *makgeolli* samples differently as the level of subjective wine knowledge, objective wine knowledge, hedonic scores of different *makgeollis* samples, alcohol consumption frequency, and rice consumption frequencies were different. For example, Lee and Lee (2008) identified three consumer groups during their consumer testing for KRW, and Wong, Muchangi, et al. (2023) noted that males and females tend to perceive *makgeolli* differently when comparing sweet, sour, and bitter tastes. Although the JAR scale provides the benefit of penalty analysis for product optimisation, *makgeolli* is not a common product within New Zealand. Participants may have found the JAR task difficult during sensory evaluation because the JAR scale assumes that they are familiar with the terms (e.g., sourness, sweetness, and colour) being examined and have an ideal product (e.g., rice wine) for comparison (Lawless, 2013).



**Figure 4.2** (A), (B), (C), and (D) are the penalty analysis performed on 1SF-YN, 1SF-N, 2SF, and 3SF respectively. The y-axis represents the penalty and the x-axis represents the frequency of participants citing the sensory attribute either ‘Not enough’, or ‘Too-much’. The sensory attribute is abbreviated in the left part of the underscore: so = sourness, al = alcoholic strength, sm = smoothness, sw = sweetness, fr = fruitiness, as = astringency, and co = color. The right side of the underscore denotes the intensity of the attribute either not enough (=ne) or too much (=tm).

#### 4.4.5 Volatile and flavour analysis

From the scientific literature, researchers have observed rice (Chen et al., 2020) and fermentation culture (*nuruk*) significantly impact the flavour and volatile compounds produced in rice wine (L. Chen, L. Ren, et al., 2021; Kang et al., 2020; Shin et al., 2017). Esters tend to be the most abundant volatile compound found in different rice wines including Hong Qu glutinous rice wine (Chinese rice wine) (Liu et al., 2022), sake (Japanese rice wine) (H.-R. Kang et al., 2016), and *makgeolli* (Jung et al., 2014; Park et al., 2014). In Hong Qu glutinous rice wine, specific esters that were identified include isoamyl acetate and ethyl acetate (Liu et al., 2022). In sake, isoamyl acetate and ethyl decanoate play an important role in the overall quality of the product (H.-R. Kang et al., 2016).

A total of 45 aroma compounds were detected from the four *makgeolli* samples by SPME–GC–MS, including 10 alcohols, 25 esters, four aldehydes, one terpene, one ether, one heteroaromatic compound, and three other compounds. The majority of the volatile compounds identified from the SPME–GC–MS for *makgeolli* are esters that are derived from alcohols and aldehydes. Esters are important aromatic compounds that that influences the quality of alcoholic beverages such as rice wine (H.-R. Kang et al., 2016). Examples of esters include phenethyl acetate, ethyl butanoate (pineapple-like flavour), and ethyl octanoate. In general, 2SF and 3SF have more ethyl esters than the single-stage-fermented *makgeolli* samples (1SF-N and 1SF-YN) due to a higher concentration of acyl-coenzyme A (acyl-CoA) produced by *Saccharomyces cerevisiae* (Saerens et al., 2008). The double and triple pre-fermentation steps to produce 2SF and 3SF *makgeolli* samples, respectively, produce a starter culture that has significantly higher microbial counts before the primary fermentation step (S. Kim et al., 2015). This means that *S. cerevisiae* can quickly reach peak activity during primary fermentation. Acyl-CoA produced by *S. cerevisiae* is a precursor for the formation of ethyl esters by enzymatic condensation of organic acids and ethanol via anabolism during fermentation (Pires et al., 2014). Other aroma compounds found in the *makgeolli* samples were consistent with the literature, as benzaldehyde (almond flavour) (L. Chen, S. Wang, et al., 2021), 1-octanol, 2-octanol (earthy/must aroma), ethyl acetate (fruity aroma) (L. Chen, L. Ren, et al., 2021), and phenylethyl alcohol (rose and floral aroma) (Yu et al., 2019) were previously identified in the literature and also present in this study.

**Table 4.3** shows the volatile compounds identified from the SPME–GC–MS. PCA was conducted and is represented in **Figures 4.3 and 4.4**. A scree plot (see **Appendix H**) was constructed, and the first three dimensions explain 86.28% of the total variance; however, only Dimension 1 and Dimension 2 will be used for further analysis. Both **Figure 4.3** (*makgeolli samples only*) and **Figure 4.4** (variable correlation circle of volatiles) contain Dimension 1 and Dimension 2 where the graph explains 63.58% of the total variance (36.73% and 26.85%, respectively). From **Figure 4.3**, both 2SF and 3SF samples tend to cluster together, while 1SF-N and 1SF-YN are distinctively different. This can be explained by the different processing methods of making *makgeolli* where 1SF-N had the highest concentration of *nuruk* among the four different processing methods and 1SF-YN had the lowest concentration of *nuruk*, but yeast was added to reduce the amount of *nuruk* required during the fermentation process. This practice is used to reduce the potential formation of excessive bioamines (histamine, tyramine, and putrescine) that can give *makgeolli* samples an unpleasant odour (Kim et al., 2011). Both 2SF and 3SF required a fermentation base prior to the fermentation process, in which the ingredients consist of non-glutinous rice and *nuruk*. Volatile compounds that had similar relative content between 2SF and 3SF include benzaldehyde (almond flavour), ethyl heptanoate (grape-like flavour), limonene (citrus peel-like flavour), and ethyl tetradecanoate. Volatile compounds that were distinctively unique to 1SF-N based on relative content include 1-heptanol, 1-nonanol, 1-octen-3-ol (mushroom-like flavour), 2-decanol, and ethyl-9-hexadecenoate.

In comparison, three volatile compounds—ethylidene diacetate, ethyl-9-decenoate (fruity-like flavour), and ethyl-trans-4-decenoate—are unique to 1SF-YN based on their relative content. The variable correlation circle of volatiles (**Figure 4.4**) shows that 2-ethoxy-2-methyl-propane, 2-methyl-1-propanol, isobutyl acetate, hexanal, limonene, and 2-pentyl-furan are well represented in the factor map, meaning that these volatiles are well correlated in either Dimension 1 or Dimension 2. Volatiles that provided the highest contribution for Dimension 1 are limonene, ethyl pentanoate, and hexanal, while 2-ethoxy-2-methyl-propane, 2-methyl-1-propanol, and isobutyl acetate were the three highest variables in Dimension 2.

Although statistical analysis was not performed when comparing sensory evaluation and chemical analysis, some volatile compounds identified from the SPME–GC–MS and sensory attributes from the CATA questionnaire showed similar sensory characteristics. For example, fruity attributes that were

identified in the CATA questionnaire were also identified in the SPME–GC–MS such as isobutyl acetate (pear-like flavour) and isobutyl octanoate (fruity-like flavour) with varying relative content between the *makgeolli* sample. The sensory attribute “hay-like” in the CATA questionnaire was also identified in the SPME–GC–MS, with hexanal (hay-like flavour) being identified as the volatile compound.

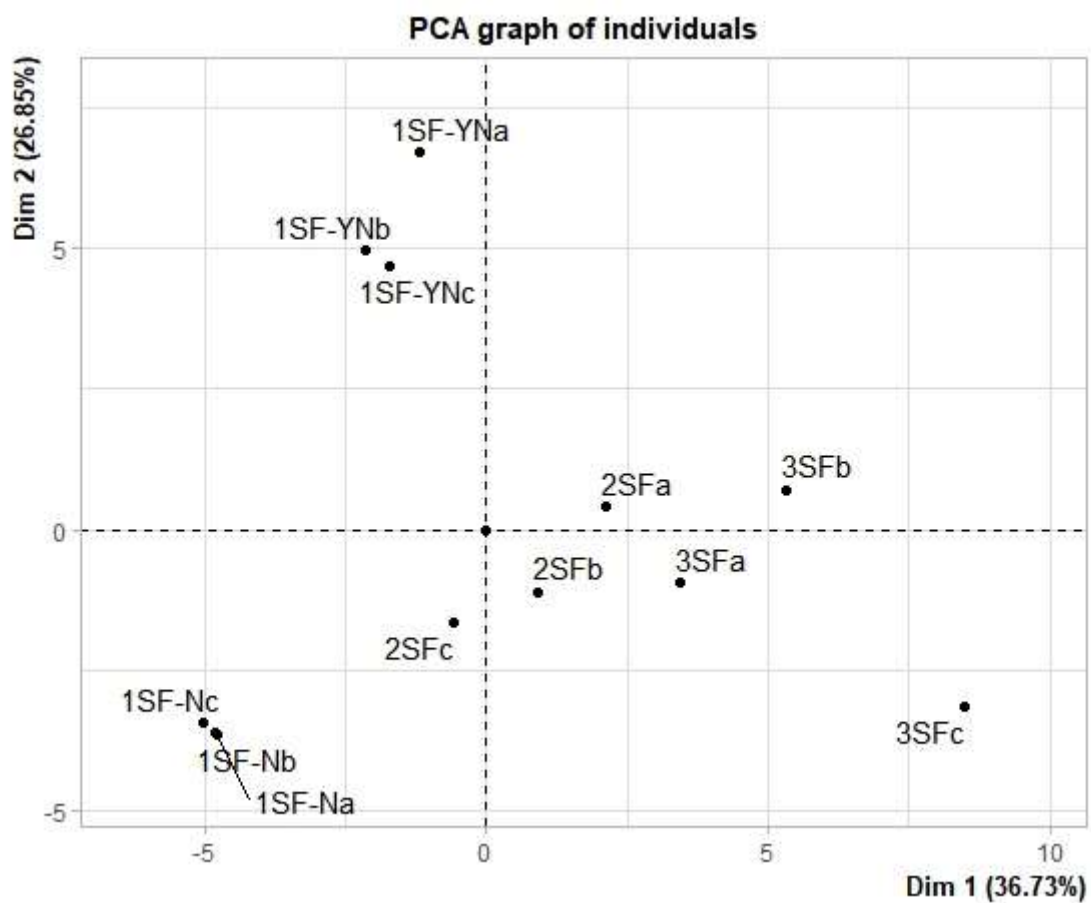
**Table 4.3** Normalised GC-MS response ratio of volatiles with mean values and standard deviation identified from *makgeolli* samples (n = 3).

Volatile compounds	1SF-N	1SF-YN	2SF	3SF
2-Ethoxy-2-methyl-propane	0.005 ± 0.000	0.009 ± 0.001	0.006 ± 0.000	0.006 ± 0.002
Ethyl Acetate	1.406 ± 0.025	1.493 ± 0.139	2.146 ± 0.233	1.630 ± 0.337
Isobutyl acetate	0.064 ± 0.005	0.230 ± 0.016	0.136 ± 0.015	0.125 ± 0.070
Ethyl butanoate	0.145 ± 0.010	0.095 ± 0.006	0.230 ± 0.020	0.175 ± 0.061
Hexanal	0.018 ± 0.000	0.038 ± 0.004	0.029 ± 0.002	0.035 ± 0.015
2-Methyl-1-propanol	0.320 ± 0.019	0.889 ± 0.117	0.571 ± 0.106	0.616 ± 0.229
Isoamyl acetate	0.303 ± 0.010	0.381 ± 0.061	0.503 ± 0.075	0.377 ± 0.094
Ethyl pentanoate	0.033 ± 0.001	0.033 ± 0.003	0.041 ± 0.004	0.043 ± 0.014
Limonene	0.002 ± 0.000	0.003 ± 0.000	0.005 ± 0.001	0.004 ± 0.002
2-Pentyl-furan	0.014 ± 0.000	0.011 ± 0.002	0.053 ± 0.004	0.032 ± 0.032
Ethyl hexanoate	0.719 ± 0.028	2.315 ± 2.105	0.925 ± 0.080	1.876 ± 2.158
3-Methylbutanol	0.810 ± 0.018	3.107 ± 1.809	1.129 ± 0.155	2.910 ± 2.998
Ethyl heptanoate	0.622 ± 0.026	1.251 ± 0.138	1.784 ± 0.107	1.409 ± 0.560
(Z)-2-Heptenal	0.006 ± 0.000	0.056 ± 0.027	0.007 ± 0.001	0.030 ± 0.033
2-Methylpropyl hexanoate	0.044 ± 0.004	0.203 ± 0.027	0.062 ± 0.005	0.094 ± 0.071
1-Hexanol	0.172 ± 0.007	0.568 ± 0.056	0.925 ± 0.079	0.504 ± 0.296
Ethyl octanoate	1.899 ± 0.048	2.762 ± 0.294	3.356 ± 0.229	2.794 ± 0.616
2-Octanol	0.285 ± 0.006	0.233 ± 0.169	0.055 ± 0.008	0.185 ± 0.156

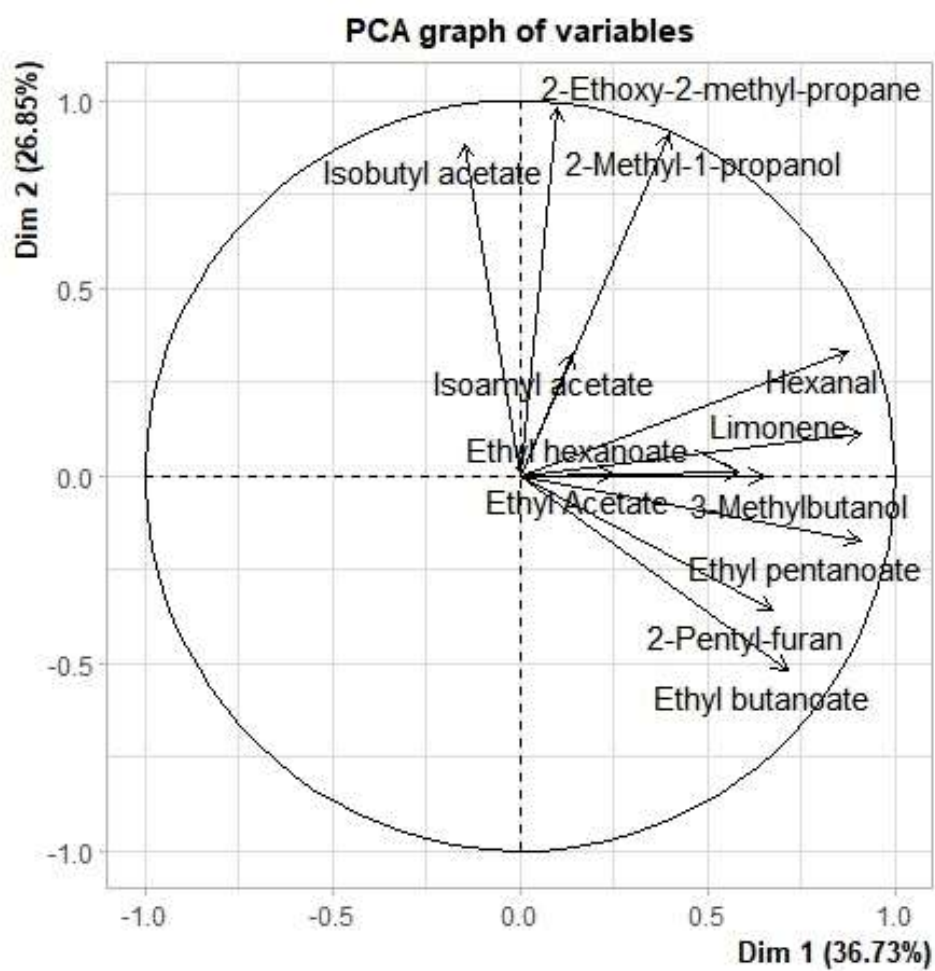
Isopentyl hexanoate	0.212 ± 0.014	0.298 ± 0.037	0.216 ± 0.014	0.288 ± 0.094
1-Octen-3-ol	0.040 ± 0.001	0.149 ± 0.004	0.105 ± 0.016	0.010 ± 0.041
Acetic acid	0.591 ± 0.116	1.899 ± 0.464	1.773 ± 0.314	1.176 ± 0.738
1-Heptanol	0.047 ± 0.004	0.135 ± 0.013	0.186 ± 0.019	0.123 ± 0.053
2-Ethyl-1-hexanol	0.039 ± 0.006	0.046 ± 0.003	0.053 ± 0.029	0.048 ± 0.015
Ethyl nonanoate	0.724 ± 0.099	1.112 ± 0.147	1.880 ± 0.112	1.366 ± 0.502
Benzaldehyde	0.031 ± 0.002	0.043 ± 0.001	0.037 ± 0.018	0.040 ± 0.011
Isobutyl octanoate	0.017 ± 0.001	0.066 ± 0.007	0.031 ± 0.002	0.035 ± 0.020
Ethyl (E)-2-octenoate	0.020 ± 0.001	0.022 ± 0.002	0.030 ± 0.001	0.029 ± 0.010
1-Octanol	0.047 ± 0.001	0.164 ± 0.016	0.196 ± 0.016	0.138 ± 0.060
Ethylidene diacetate	0.063 ± 0.006	0.261 ± 0.030	0.061 ± 0.016	0.112 ± 0.092
2-Decanol	0.014 ± 0.001	0.030 ± 0.003	0.029 ± 0.004	0.022 ± 0.009
Ethyl decanoate	0.014 ± 0.001	0.030 ± 0.003	0.029 ± 0.004	0.021 ± 0.009
Benzeneacetaldehyde	0.024 ± 0.004	0.023 ± 0.001	0.024 ± 0.003	0.029 ± 0.010
3-Methylbutyl octanoate	0.148 ± 0.006	0.127 ± 0.013	0.143 ± 0.011	0.139 ± 0.012
Ethyl trans-4-decenoate	0.023 ± 0.001	0.020 ± 0.002	0.039 ± 0.003	0.028 ± 0.008
1-Nonanol	0.037 ± 0.001	0.073 ± 0.007	0.089 ± 0.009	0.072 ± 0.023
Ethyl 9-decenoate	0.015 ± 0.000	0.079 ± 0.009	0.013 ± 0.001	0.029 ± 0.031
Phenylethyl acetate	0.308 ± 0.012	0.220 ± 0.014	0.374 ± 0.034	0.261 ± 0.094
Ethyl decanoate	0.756 ± 0.031	0.665 ± 0.061	1.058 ± 0.080	0.863 ± 0.176

Phenylethyl alcohol	$2.772 \pm 0.091$	$1.705 \pm 0.243$	$2.792 \pm 0.256$	$2.620 \pm 0.614$
Ethyl tetradecanoate	$0.585 \pm 0.033$	$1.008 \pm 0.102$	$1.790 \pm 0.159$	$1.336 \pm 0.597$
Ethyl hexadecanoate	$2.384 \pm 0.096$	$1.824 \pm 0.180$	$2.467 \pm 0.128$	$2.508 \pm 0.593$
Ethyl 9-hexadecenoate	$0.033 \pm 0.002$	$0.054 \pm 0.004$	$0.034 \pm 0.004$	$0.036 \pm 0.011$
Ethyl octadecenoate	$0.080 \pm 0.006$	$0.037 \pm 0.005$	$0.047 \pm 0.001$	$0.055 \pm 0.017$
Ethyl oleate	$0.196 \pm 0.013$	$0.131 \pm 0.045$	$0.228 \pm 0.030$	$0.193 \pm 0.043$
Ethyl linoleate	$0.281 \pm 0.043$	$0.126 \pm 0.020$	$0.298 \pm 0.041$	$0.231 \pm 0.077$

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**Figure 4.3** Represents the results of the PCA of four makgeolli samples with triplicates from the SPME-GC/MS analysis. The triplicates are denoted as a, b, or c which refers to the sequence of the analysis took place in the SPME-GC/MS.



**Figure 4.4** Represents the variable correlation circle of volatiles from the four makgeolli samples with triplicates. The distance between volatiles represents the quality of the information displayed on the PCA with volatiles further from the centre being better represented.

## 4.5 Implications and limitations

The current study is the combination of sensory science and chemistry to understand the sensory and flavour attributes that best describe *makgeolli* in a New Zealand context. CATA allowed researchers to capture the sensory attributes that describe *makgeolli*, while the JAR scale was used to calculate the penalty analysis regarding sensory attributes and the effects it has on hedonic scores of specific *makgeolli* samples. SPME–GC–MS identifies the volatile compounds within the different *makgeolli* processing methods described by Wong, Muchangi, et al. (2023). The benefit of using the CATA questionnaire is the ease of use for participants (Fleming et al., 2015). However, the CATA term selected by the researchers for this study may not capture all the sensory attributes that describe *makgeolli* in a New Zealand context as all the terms are predetermined by the researchers.

JAR scale was included in the study due to its ability for optimising and identifying attributes that are affecting the overall acceptance of the food product. However, JAR scales require participants to rate the product against an ideal product while understanding the term being evaluated (Ares et al., 2017), which can be challenging for some participants. Although this may be a limitation of the JAR scale, researchers have used the JAR scale to assess specific food products such as kimchi (Jang et al., 2016; Park et al., 2020) and Korean traditional cookies (*yackwa*) (Hong et al., 2014), among foreign consumers with low familiarity. Future research on *makgeolli* in a Western context such as New Zealand should incorporate information about the participants' familiarity, knowledge, understanding, and experience with KRW (specifically *makgeolli*) or rice wine. This will be beneficial to identify different cluster groups among consumers in New Zealand.

SPME–GC–MS provided a qualitative understanding of the different volatiles within the four different *makgeolli* samples. The concentration of the volatile compounds identified in this study can only be expressed relative to the four *makgeolli* samples tested. Absolute concentration measures of volatile compounds would require a different GC–MS method. The performance of sensory evaluation and chemical analysis (SPME–GC–MS) provided good insight into describing *makgeolli* with different processing methods. Both sensory evaluation and chemical analysis have revealed an overlap of sensory attributes and volatiles; 2SF and 3SF tend to share similar attributes that can be explained by their similar processing

methods (e.g., fermentation base from non-glutinous rice and *nuruk*). 1SF-N had a higher concentration of *nuruk*, while 1SF-YN requires yeast to enhance the fermentation process due to the low concentration of *nuruk*. The sensory evaluation provided complementary results to the chemical analysis (SPME–GC–MS), such as the identification of acetic acid (vinegar-like taste) for sourness, ethyl pentanoate for apple-like flavour, and hexanal for hay-like flavour.

#### 4.6 Conclusion

This research paper extends our knowledge of understanding the sensory attributes that best describe *makgeolli* using sensory evaluation and chemical analysis. The CATA technique was implemented to understand how participants describe different *makgeolli* samples, while the JAR scale provides information on ways to optimise *makgeolli* to increase overall liking on the hedonic category scale. Key attributes that were used to describe all four *makgeolli* samples by participants include sour, followed by cider, apple, creamy, and bubbly. Fruity attributes such as apple, apricot, and peach were statistically significant among the *makgeolli* samples where 1S-YN had more fruity attributes describing the alcoholic beverage by participants than 1SF-N, 2SF, and 3SF. In terms of the JAR results, the high penalty score (e.g., greater than 1) for most of the attributes may indicate that subjects may not be accustomed to consuming *makgeolli*. *Makgeolli* is not a common alcoholic beverage in New Zealand, and the higher penalty score is influenced by the low overall liking score accompanied by the “not enough” or “too much” categories of attributes. SPME–GC–MS provided similar insights to the sensory experiment where volatile compounds such as isobutyl acetate (pear-like flavour), isobutyl octanoate (fruity-like flavour’s), and hexanal (hay-like flavour) were identified. Both sensory evaluation and chemical analysis indicate that terms such as apple, cider, and sourness are good descriptors for describing *makgeolli*.

## **Chapters 5. Product categorisation of Korean rice wine (*makgeolli*) compared to beer and wine using sensory evaluation methods**

### **5.1 Prelude**

From the previous two chapters, the physicochemical and sensory properties of *makgeolli* were established, however, the placement or marketing of rice wine is often confusing because rice wine share similar traits to both beer and wine. In addition, both previous chapters (**Chapters 3 and Chapter 4**) were solely focused on *makgeolli*'s physicochemical and sensory properties. It is an important part of this research to determine how *makgeolli* performed among different alcoholic beverages. Currently, a published study by Kwak et al. (2015) hypothesised that Korean rice wine can be marketed in the semi-sweet white wine category, as Korean rice wine has similar sensory traits to semi-sweet white wine. However, no research has been conducted to accept or reject their hypothesis. In addition, the process of producing *makgeolli* resembles beer as starch cereal is the key carbohydrate for fermentation. **Chapter 5 – Product categorisation of Korean rice wine (*makgeolli*) compared to beer and wine using sensory evaluation methods** aims to determine whether *makgeolli* should be characterised as a beer or wine within the consumer market.

Two sensory evaluation studies were conducted in this chapter, (1) projective mapping, and (2) polarised sensory positioning. Projective mapping (also known as Napping®) requires participants to sort samples into different groups on a perceptual map often represented as an A3 or A2 sheet of paper. The distance between each sample allows researchers to determine an explainable relationship between them. Samples used in the projective mapping include four *makgeollis*, four beers and four wines. Polarised sensory positioning (PSP) uses references or 'poles' for participants to compare the samples.

## 5.2 Introduction

Market positioning determines the direction of the overall marketing strategy of promoting, pricing, and communicating products to consumers (Aaker & Shansby, 1982). Currently, *makgeolli* (Korean rice wine [KRW]) is a novel product within the Western market due to its low availability and awareness in the alcoholic beverage market. A few studies have looked into the sensory and consumer acceptance of KRW including Kwak et al. (2015); Wong, Muchangi, et al. (2023); Wong, Owens, et al. (2023) with Western consumers and participants. KRW acceptance was positively correlated with fruity characteristics and was negatively affected by a yeasty and bitter taste among American consumers. Other research conducted on KRW using sensory methods in the English scientific literature, include Check-All-That-Apply, Just-About-Right (Lee, Kwak, Kim, et al., 2021; Wong, Owens, et al., 2023), consumer testing (Jung et al., 2014), and projective polarised mapping (Wong, Muchangi, et al., 2023).

A key research gap for *makgeolli* is product categorisation within the alcoholic beverage market and to identify which marketing strategy, such as product differentiation or subtype strategy, is most suitable within Western markets such as New Zealand. This study sets out to use sensory methods such as projective mapping (PM) and polarised sensory positioning (PSP) to understand how participants categorise and characterise *makgeolli* on perceptual maps. PM (also known as Napping®) often coupled with ultra-flash profiling (UFP) is a holistic approach to product profiling. All samples of interest are presented simultaneously to the participants who are instructed to group samples according to their similarities and differences. Participants are asked to group samples according to their criteria and not restricted to grouping products by one sensory modality such as sight, taste, texture, and smell; in addition, more complex instructions can be included such as using red light to reduce visibility. Distances are then analysed to identify the different clusters of food samples or consumer groups and identify reasons for their arrangement based on their product similarities (Valentin et al., 2018).

PSP is a reference-based method where specific sensory characteristics are predetermined and samples are rated against the similarities of a set of references called poles (Teillet, 2015). This technique was originally created by Teillet et al. (2010) to understand the flavour attributes of water and was later used to analyse other food products such as wine (Wilson et al., 2018) and fruit-flavoured drinks (De Saldamando et al., 2015).

Categorisation plays a vital role in product positioning, according to categorisation theory, people naturally divide the world of objects such as consumer products for ease of information processing and is a fundamental learning process in psychology, where people identify the overlapping similarities of objects, and maximise the differences between groups (Mervis & Rosch, 1981). Categorisation theory can also be used in new product development, where researchers and producers can identify potential gaps in the current market and introduce new products using either product differentiation or subtype strategy (Sujan & Bettman, 1989). According to the literature, categorisation is a natural process that consumers undergo to understand and familiarise themselves with new products (Durand & Khaire, 2017; Gregan-Paxton et al., 2002; Ozanne et al., 1992). Research such as Goode et al. (2013) showed that new products placed in a category that is mismatched from consumer expectations would be underappreciated and ultimately fail within the marketplace, while Kuijken et al. (2017) demonstrated that consumers use category cues for average price referencing for new products.

When new products share noticeable similar attributes in the market, then using the product differentiation strategy would be beneficial as this highlight's superior features of the new product to consumers; creating a competitive advantage for the producer (Sujan & Bettman, 1989). Product differentiation allows the producer to enter their brands into other product markets (e.g., brand extension). When the new products' attributes are perceived to be different from other products within the category, a subtype strategy would be more beneficial as it creates new boundaries for the new product which disassociates itself from other products currently in the market (Sujan & Bettman, 1989).

This study aims to use sensory evaluation to understand how New Zealand participants categorise and characterise *makgeolli* compared to other alcoholic beverages such as beer and wine. As both beer and wine have traditionally been consumed in New Zealand, identifying whether *makgeolli* fits in either alcoholic beverage category can determine what type of marketing strategy could be used. For example, due to New Zealand's cultural ties with the United Kingdom, beer was considered as New Zealand's national beverage (Gollidge, 1963). As a sense of consumer identity, beer was often associated with masculinity or a rural male image (Campbell, 2000; Law, 1997). However, in the past 30 years, New Zealand's identity of consuming beer somewhat changed with the introduction of craft beer (Murray & Overton, 2016), female-led beer brewers (Kuehn & Parker, 2021), and the development of the wine industry (Wilson & Goddard, 2004).

Both beer and wine products were included in this study because both alcoholic beverages are the most popular alcoholic variety in New Zealand. In addition, the choice of specialty beer provides a greater sensorial range. Specialty beer (also known as craft beer) has been extensively researched in New Zealand for their sensory properties in research articles written by Jaeger et al. (2017); Jaeger et al. (2020); Jaeger et al. (2019). Therefore, the authors deemed specialty beer more appropriate for this study as regular beer tends to be homogenous in flavour and taste. In terms of wine, New Zealand has been known for wine production and are regular consumers of wine products (Jaeger et al., 2009; Mouret et al., 2013; Parr et al., 2007; Thomas & Pickering, 2003). Sauvignon Blanc was chosen due to its “green” characteristics (alternatively known as capsicum or vegetable flavour attributes) (Green et al., 2011; Parr et al., 2007), while Chardonnay has fruity and floral flavour attributes (Kustos et al., 2020; Lucas et al., 2023). Rosé was chosen due to its unique sensory properties of encapsulating both red wine and white wine properties (Ballester et al., 2009; Wang & Spence, 2019). Finally, Shiraz was chosen due to its full-bodied and spice (e.g., peppery) characteristics (Johnson et al., 2013; Kustos et al., 2020).

This information is important because it aids producers and researchers in correctly identifying the market position of rice wine (specifically *makgeolli*) in New Zealand. This study was carried out in two parts with PM with UFP being implemented first, followed by PSP. By completing both PM with UFP and PSP experiments, the results should provide greater insight into the potential ways of marketing *makgeolli* in the New Zealand beverage market.

## **5.3 Materials and methods**

The following section is a description of the methods and procedures of PM with UFP and PSP experiments carried out in this research study. The specific tests and methods in the two sensory evaluation experiments will be discussed in **Section 5.3.3.1** for PM with UFP and **Section 5.3.3.2** for PSP.

### **5.3.1 Alcoholic beverages for sensory analysis**

#### **5.3.1.1 *Makgeolli* samples and processing methods**

From the literature, there are multiple methods of producing *makgeolli*. However, the four *makgeolli* samples used in this study were identified by Wong, Muchangi, et al. (2023) and will be

referred to as 1SF-N, 1SF-YN, 2SF, and 3SF in this study. Based on Wong, Muchangi, et al. (2023) naming convention of the *makgeolli* samples, the number code on the *makgeolli* sample refers to fermentation stages, and the right hyphenated part of the *makgeolli* name refers to the culture used for fermentation. All *makgeolli* samples were prepared in the Food Science Laboratory of Auckland University of Technology (Auckland, New Zealand) and all materials were acquired from the Auckland CBD area.

Single-stage fermented *makgeolli* with *nuruk* (1SF-N) involved washing 2 kg of glutinous rice (Wang Ltd., Korea) with deionized (DI) water until the water ran clear (around 10 min of continuous washing). The washed glutinous rice was then soaked for 3 h before being drained for 1 h. The glutinous rice is then steamed for 120 min and then cooled to 25°C, followed by mixing 3 L of DI water and 500 g of crushed *nuruk* (Wang Ltd., Korea). The rice mixture was then fermented at 25°C for 7 days. 1SF-N was then filtered and stored in an amber-coloured bottle at 4°C refrigerator until it was used for either PM or PSP (all *makgeolli* samples were consumed within a week).

Single-stage fermented *makgeolli* with yeast and *nuruk* (1SF-YN) was produced in a similar procedure as 1SF-N; however, 40 g of ground *nuruk* and 11 g of dry yeast (Safale US-05 dry ale yeast, Fermentis, S.I. Lesaffre, France) were used instead of 500 g of *nuruk* for fermentation.

Two-stage fermented *makgeolli* (2SF) differs from 1SF-N and 1SF-YN samples where the fermentation time is longer, and a fermentation base was first produced before being incorporated in the glutinous rice and DI water mixture. The fermentation base was produced by first washing 400 g of non-glutinous (Wang Ltd., Korea) with DI water. Once the DI water ran clear (around 10 min of continuous washing), the non-glutinous rice was soaked for 3 h and then drained for 1 h. The non-glutinous rice is then pulverized into smaller particles using a blender (Russell Hobbs, UK). The non-glutinous rice powder is cooked for 15 min with 1.25 L of DI water and then cooled to 25°C before combining 200 g of ground *nuruk*. The fermentation base is then left to ferment for 1 day at 25°C. The rice mash consisting of the non-glutinous rice and *nuruk* was filtered and 1 L of the fermentation base was incorporated into the 2 kg of glutinous rice with 1.5 L of DI water; the following steps were similar to what was described for 1SF-N and left to ferment for 7 days at 25°C.

Three-stage fermented *makgeolli* (3SF) followed the same procedure as 2SF; however, the preparation of the fermentation base was longer, and the fermentation base was fermented two times. After 1 day of fermentation, the rice mash was filtered from the first fermentation base, and 1 L of the fermentation base was incorporated into another set of 400 g of washed, drained, pulverized, and cooked non-glutinous rice. No additional *nuruk* was incorporated into the second fermentation base and it was fermented for 1 day at 25°C. The second fermentation base was incorporated into steamed glutinous rice and followed the same procedure as 2SF.

### 5.3.1.2 Samples used in PM with UFP

Twelve samples of alcoholic beverages were used for the PM with an ultra-flash profiling (UFP) experiment. Four beers (Pilsner, Pale ale, Porter, and IPA), four wines (Shiraz, Chardonnay, Rosé, and Sauvignon Blanc), and four *makgeollis*, as shown in **Table 5.1** with the brand name, alcoholic type, alcohol content/percentage, and origin of production. Beer was also included in the PM with UFP experiment because the processes of producing rice wine are similar to beer. For example, the yeast strain required for rice wine fermentation closely resembles beer rather than wine (Legras et al., 2007) and the predominant sugar source for fermentation is cereal. All beers and wines were purchased from a New Zealand local supermarket (Countdown, New Zealand) in the Auckland CBD area, while *makgeolli* was produced in the Auckland University of Technology Laboratory. About 15 mL of the sample was pipetted in a 30-mL transparent portion cup with a lid and was presented in two rows, with six samples in each row. All samples were presented simultaneously with three randomised digit numbers in randomised order to reduce the sample placement effect. Participants were aware of the different types of alcoholic beverages that they were consuming from the information sheet; however, the researcher did not specify or identify the corresponding alcoholic beverage to the three randomised digit numbers on the 30 mL transparent portion cup until the participants ended their PM with UFP experiment.

**Table 5.1** Summary table of the alcoholic beverages used during the projective mapping with ultra-flash profiling (PM with UFP) (n = 12) and polarised sensory positioning (PSP) (n = 9) experiment consisting of beer, wines, and *makgeolli* samples.

Present during experiment	Name of sample	Alcoholic type	Brand/Product name	Country of origin	Alcohol content <sup>§</sup>
Both PM & PSP	Shiraz	Wine	Yalumba Premium	Australia	13.0%
Both PM & PSP	Chardonnay	Wine	Yalumba Winesmiths	Australia	13.0%
Both PM & PSP	Rose	wine	Yalumba Winesmiths	Australia	12.5%
Both PM & PSP	Sauvignon Blanc	Wine	Yalumba Winesmiths	Australia	10.5%
Both PM & PSP	1SF-YN	KRW <sup>†</sup>	N/A <sup>‡</sup>	New Zealand	4.5%
Both PM & PSP	1SF-N	KRW <sup>†</sup>	N/A <sup>‡</sup>	New Zealand	13.0%
Both PM & PSP	2SF	KRW <sup>†</sup>	N/A <sup>‡</sup>	New Zealand	7.8%
Both PM & PSP	3SF	KRW <sup>†</sup>	N/A <sup>‡</sup>	New Zealand	12.6%
PM only	Pilsner	Beer	Mac's Pilsner Miss Conduct	New Zealand	5.2%
PM only	Pale Ale	Beer	Mac's Craft Beer Three Wolves	New Zealand	5.1%
PM only	Porter	Beer	Mac's Beer Black	New Zealand	4.8%
PM only	IPA	Beer	Mac's Pale Ale Green Beret	New Zealand	5.4%
PSP only	Cabernet Sauvignon	Wine	Yalumba Winesmiths	Australia	13.0%

<sup>†</sup>KRW is the abbreviation for Korean rice wine (*makgeolli*), <sup>‡</sup>Korean rice wine (*makgeolli*) was produced in the university laboratory, therefore brand name is not applicable for this section, <sup>§</sup>Alcohol content information was provided by either product package or laboratory results from previously published article Wong, Muchangi, et al. (2023).

### 5.3.1.3 Samples used in PSP

The PSP is more directive, and the method requires participants to compare *makgeolli* and the alcoholic products to specific reference samples also known as “poles.” The selection of poles provides a reference point for participants to compare the similarities and differences of the product being tested (Ares et al., 2018). From the PM with UFP experiment, there was evidence that participants tend to group *makgeolli*, wine, and beer differently. However, when participants were divided into different cluster groups, Shiraz was positioned closely to *makgeolli* (see **Appendix I** for the multiple factor analysis (MFA) maps for the four different cluster groups).

In terms of the pole selection for PSP, Teillet et al. (2010) and Ares et al. (2015) did not specify the criteria needed to be fulfilled for the experiment to be conducted; however, three poles were suggested as the optimal number of references to allow researchers to produce a representative perceptual map using multidimensional scaling or MFA. Teillet (2015) noted it would be advantageous for the researcher to include “poles” that encompass the sensory aspects of all the samples, therefore Chardonnay, Shiraz, and 1SF-N were selected as the three poles for the PSP experiment.

About 15 mL of the nine wine and *makgeolli* samples was pipetted in 30 mL transparent portion cups with a lid and were presented in two rows, the first row with five samples and four in the second row. All samples were presented with three randomised digits and the placement of the nine samples was randomised. And 40 mL of Chardonnay, Shiraz, and 1SF-N was prepared in a 100-mL portion cup with a lid labelled R1, R2, and R3, respectively, as poles which the participants can refer to throughout the PSP experiment as the three reference points.

### 5.3.2 General information of participants

Participants were screened for the following criteria: (1) the participant does not suffer from food allergies such as wheat, rice, and alcohol, (2) the participant is not pregnant or trying to conceive a child, (3) not operating heavy machinery or driving within 2 h after completing the sensory test and (4) be or over the legal age of 18 were allowed to take part in the sensory study (the legal age of consuming alcohol in New Zealand). Both PM with UFP and PSP were reviewed and approved by the AUT Ethics Committee 19/241.

Participants were required to review the information sheet and to give written consent to the researchers before the experiments took place. Measures of age, ethnicity, frequency of alcoholic beverage consumption, objective wine knowledge, and subjective wine knowledge information were also collected. The objective and subjective wine knowledge questions were used to examine the participant's degree of knowledge, attitude, and behaviour toward wine (Ellis & Caruana, 2018; Flynn & Goldsmith, 1999; Forbes et al., 2008). Objective wine knowledge is often referred to the knowledge that consumers does actually know, shows that consumers are able to correctly answer questions regarding the topic of wine. In comparison, subjective wine knowledge is a self-assumed knowledge in which the consumers think they know about wine (Forbes et al., 2008). It is important to note that objective and subjective wine knowledge scale is designed for wine consumers. From other researchers regarding product categorisation, it was important to measure the participant's experience in the form of subjective and objective knowledge (Chocarro et al., 2009) and Kwak et al. (2015) stated that American consumers perceived KRW to be in a similar category with white and semi-sweet white wine. The purpose of objective and subjective wine knowledge questions was used as an exploratory tool to see whether different group clustering exists among the participants (Wong, Owens, et al., 2023) and whether this would affect the categorisation *makgeolli* in PM with UFP and PSP experiments. In terms of the wine knowledge assessments used in both PM with UFP and PSP experiments, objective wine knowledge questions were taken verbatim from Forbes et al. (2008) and Ellis and Caruana (2018). The five objective wine knowledge questions are included below with bold writing as the correct answer: “Which of the following is a red wine?” Riesling, Chardonnay, **Merlot**, Sauvignon Blanc, and I don't know; “A peppery character is most associated with which wine?” Merlot, **Shiraz/Syrah**, Semillion, Pinot Noir, I don't know; “Which grapes are never used to make Champagne?” Chardonnay, **Riesling**, Pinot Noir, Pinot Meunier, and I don't know; “Which is not a famous

French wine region?" Bordeaux, Champagne, **Rheingau**, Alsace, I don't know; What is the name of New Zealand's famed Sauvignon Blanc region? Kapiti, Hawke's Bay, Waipara, **Marlborough**, I don't know (Ellis & Caruana, 2018; Forbes et al., 2008). Subjective wine knowledge selected for both experiments differed slightly from each other; PM with UFP experiment used the modified version of the subjective wine knowledge questions by Wong, Owens, et al. (2023) which was derived from Ellis and Caruana (2018); Flynn and Goldsmith (1999); Forbes et al. (2008), while the PSP experiment were taken verbatim from Ellis and Caruana (2018) and was derived from Flynn and Goldsmith (1999). Participants were required to select the answer that best describes their situation on a 7-point category scale from "*disagree strongly*" to "*agree strongly*." The four subjective wine knowledge questions used for PM with UFP experiment include: "Among my circle of friends, I'm one of the experts on wine" (Q1), "Compared to most other people, I know less about wine" (Q2), "I am quite familiar with wine" (Q3), and "I feel very knowledge about" (Q4) (Ellis & Caruana, 2018; Flynn & Goldsmith, 1999; Forbes et al., 2008; Wong, Owens, et al., 2023). For PSP experiment, the subjective wine knowledge consists of nine questions including: "I know pretty much about wine" (Q1), "I know how to judge the quality of the bottle of wine" (Q2), "I think enough about wine to feel pretty confident when I make a purchase" (Q3), "I do not feel very knowledge about wines" (Q4), "Among my circle of friends, I'm one of the 'experts' on wines" (Q5), "I have heard of most of the new wines that are around" (Q6), "Compared to most other people, I know less about wines" (Q7), "When it comes to wine, I really don't know a lot"(Q8), and "I can tell whether a bottle of wine is worth the price" (Q9) (Ellis & Caruana, 2018).

For both PM with UFP and PSP, researchers used the self-prioritisation method as part of the sociodemographic questions where participants were asked to select one specific ethnic group with whom they strongly associate (Kukutai & Callister, 2009). Where appropriate, the researchers grouped smaller ethnic groups that best represented the sociodemographic information of the participants. For example, the East Asian ethnic group shown in **Table 5.2** consists of individuals who self-identify as Chinese, Japanese, Korean, Indonesian, Vietnamese, Filipino, or regions in East and Southeast Asia. Classification of specific ethnic groups such as East Asian, South Asian, and European are explained in the footnote of **Table 5.2**. New Zealand and Australian Europeans are defined as individuals who have strong affiliations with New

Zealand or Australia (e.g., by citizenship or strong cultural identity with either New Zealand or Australia) with European ancestry.

**Table 5.2** shows the sociodemographic information of participants taking part in the PM with UFP and PSP experiment. Sixty-eight participants completed the PM with UFP experiment with a gender distribution of 47.1% ( $n = 32$ ) female participants and 52.9% ( $n = 36$ ) male participants. Ninety-one participants took part in the PSP experiment with a gender distribution of 36.3% ( $n = 33$ ) female participants and 63.7% male participants ( $n = 58$ ).

**Table 5.2** Summary table of the sociodemographic information of participants in the projective mapping with ultra-flash profiling (PM-UFP) (n = 68) and polarized sensory positioning (PSP) (n = 91) study including gender, age, ethnicity, rice, and alcoholic beverage consumption.

PM with UFP sociodemographic information			
Groups		(n)	(%)
Gender	Female	32	47.1%
	Male	36	52.9%
Age <sup>†</sup>	18 – 24	18	26.9%
	25 – 39	43	64.2%
	40 +	6	8.9%
Frequency of consuming alcohol <sup>†</sup>	More than once a week	14	20.9%
	At least once a week	23	34.3%
	Every second week	10	14.9%
	Once a month	20	29.9%
Ethnicity <sup>†</sup>	New Zealand/Australian European	15	22.4%
	East Asian <sup>1</sup>	20	29.9%
	South Asian <sup>2</sup>	11	16.4%
	Americas <sup>4</sup>	9	13.4%
	European <sup>3</sup>	7	10.4%
	Middle Eastern/African <sup>5</sup>	4	6.0%
	Māori/Pacific Islander	1	1.5%

PSP sociodemographic information			
Groups		(n)	(%)
Gender	Female	33	36.3%
	Male	58	63.7%
Age	18 – 24	32	35.2%
	25 – 39	46	50.5%
	40 +	13	14.3%
Frequency of consuming alcohol	More than once a week	25	27.4%
	At least once a week	26	28.6%
	Every second week	16	17.6%
	Once a month	24	26.4%
Ethnicity <sup>†</sup>	New Zealand/Australian European	26	29.2%
	East Asian <sup>1</sup>	22	24.7%
	South Asian <sup>2</sup>	21	23.6%
	European <sup>3</sup>	6	6.7%
	Americas <sup>4</sup>	3	3.4%
	Middle Eastern/African <sup>5</sup>	7	7.9%
	Māori/Pacific Islander	4	4.5%

<sup>†</sup>Missing data from the sociodemographic section, percentage is calculated based on the available information.

<sup>1</sup>East Asian/Southeast Asian includes individuals of Japanese, Korean, Indonesian, Filipino, Vietnamese descent or who address themselves as East Asian in the ethnic group section.

<sup>2</sup>South Asian includes individuals with Indian, Sri Lankan, or Fiji Indian descent.

<sup>3</sup>European includes individuals of German, Spanish, or British descent or individuals who address themselves as Europeans in the ethnic group section.

<sup>4</sup>Americas includes individuals from North America (e.g., United States) and Latin/South America (e.g., Chilean, Mexican, Peruvian).

<sup>5</sup>Middle Eastern/African includes individuals with Iranian, Kenyan, South Africa and no specified individuals from the African and Middle Eastern region.

### **5.3.3 Sensory evaluation procedures**

Both experiments were advertised using social media, word-of-mouth, and posters around the Auckland University of Technology (AUT) City campus. Both PM with UFP and PSP took place in the AUT Food Science Laboratory with the temperature set at 22°C. Still water and plain water crackers (Countdown, Australia) were available for palate cleansing between samples of the PM with UFP and PSP experiments. Palate cleansing was not enforced for PM with UFP; however, PSP instructions required participants to cleanse their palate between each sample (e.g., take a sip of water and a bite of the plain water crackers). A minute (60 s) waiting time between each sample was strictly enforced in the PSP experiment with timers provided to the participants. PM with UFP experiment was conducted in October 2019, while PSP was conducted in March 2020 separately from each other. Participants who attended the PM with UFP experiment were not excluded from the PSP experiment; however, it was not a requirement that participants needed to attend both. Upon arrival at the sensory evaluations, participants were presented with an information sheet describing the nature and purpose of the experiment (either PM with UFP or PSP), a participant consent form, a set of printed questionnaire surveys, and instructions for the experiments. PM with UFP consists of an A3 piece of paper and a set of sociodemographic questions which will be discussed in **Section 5.3.3.1**. PSP consists of a set of questions including a page for “poles” training and sampling, questions regarding the PSP questions, and overall liking of the sample presented on a 100 mm unstructured line scale anchored dislike extremely (left end) and like extremely (right end) will be discussed in **Section 5.3.3.2**.

### 5.3.3.1 PM with UFP testing

PM was selected for experimentation due to its richness in information that allows researchers to understand the sensory attributes of multiple products simultaneously. The results from PM are often presented with a perceptual map and are accompanied by UFP, allowing participants to develop a larger range of words describing the samples. Before the experiment took place, a researcher explained the instructions and told the participants to familiarise the alcoholic beverages presented to the participants and their primary goal was to compare the similarities and differences between each alcoholic beverage. The researcher explained to the participants that they had to organise the 12 samples according to their criteria on an A3 sheet of white paper (42 × 30 cm). Participants were advised that similar alcoholic beverages should be placed close together, while different samples should be located further away. Participants were encouraged to write three to five words to describe each sample to why the samples were placed in a specific location. Examples of different perceptual maps were located around the Food Science Laboratory to demonstrate how participants can group their alcoholic beverages. Examples of the perceptual map include New Zealand Political parties, International Airlines, and different variations of colours. The perceptual map examples were not extracted from peer-reviewed articles or formal scientific research. All example perceptual maps were created by the researcher, and they do not specify the criteria or reasoning for the grouping to avoid creating bias among participants taking part in the PM with UFP experiment.

### 5.3.3.2 PSP testing

Before the participants started the PSP experiment, participants were instructed to first consume the three poles (R1, R2, and R3) and to familiarise the flavour, taste, texture, and visual attributes. Participants were then instructed to evaluate the nine samples against the three poles and to quantify the degree of difference using a bi-polar 100 mm line scale from “*exactly the same*” to “*completely different*.” Overall liking was also asked during the study with nine of the samples, using a 100-mm line scale from “*extremely dislike*” to “*extremely like*” after the participants compared the sample against the three poles.

### 5.3.4 General data analysis

All data from PM with UFP and PSP experiments were first measured by the researchers and inputted into an Excel spreadsheet for further processing. Statistical analysis for both PM and PSP experiments was analysed using the R language software (version 4.2.0) and the Excel Addinsoft XLSTAT

extension program (Addinsoft, USA). R packages used in this paper include “FactoMineR” (Lê et al., 2008) analysing and visualising the sensory data. Other R programs used include “cluster” for the hierarchical cluster analysis. The level of statistical significance was set at 0.05. Further description of the statistical methods used for PM with UFP is discussed in **Section 5.3.4.1** and for PSP is discussed in **Section 5.3.4.2**.

#### **5.3.4.1 PM with UFP data analysis**

To analyse the PM data, data were first separated into two parts: quantitative and qualitative. For quantitative analysis, all alcoholic beverage samples on the A3 piece of paper were located using  $X$  and  $Y$  coordinates. The  $X$  and  $Y$  coordinates of each sample were determined by using the left bottom corner of the A3 sheet of paper (landscape layout) as the origin of the coordinates. MFA was used to analyse the  $X$  and  $Y$  coordinates of the alcoholic beverages (Pagès et al., 2010).

The qualitative data of PM (e.g., UFP) were first transcribed onto an Excel spreadsheet as single words that participants used to describe the alcoholic beverages on the A3 piece of paper. Due to the range of words used to describe each sample, the researchers consolidated words that have similar meanings into a smaller number of attributes that best represent the alcoholic beverages described by the participants. For example, if two or more words have similar meanings, for example, “disgusting,” “horrible,” and “terrible”; these words were integrated into one word, for example, “unpleasant.” A set of 12 words including astringent, bitter, creamy, dark, dry, fruity, light, pleasant, sour, strong, sweet, and unpleasant were selected to best represent the word description that participants used to describe the alcoholic beverage samples. Cochran's  $Q$  test was performed to test for statistical significance ( $p < 0.05$ ) among the 12 samples with sensory attributes. When statistical significance was observed, a post hoc test was performed by using McNemar's test with Bonferroni alpha adjustment and only on items that were mentioned in over 20% of participants being selected. Correspondence analysis (CA) was carried out to visualise the interaction between the sensory attributes and alcoholic beverages. Graphical representation of the CA data is computed through R language while Cochran's  $Q$  test and McNemar's test with Bonferroni alpha adjustment was performed using Addinsoft XLSTAT (Addinsoft, USA).

#### **5.3.4.2 PSP data analysis**

Data from the overall liking of nine samples and each of the three poles were analysed using one-way analysis of variance (ANOVA). Tukey's post hoc test was carried out when statistical significance was observed. Like PM with UFP, PSP information, such as the three poles, was analysed using MFA.

#### **5.3.4.3 Hierarchical cluster analysis and RV coefficient analysis**

Hierarchical cluster analysis (HCA) with Euclidian distances, Ward's aggregation criterion was used to identify the different cluster groups of participants in both PM with UFP and PSP experiments. The cluster group was determined by the answers of the objective and subjective wine knowledge information given by participants; however, only subjective wine knowledge was used in the PM with UFP to construct the different cluster groups due to many participants not answering the questions in the format that was given or avoiding this part of the sensory experiment entirely. Once cluster groups were identified in both PM with UFP and PSP, participants were separated into their respective groups to evaluate how each cluster group performed for the PM with UFP and PSP using MFA.

RV coefficients were employed to understand the similarity between two matrices between the cluster groups within both PM with UFP and PSP experiments (i.e., to what degree does one MFA map resemble the other). RV coefficient allows researchers to compare perceptual maps such as MFA and principal component analysis using numerical values such as Dimension 1 and Dimension 2 against different groups of participants or samples. Josse et al. (2008) state that the RV coefficient can be interpreted similarly to the Pearson correlation coefficient with multivariate data. Only the first two dimensions of the MFA results were used for calculation; these results include the general MFA generated from the PM with UFP and PSP and the cluster group identified from HCA. Different cluster groups were not evaluated between PM with UFP and PSP experiments. RV coefficient ranges between 0 and 1, if the value is close to 1 this indicates that there is a higher degree of similarity between the perceptual maps (Louw et al., 2013). Several research articles have indicated that an RV value over 0.75 is considered high in the similarity between the perceptual maps (Kennedy, 2010; Lawless & Glatter, 1990); however, some researchers stated that an RV value of around 0.95 is more preferable (Schlich & Guichard, 1989). Significant tests for the RV coefficient were performed using a permutation test, where statistical significance signals that the configuration of the perceptual map is similar (Josse et al., 2008).

## 5.4 Results and discussion

### 5.4.1 Cochran's Q test and pairwise McNemar's test for PM with UFP

Twelve attributes were identified by the researchers as important and encompass the sensory attributes used by all participants who took part in the PM with UFP experiment. Cochran's *Q* test was applied to the 12 attributes and showed that 10 were statistically significant including *dark*, *dry*, *sweet*, *sour*, *bitter*, *creamy*, *strong*, *light*, *fruity*, and *unpleasant*. Further analysis using pairwise McNemar's test showed that *bitter*, *fruity*, and *sour* were statistically significant.

Participants associated bitterness more with beer samples compared to wine and *makgeolli* samples, which is not surprising as bitterness is a common taste characteristic of beer with 80% of its bitterness derived from the addition of hops during the boiling stage of the beer brewing process (Oladokun et al., 2016). It is important to note that bitterness is a common taste in all alcoholic beverages, but the causes of the bitterness can be attributed to different reasons. For example, the addition of hops in beer production which contain  $\alpha$ -acids such as humulones which converts to iso- $\alpha$ -acids, the principal source of bitterness (Luo et al., 2020; Oladokun et al., 2016) while wine bitterness can be attributed to phenolic compounds such as catechin, epicatechin, caffeic acid, and quercetin for wine (Luo et al., 2020; Rudnitskaya et al., 2010). In comparison, non-volatile compounds such as peptides and bitter amino acids are key contributors to the bitter taste of rice wine (Luo et al., 2020). Examples of bitter peptides include QLFNPS, QLFNPSTNP, QLFNPSTNPWH, QLFNPSTNPWHSP, and QLFGPNVNPWHNP were sobered in the pre-fermentation stages of Japanese rice wine (Maeda et al., 2011).

For the *fruity* term, participants tend to use these to describe wine samples more than beer and *makgeolli* samples. Sauvignon Blanc was perceived as the *fruitiest* alcoholic beverage examined in the PM with UFP experiment with 32.4% of participants commenting on their perceptual map, followed by Shiraz with 23.1% of participants. Both IPA and Pilsner had 13.2% of participants using fruity terms to describe these two beer samples, and the least fruity sample among the 12 alcoholic beverages examined was Porter with 2.90% of participants using fruity terms to describe this beer sample. For *makgeolli*, both 1SF-YN and 3SF were noted as the *fruitiest* among 11.8% of participants compared to other *makgeolli* samples, 8.80% for 2SF and 7.40% for 1SF-N. These findings are consistent with scientific literature, as consumers

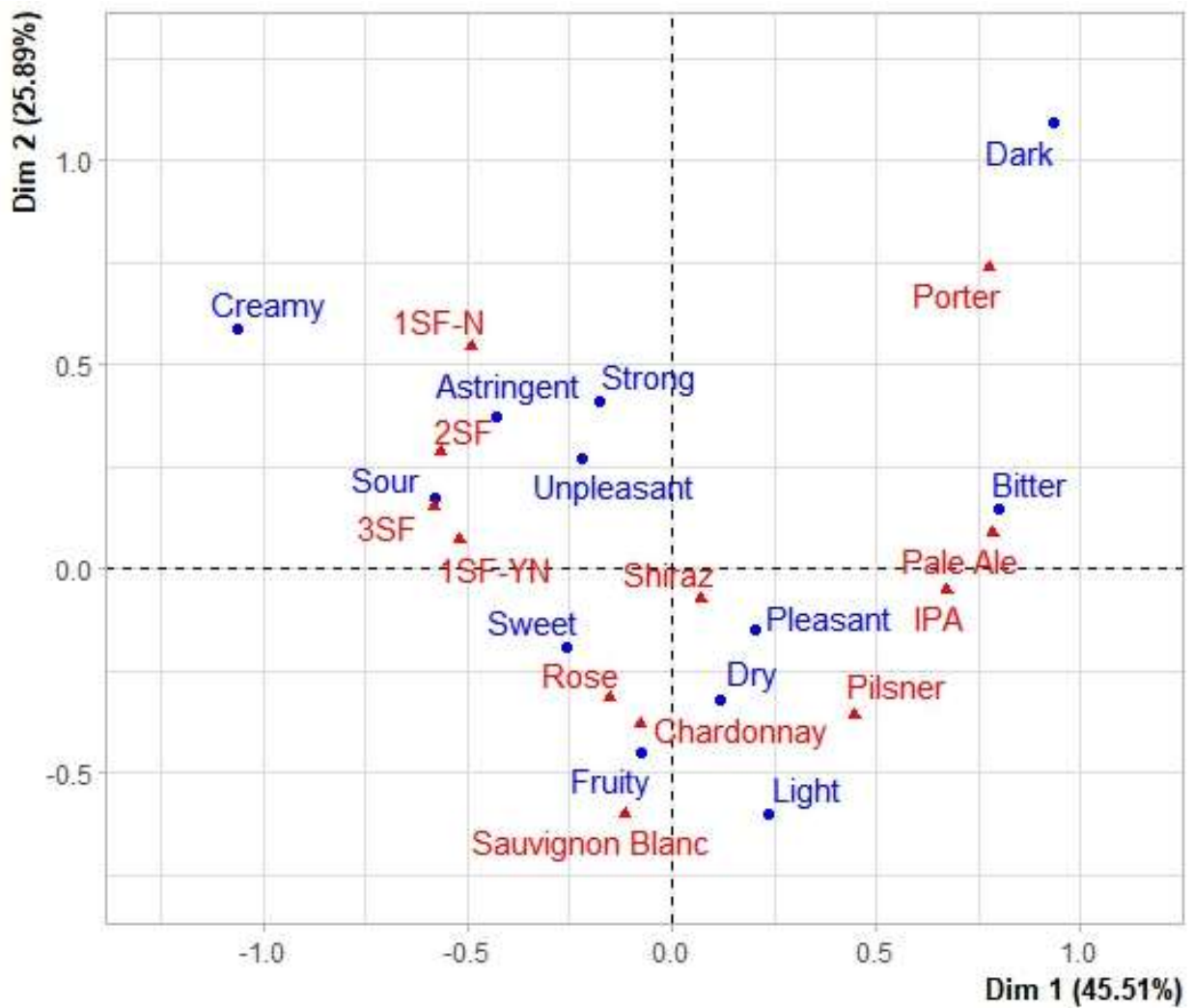
tend to describe wine products with fruitier attributes, such as Sauvignon Blanc, which is often associated with green capsicum flavour (Parr et al., 2007) or Chardonnay with fruity aromas (e.g., citrus, passion fruit and more) (Gambetta et al., 2014). The fruity aroma in wine products is likely to be caused by a number of factors, such as amino acid metabolism, enzymatic formation of esters, or secondary fermentation, also known as malolactic fermentation (Styger et al., 2011).

For *sour*, participants used more sour terms to describe *makgeolli* than beer and wine. Around 27.9% of participants used sour terms to describe 1SF-N, followed by 2SF (25.0% of participants) and then 1SF-YN (19.1% of participants). Similar to fruity terms and the association with wine products, using sour terms to describe *makgeolli* or KRW was found in a number of studies (Jung et al., 2014; Kwak et al., 2015; Wong, Muchangi, et al., 2023; Wong, Owens, et al., 2023). In a study conducted by Wong, Muchangi, et al. (2023), the researchers showed a number of organic acids were present in *makgeolli* samples used in this study including pyruvic acid, malonic acid, succinic acid, citric acid, malic acid, tartaric acid, lactic acid and also acetic acid. 1SF-N had higher levels of citric acid, malic acid, and tartaric acid compared to the other *makgeolli* samples; this may explain the high perceived sourness of 1SF-N among participants in the PM with UFP experiment. Another study conducted by Wong, Owens, et al. (2023) also indicated that sourness was present in all *makgeolli* samples using sensory evaluation (Check-All-That-Apply). Seventy-seven percent of participants from their study selected 1SF-N sample to be the sourest, followed by 3SF with 28.7% of participants.

#### 5.4.2 CA and MFA for PM

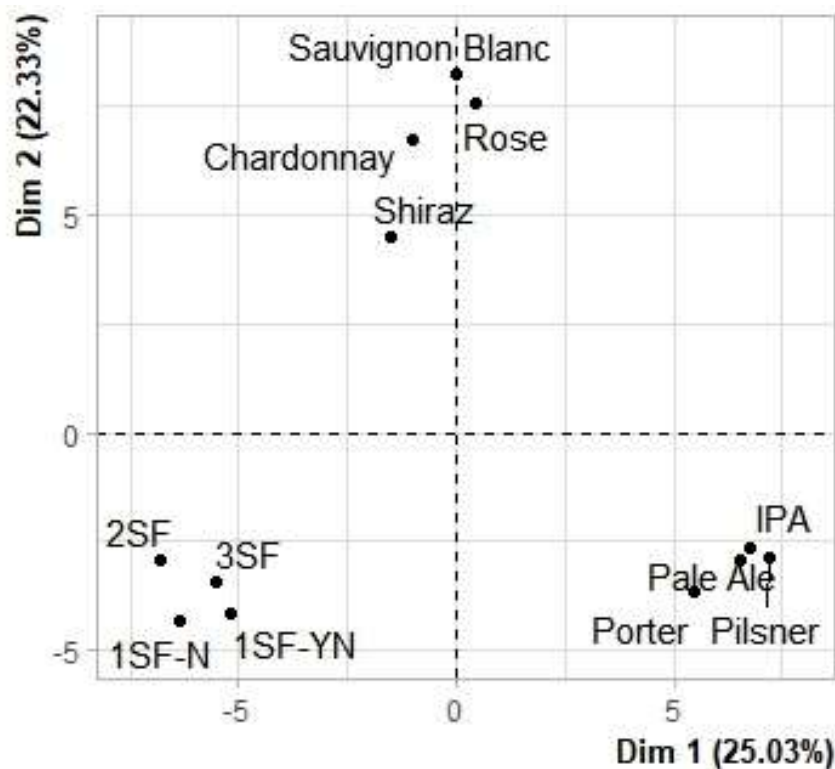
**Figure 5.1** is the CA bi-plot map of the qualitative data extracted from the PM with UFP experiment and was formulated after the attributes were converted to a contingency table. The CA map was designed to aid researchers in visualising the interaction between alcoholic beverages and the sensory attributes identified in the PM with UFP experiment. In **Figure 5.1**, the first two dimensions explained a total of 71.4% of the total variance (Dimension 1 = 45.5% and Dimension 2 = 25.9%). Key attributes that were of interest for this research include “bitter,” “fruity” and “sour” due to statistical significance reached in Cochran's *Q* test and pairwise McNemar's test. As expected, *sour* and all *makgeolli* samples can be seen positioned on the top left quadrant alongside other sensory attributes such as *creamy*, *astringent*, *strong*,

and *unpleasant*. The CA map from the PM with UFP somewhat mirrors the findings published in Wong, Owens, et al. (2023) study as participants in their study also used the terms *astringent* and *creamy* to describe *makgeolli* samples. Wine samples such as Chardonnay, Rosé, and Sauvignon Blanc clustered around the term *fruity*, which supports the Cochran's  $Q$  test and pairwise McNemar's test that participants used more *fruity* terms to describe wine than beer and *makgeolli*. Pale Ale and IPA are relatively close to *bitter* due to the high number of participants using this term to describe these alcoholic beverages. Group clustering of alcoholic beverages was less obvious as the location of alcoholic beverage samples was determined by the attributes that they share on the contingency table.



**Figure 5.1** Correspondence analysis of the participants' (n= 68) attributes describing the 12 alcoholic beverages in the projective mapping experiment and the corresponding alcoholic beverage consisting of beer, wine, and makgeolli. Red terms refer to the alcoholic products and blue terms refer to the terms used within the PM with UFP experiment.

**Figure 5.2** is the MFA map constructed from the PM with UFP experiment position of the beer, wine, and *makgeolli* samples on the A3 piece of paper. Unlike **Figure 5.1**, where the CA map is based on qualitative information, the MFA map of PM with UFP experiment is based on the coordinates arranged by the participants. The first and second dimensions of the PM with UFP experiment explained 47.4% of the variance of the experimental data (Dimension 1 = 25.0% and Dimension 2 = 22.3%; **Figure 5.2**). From the PM with UFP MFA map, participants separated the *makgeolli*, beer, and wine samples into three groups. This is an indication that participants do not perceive *makgeolli* as having similar traits to either beer or wine when placing the alcoholic beverage sample on the A3 piece of paper.



**Figure 5.2** Multiple factor analysis (MFA) map from the projective mapping with ultra-flash profiling (PM with UFP) experiment constructed by participants ( $n = 68$ ) grouping *makgeolli* samples among wine and beer products. The total variance of the PM with UFP MFA map is 47.4% (Dimension 1 = 25.0%, Dimension 2 = 22.3%).

All *makgeolli* samples are grouped in the negative values of Dimension 1, while all the beer samples, including Porter, Pale Ale, Pilsner, and IPA, are placed in the positive value. All wine samples, including Sauvignon Blanc, Chardonnay, Rosé, and Shiraz, are positioned in the positive value of Dimension 2. Although previous research indicates that *makgeolli* tends to share some wine traits such as Rosé and semi-sweet white wine (Kwak et al., 2015), participants in the PM with UFP experiment show that *makgeolli* was categorised in its distinctive group. Based on the information extracted in **Figure 5.2**, it is hard to conclude the reasons for their group categorisation because additional qualitative information, such as focus groups or participant interviews, is required. However, it was likely that participants grouped the alcoholic beverage based on alcoholic beverage class (e.g., beer or wine), sensory attributes such as *bitter*, *sour*, and *fruity* that were noted as significant in **Section 5.4.1** (use the Cochran's Q and pairwise McNemar's test for PM with UFP), or other external factors may be contributing factors to alcoholic beverage placement on the perceptual map that is unforeseen by the researchers. It should be noted that the MFA map constructed by the PM with UFP experiment in **Figure 5.2** was relatively low in explaining the total variance of the alcoholic beverages; this can be attributed to the low agreement of the alcoholic beverage sample placement on the perceptual map.

Previous research has seen discrepancies in product clustering between consumers who are either knowledgeable or familiar with the food product (including experts or trained panellists) and novices (e.g., consumers with limited knowledge) in PM. From the literature, experts (e.g., individuals with high knowledge and familiarity with the product) tend to have higher discriminability and can identify product duplicates in PM, while consumers with limited knowledge cannot (Barton et al., 2020; Nestrud & Lawless, 2008). Participants were further divided based on their wine knowledge to determine the similarities and differences of each perceptual map in this study. This is due to research indicating how product knowledge influences the behaviour of categorising products (Chocarro Eguaras et al., 2012) and to understand how different cluster groups contribute to the total variance explained in the overall PM with UFP MFA map.

### 5.4.3 HCA and RV coefficient for PM with UFP

Based on the subjective wine knowledge results reported by participants, four clusters were identified using HCA. Consumer wine product knowledge is important information for producers as it allows them to understand the decision-making process while purchasing wine in the marketplace (Ellis & Caruana, 2018). The level of involvement and knowledge also impacts how consumers rank in the order of importance on intrinsic (e.g., flavour and taste) and extrinsic (e.g., packaging and brand name) properties of the wine product (Bruwer et al., 2017). For example, Ellis and Caruana (2018) identified four segments of wine consumers based on their subjective and objective wine knowledge score: neophytes (e.g., scored low for both subjective and objective wine knowledge), snobs (e.g., scored high in subjective wine knowledge but low on objective wine knowledge), modest (e.g., scored high in objective but low in wine knowledge), and experts (e.g., scored high in both subjective and objective wine knowledge). A follow-up study showed that consumer groups in neophytes and experts are more likely to have variety-seeking behaviour which implies that there is low customer retention and loyalty to the wine product among these two groups of consumers (Ellis & Mattison Thompson, 2018). Like Ellis and Caruana (2018), this paper uses the subjective and objective wine knowledge scale to segment and identify the different consumer groups among the subjects.

Four cluster groups were identified with Cluster 1 consisting of 22.7% participants, Cluster 2 consisting of 34.8%, Cluster 3 consisting of 16.7%, and Cluster 4 consisting of 25.8% participants (for a brief description of each cluster group, see **Appendix I**). Cluster 1 tends to rate their subjective wine knowledge higher than the other cluster groups and Cluster 2 participants indicated that they are familiar with wine. Cluster 3 participants indicated that they are not familiar with wine, while Cluster 4 participants are familiar with wine but not knowledgeable of wine. The visual representation of the alcoholic beverages seems to be grouped relatively similar to the overall PM with UFP MFA map; however, the rotation of the three alcoholic groups is different (see **Appendix I**).

The comparison of the RV coefficient results between different cluster groups is shown in **Table 5.3** with its  $p$  value level of significance. The RV coefficient between Cluster 1 and Cluster 2 is 0.917 ( $p < .001$ ), indicating that the results are similar and there is a general agreement in the grouping of the 12 alcoholic beverages. The results between Cluster 1 and Cluster 4 are relatively low with an RV coefficient of

0.645 ( $p < .01$ ), indicating that the grouping criteria may have been different in the PM with UFP experiment between the two clusters of participants. Based on the guidelines set out by Kennedy (2010) and Lawless and Glatter (1990) show that Cluster 1 participants and Cluster 4 participants may have used different sets of criteria to sort the 12 alcoholic beverages on the perceptual map. The RV coefficients when comparing Cluster 4 to Cluster 2 and Cluster 3 were 0.740 ( $p < .001$ ) and 0.718 ( $p < .001$ ), respectively. For further details of the individual cluster group's RV coefficient value compared against the overall PM with UFP MFA map in **Figure 5.2**, see **Appendix J** for the RV coefficient and  $p$  value. From the RV coefficient comparison, subjective wine knowledge may have influenced the way the 12 alcoholic beverages were grouped during the PM with UFP experiment and there is a potential attribute that participants are using to categorise beer, wine, and *makgeolli* that is unknown to the researchers. The qualitative information from the PM with UFP showed that there is a possible interaction based on three sensory attributes including *bitter*, *sour*, and *fruity*. Further investigation for the categorisation of the *makgeolli* was warranted as two cluster groups (e.g., Cluster 3 and Cluster 4) indicated that Shiraz was sharing sensory attributes with *makgeolli* that the researchers were not aware or sorted within close proximity between *makgeolli* samples and Shiraz. This is likely due to their low subjective wine knowledge and their criteria of grouping the 12 alcoholic beverages were different compared to Cluster 1 and Cluster 2.

**Table 5.3** Summary table of RV coefficient comparison values between different PM with UFP cluster groups and their MFA map results in conjunction with PSP cluster groups and their MFA map results.

PM Cluster Comparison	RV coefficient
PM Cluster 1 versus PM Cluster 2**	0.917
PM Cluster 1 versus PM Cluster 3**	0.836
PM Cluster 1 versus PM Cluster 4*	0.645
PM Cluster 2 versus PM Cluster 3**	0.870
PM Cluster 2 versus PM Cluster 4**	0.740
PM Cluster 3 versus PM Cluster 4**	0.718
PSP Cluster Comparison	RV coefficient
PSP Cluster 1 versus Cluster 2**	0.950
PSP Cluster 1 versus Cluster 3**	0.972
PSP Cluster 1 versus Cluster 4**	0.977
PSP Cluster 2 versus Cluster 3**	0.972
PSP Cluster 2 versus Cluster 4**	0.950
PSP Cluster 3 versus Cluster 4**	0.976

Note: \* Statistical significance level  $p < 0.01$ , \*\* Statistical significance level  $p < 0.001$

Abbreviations: MFA, multiple factor analysis; PM, projective mapping; PSP, polarized sensory positioning; UFP, ultra-flash profiling.

#### 5.4.4 PSP and one-way ANOVA

In **Table 5.4**, one-way ANOVA showed strong statistical significance in the mean hedonic ratings among the alcoholic beverages ( $n = 9$ ) among the alcoholic beverages in the PSP experiment ( $p < .001$ ). The degree of significance is denoted as letters, mean hedonic rating, and the standard deviation are shown in **Table 5.4**. Chardonnay was rated the highest among the nine alcoholic beverage samples with a mean score and standard deviation of  $67.9 \pm 20.3$  mm, followed by 2SF ( $60.2 \pm 24.9$  mm) and Rosé ( $59.7 \pm 23.5$  mm) on the 100 mm line scale; however, all were not statistically different. The least-liked alcoholic beverage was 3SF with a hedonic score of  $39.9 \pm 28.7$  mm and was not statistically different compared to 1SF-N ( $48.7 \pm 25.2$  mm), and 1SF-YN ( $48.4 \pm 28.5$  mm). A possible explanation for the high hedonic rating toward grape wines (apart from 2SF) in the PSP experiment likely to be the familiarity of grape wines among New Zealand participants. High familiarity with a food product (e.g., Chardonnay and Rosé) allows consumers to form positive expectations, thus increasing the overall acceptance of the food product (Hong et al., 2014; Park et al., 2020). The low hedonic rating of *makgeolli* samples, such as 1SF-N, 2SF, and 3SF, could be attributed to the lack of familiarity and experience consuming the product (Choe & Hong, 2018). One-way ANOVA was also performed to compare the similarities and differences between the different alcoholic beverages against R1 (Chardonnay as pole 1) ( $p < .001$ ), R2 (Shiraz as pole 2) ( $p < .001$ ), and R3 (1SF-N as pole 3) ( $p < .001$ ) to understand the sensorial differences of each alcoholic beverage. Each reference sample (e.g., R1, R2, and R3) represents either white wine (e.g., Chardonnay), red wine (e.g., Shiraz), and *makgeolli* (e.g., 1SF-N) and are used as a point of reference for the participants. As expected, participants perceived the Chardonnay sample to be the closest to R1 with  $25.0 \pm 22.1$  mm followed by Sauvignon Blanc ( $32.0 \pm 25.5$ ) but were not statistically different between the two as participants perceived the sensorial attributes to be similar. Rosé ( $40.0 \pm 25.0$  mm) was statistically significant compared to Chardonnay but not Sauvignon Blanc. 3SF was the most different alcoholic beverage sample ( $77.5 \pm 22.5$  mm) compared to R1 according to the participants but was not statistically different from Cabernet Sauvignon ( $70.4 \pm 24.9$  mm), 2SF ( $69.9 \pm 26.6$  mm), 1SF-YN ( $68.3 \pm 26.3$ ), and Shiraz ( $68.1 \pm 27.8$  mm). Based on qualitative information from PM with UFP experiment, it is likely that 3SF shares similar sensory attributes such as *fruity*, *sour*, and *sweet* with Cabernet Sauvignon, 2SF, 1SF-YN, and Shiraz. Due to the design of the PSP experiment, it is difficult to have a conclusive answer without the aid of chemical analysis or including the use of other sensory evaluation methods such as descriptive analysis.

Shiraz ( $26.5 \pm 24.7$  mm) was rated as the closest sample to R2 followed by Cabernet Sauvignon ( $26.7 \pm 23.6$  mm) but are not statistically significant due to the fact that they are both red wines. **Table 5.4** shows that Rosé ( $65.8 \pm 25.2$  mm) was the third sample that was most similar to R2; however, it was interesting to note that participants in this study rated Rosé to have closer sensory attributes to Chardonnay than Shiraz. According to literature, Rosé shares both elements of red and white wines due to its processing method. For example, some red grapes must be added to the fermentation process and drained after a short maceration or maintaining macerating grapes with their skins after crushing (Guerrini et al., 2022). From flavour analysis using SPME-GC-MS, researchers noted that white and Rosé wines have higher concentrations of ethyl esters of fatty acids (EEFAs) (Antalick et al., 2014). The cause of higher concentrations of EEFAs is due to the winemaking condition, where restricting oxygen levels such as carbonic maceration is a common practice in producing white and Rosé wine. In comparison, red wines have higher concentrations of ethyl esters of branched acids (EEBAs) which is possibly due to the grape skin contact during processing and malolactic fermentation (Antalick et al., 2014). From sensory science, participants tend to struggle with categorising and characterising Rosé due to its unique feature of having different shades of red. Ballester et al. (2009) observed that participants struggled to sort Rosé wine into groups and were less accurate compared to white and red wine. In this study, it was surprising to observe that participants rated the Rosé wine sample more closely to R1 (Chardonnay) than R2 (Shiraz) as all the alcoholic beverages were visible to the participants, Participants rated 1SF-N as the closest sample to R3 (1SF-N) with a mean score of  $26.6 \pm 22.6$  mm. Grape wines, including Rosé ( $72.2 \pm 27.2$  mm), Sauvignon Blanc ( $72.4 \pm 24.0$  mm), Chardonnay ( $74.5 \pm 24.2$  mm), Cabernet Sauvignon ( $77.7 \pm 24.2$  mm), and Shiraz ( $78.8 \pm 24.5$  mm), were not statistically significant between each other but was statistically significant to all *makgeolli* samples.

**Table 5.4** PSP results from participants (n = 91) including mean hedonic rating, similarities/differences compared to R1 (Chardonnay), R2 (Shiraz), and R3 (1SF-N) on 100 mm line scale.

Alcoholic beverages	Overall liking	R1 (Chardonnay)	R2 (Shiraz)	R3 (1SF-N)
1SF-N	48.9 ± 24.9 <sup>bcd</sup>	65.7 ± 27.0 <sup>b</sup>	76.3 ± 24.5 <sup>abcd</sup>	26.6 ± 22.6 <sup>d</sup>
1SF-YN	47.2 ± 28.7 <sup>cd</sup>	68.3 ± 26.3 <sup>ab</sup>	81.5 ± 17.4 <sup>ab</sup>	42.9 ± 26.9 <sup>bc</sup>
2SF	60.2 ± 24.9 <sup>ab</sup>	69.9 ± 26.6 <sup>ab</sup>	78.6 ± 21.3 <sup>abc</sup>	33.6 ± 22.2 <sup>cd</sup>
3SF	39.5 ± 28.6 <sup>d</sup>	77.5 ± 22.5 <sup>a</sup>	83.0 ± 18.1 <sup>a</sup>	48.2 ± 28.8 <sup>b</sup>
Cabernet Sauvignon	55.0 ± 24.1 <sup>bc</sup>	70.4 ± 24.9 <sup>ab</sup>	26.7 ± 23.6 <sup>e</sup>	77.7 ± 24.2 <sup>a</sup>
Chardonnay	67.9 ± 20.5 <sup>a</sup>	25.0 ± 22.1 <sup>d</sup>	70.4 ± 23.5 <sup>cd</sup>	74.5 ± 24.2 <sup>a</sup>
Rose	59.7 ± 23.6 <sup>ab</sup>	40.0 ± 25.0 <sup>c</sup>	65.8 ± 25.2 <sup>d</sup>	72.2 ± 27.2 <sup>a</sup>
Sauvignon Blanc	57.5 ± 24.6 <sup>abc</sup>	32.0 ± 25.5 <sup>cd</sup>	71.8 ± 26.0 <sup>bcd</sup>	72.4 ± 24.0 <sup>a</sup>
Shiraz	59.0 ± 23.7 <sup>ab</sup>	68.1 ± 27.8 <sup>ab</sup>	26.5 ± 24.7 <sup>e</sup>	78.8 ± 24.5 <sup>a</sup>

Results are expressed as mean ± standard deviation (n = 91). Statistical significance between samples is expressed as a – e superscript letters in the column for overall liking, similarities/differences compared to R1 (Chardonnay), R2 (Shiraz), and R3 (1SF-N). Statistical significance level was set at ( $p < 0.05$ ).

#### 5.4.5 MFA for PSP

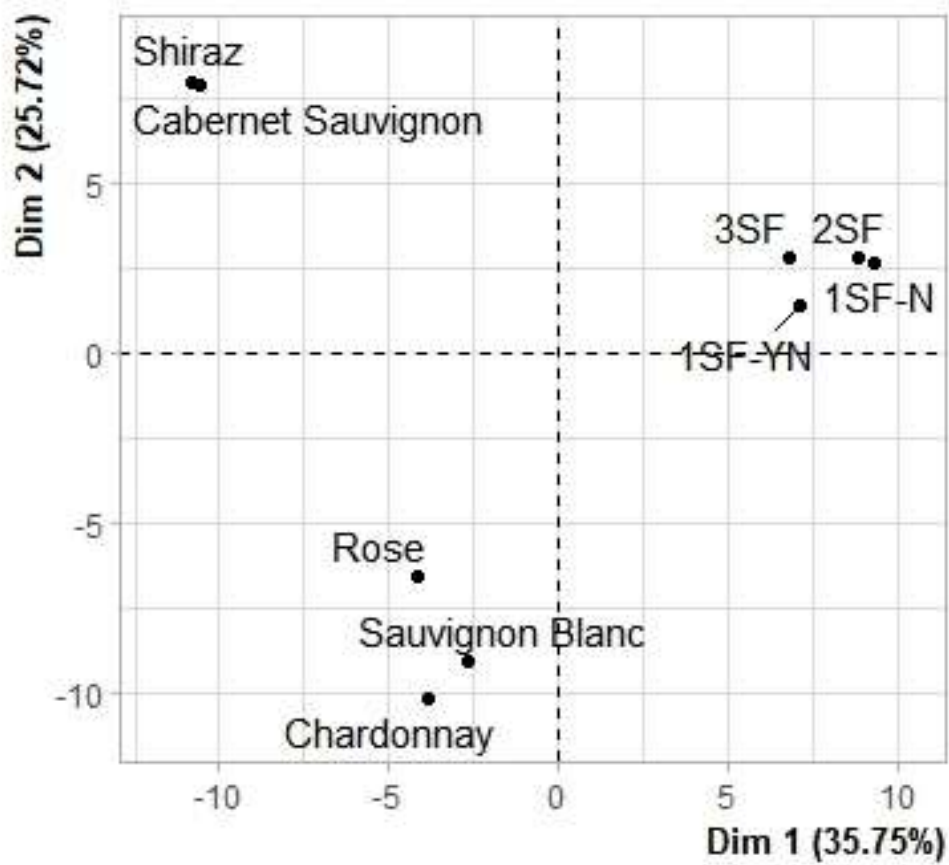
The PSP MFA map was constructed based on the information provided by participants while comparing the similarities and differences of each alcoholic beverage against R1, R2, and R3. The first and second dimensions of the PSP MFA map explained 61.5% (Dimension 1 = 35.8% and Dimension 2 = 25.7%) in **Figure 5.3**, a slight increase from the PM with UFP MFA map indicating that the PSP MFA map captured more information while determining the group clustering of the nine alcoholic beverage samples. Compared to the PM with UFP MFA map, there was a high consensus in categorising the alcoholic beverage samples using PSP. As stated earlier, the PSP experiment was more directive and required participants to follow specific instructions from the researchers. Specific sensory attributes and characteristics were pre-determined by the researchers, where participants compared the samples against the three poles prescribed by the researcher. In **Figure 5.3**, three groups of alcoholic beverages can be observed (e.g., red wine, white wine, and *makgeolli*). All the wine samples, including Shiraz, Cabernet Sauvignon, Rosé, Sauvignon Blanc, and Chardonnay, are in the negative values of Dimension 1, while all the *makgeolli* samples are in the positive value. For Dimension 2, all the *makgeolli* samples and red wines (e.g., Shiraz and Cabernet Sauvignon) are in the positive value, while all the white wines (e.g., Sauvignon Blanc and Chardonnay) are in the negative value. Interestingly, Rosé is grouped in the white wine cluster which was likely due to the high concentrations of EEFAs that they tend to share.

#### 5.4.6 HCA and RV coefficient for PSP

Participants were separated into individual clusters that best represent their knowledge of wine for further analysis to determine whether the clustering of the nine alcoholic beverages based on three poles or reference samples was affected. Like PM with UFP, participants were separated based on their wine knowledge, however, objective wine knowledge questions were also included in the HCA process due to the fact all participants took part in answering the questions with no missing data. Four clusters were identified: Cluster 1 consists 19.8% of participants, Cluster 2 consists 22.0%, Cluster 3 consists 25.3%, and Cluster 4 consists 32.9%, respectively. Cluster 1 had low subjective and objective wine knowledge, while Cluster 2 scored relatively higher in objective wine knowledge but still low in subjective wine knowledge. Cluster 3 had the most correct answers for objective wine knowledge, while Cluster 4 was relatively high compared to

the other Clusters. A detailed description of each cluster group is discussed in **Appendix K** and **Appendix L** compares the different clusters against the overall PSP MFA map.

Compared to the RV coefficient performed on the different clusters of PM with UFP, the RV coefficient for the paired comparison of PSP clusters was high; all are above 0.95 as shown in **Table 5.3**. The high RV coefficient indicates that MFA maps produced by PSP participants are in strong agreement between each cluster group in their product configuration on the MFA map, even though the rotations of sample placements are different. Participants with different subjective and objective knowledge of wine are able to perceive and use the same sensorial clues to characterise different alcoholic beverages and to use this information for categorisation.



**Figure 5.3** PSP-MFA map of comparing alcoholic beverages (n = 9) in the PSP experiment against three poles (Chardonnay, Shiraz, and 1SF-N). The total variance of the PSP-MFA plot map is 61.5% (Dimension 1 = 35.8%, Dimension 2 = 25.7%).

#### 5.4.7 General discussion

Research on the perception of *makgeolli* outside of Asia is very limited and market positioning of rice wine within the alcoholic beverage market might be problematic. This study was set to understand how New Zealand participants categorise and characterise *makgeolli* among other commercial alcoholic beverages and to provide some guidance in positioning *makgeolli* in the alcoholic beverage market. To the best of our knowledge, this is one of the first studies that examined the sensory interactions between *makgeolli* and other alcoholic beverages in terms of placing *makgeolli* on perceptual map with other alcoholic beverages.

Although Kwak et al. (2015) paper states that Western consumers perceive KRW as belonging to the wine category of alcoholic beverages, specifically sharing similar sensory attributes with semi-sweet white wine, this was not observed in this study. The results from PM with UFP MFA map show that there are three distinctive groups (e.g., wine, beer, and *makgeolli*). From the qualitative data of the PM with UFP, participants indicate that *makgeolli* samples are sourer than wine and beer samples. Beer differs from wine and *makgeolli* samples due to its bitter taste and participants indicated that wine has more fruity attributes than the other class of alcoholic beverages. From the PM with UFP MFA map, it was interesting to see how participants categorise *makgeolli* separately from beer and wine. When participants were divided into specific clusters from PM with UFP experiments based on wine subjective knowledge, Shiraz was placed relatively close to *makgeolli* samples in two cluster groups (Cluster 3 and Cluster 4). Participants from PM with UFP experiments allocated into Cluster 3 and Cluster 4 do not frequently consume alcoholic beverages and also noted that their subjective wine knowledge is low compared to their peers. Cluster 4 from the PM with UFP experiment, had the lowest total explained variance (42.1%) which suggests that there is low consensus in the criteria of characterising and categorizing alcoholic beverages compared to the other cluster groups in the PM with UFP experiment.

The combined total variance for PM with UFP MFA map was lower than PSP MFA map, and this can be explained by two reasons. First, the PSP experimental method was more directive compared to PM with UFP with reference-based instructions to the participants (Teillet et al., 2010). Researchers need to

identify specific reference points or “poles” for participants to compare the sample to characterise the food product. However, it is important to note that participants were not sorting the samples into different categories but examining whether the sample was either similar or different to the “poles” selected by the researchers. Second, the number of samples used in the PM with UFP may have reduced the total explained variance as shown in other published research (Hopfer & Heymann, 2013; Kim et al., 2019; Torri et al., 2013). Kim et al. (2019) noted that published research had lower total explained variance when samples ranged from 12 to 18 samples (21%–31%) compared to 7 to 9 samples (38%–56%) (Lelièvre et al., 2008; Lezaeta et al., 2017). Therefore, PM with UFP experiment was restricted to beer and wine samples and unable to include more alcoholic beverages such as cider, mead, or spirits without causing a lowering of combined explained variance or sensory fatigue to the participants.

From the PSP experiment, it was evident that all *makgeolli* samples do not share the same wine traits presented in this study. However, in the overall acceptance question, it was interesting to note that 2SF was the second most liked alcoholic beverage among the nine samples that were examined in the PSP experiment. In another study where the same processing of *makgeolli* was used, participants noted that 2SF had a sweeter taste than the other *makgeolli*. Sugar content analysis showed that 2SF had higher glucose and maltose content than 1SF-YN, 1SF-N, and 3SF (Wong, Muchangi, et al., 2023). In terms of other sensory attributes, 2SF has been described as having a creamier texture, pear flavour, and sweeter taste compared to the other *makgeolli*, such as 1SF-YN, 1SF-N, and 3SF. This may explain a higher overall acceptance of 2SF compared to the rest of the *makgeolli* samples. One limitation that should be addressed is that the methods used in this research paper are all sensory techniques; for future work, it would be beneficial to incorporate chemical analysis such as sugar analysis, colour, and quality of the different alcoholic beverages (Ailer et al., 2020), just to name a few parameters to consider for future research development of *makgeolli* in New Zealand. However, the main focus of this research paper was to understand how participants categorised and characterised *makgeolli* among beer and wine.

With consideration of the categorisation theory and *makgeolli* product, future marketing campaigns should consider positioning *makgeolli* as a separate alcoholic beverage category as participants grouped *makgeolli* into a separate alcoholic category in the PM with UFP and PSP experiments. Due

to *makgeolli* being perceived differently compared to wine and beer samples from the PM with UFP and PSP experiments, a subtype strategy would be more beneficial for *makgeolli* as it can disassociate itself from other products currently in the market (Sujan & Bettman, 1989). Another benefit of using the subtype strategy is the “mere categorisation effect.” The “mere categorisation effect” focuses on the number of categories rather than the number of offerings from the producers to the consumers (Mogilner et al., 2008). The “mere categorisation effect” suggests that consumers perceive products are abundant without overloading the consumer with information about individual products are sorted into different categories (Mogilner et al., 2008). For example, producers may consider a separate section of “rice wine only” products on a food menu at a restaurant or a separate section on the store shelf to differentiate rice wine from other alcoholic beverages such as beer or wine. Other studies have also shown that increased categories of products do increase customer satisfaction; however, too many categories can potentially overload them as this relationship is best described as an inverted-U shape relationship according to (Yan et al., 2015).

## 5.5 Conclusion

The result from this study suggests that *makgeolli* is categorised differently compared to wine and beer. This is interesting as the process of producing *makgeolli* is similar to beer and scientific literature has noted that Western consumers perceive KRW including *makgeolli* to share similar traits to Rosé or semi-sweet white wine products. *Makgeolli* producers and marketing professionals need to consider positioning *makgeolli* differently within the alcoholic beverage market in New Zealand.

## Chapters 6. Determining the appropriate location for consuming Korean rice wine (makgeolli) in New Zealand

### 6.1 Prelude

**Chapter 6** – *determining the appropriate location for consuming Korean rice wine (makgeolli) in New Zealand* aims to evaluate the different emotions and moods emitted while consuming *makgeolli* in different environments. Throughout this thesis, overall liking of the different *makgeolli* samples were examined in different chapters such as **Chapter 3**, **Chapter 4**, and **Chapter 5**. However, other questions regarding willingness to pay, willingness to buy, and likelihood to consume were not explored for *makgeolli* in New Zealand. The purpose of **Chapter 6** is evaluating the overall acceptance of *makgeolli* in different consumer environments. Unlike the previous experimental chapters, where all four *makgeolli* samples were examined; only one *makgeolli* sample was used (2SF). 2SF was used due to its high overall liking in **Chapter 3** and **Chapter 5**, although 1SF-YN was the highest overall liked *makgeolli* in **Chapter 4**, statistical significance was not reached.

This experimental chapter was conducted in two parts, (1) evoked context which was conducted entirely in the Marketing sensory laboratory and (2) sensory evaluations were conducted in different environmental conditions examining the participants' sensory behaviour and perception between central location testing and home use testing. The results from both studies indicate environmental appropriateness was an important factor to consider when introducing food products into the market. In addition, emotions and moods were measured in both studies. Emotions and moods in some context scenarios and environments changed, however, more research is needed as the scales used to measure mood and emotions were not specific to rice wine consumption or in a food context (e.g., using the Bond-Lader scale for measuring mood change).

## 6.2 Introduction

Korean rice wine, known as *makgeolli*, is a relatively new product in Western markets, originating from the Korean peninsula. From 2019 to 2020, the number of registered *makgeolli* companies in South Korea increased from 931 to 961 (Lee & Lves, 2022) with the largest *makgeolli* exporter reporting sales worth \$10 million in 2022 (Yang, 2023). This surge in commercial interest has led to the introduction of new *makgeolli* products in Western market (Watman, 2023). In addition to commercial interest, research has shown *makgeolli* has good sources of nutrition such as vitamins (specifically vitamins B and C), organic acids (specifically succinic acid and pyruvic acid), and amino acids (specifically proline) (Nile, 2015; Wong, Muchangi, et al., 2023).

The taste of *makgeolli* is often described as being sour with floral and fruity flavours (Lee & Lee, 2008). Overall liking of Korean rice wine including *makgeolli* is correlated with sweetness while negatively correlated with yeasty flavour characteristics (Kwak et al., 2015). Research on Korean rice wine (especially *makgeolli*) in Western societies such as New Zealand is relatively limited. Although prior research shows overall liking in American consumers (Kwak et al., 2015) and differing sensory perception in New Zealand participants (Wong, Owens, et al., 2023), both studies were conducted in laboratories where the findings may not be transferrable to natural consumption settings such as restaurants and at home.

Acceptance tests are usually conducted in sensory laboratories under a controlled environment where all factors are held constant to avoid bias (Boutrolle et al., 2005). However, researchers have also criticised this practice as it is not realistic and does not mirror how consumers eat or drink. Other eating events such as feelings, emotions, and activities are referred to as the consumption context which is often ignored in sensory evaluation (Jaeger & Porcherot, 2017). Meiselman (1996) mentions there are three broad aspects of an eating event where (1) the food often includes aspects such as culinary tradition and culture (e.g., packaging, naming, and also labelling), (2) people interact with the social and physical environment, and (3) consumers have food preferences, different food attitudes, and consumption patterns. Köster (2003) commented that sensory evaluation falls into the problem of situational fallacy where food is evaluated in the absence of a situational context. Köster (2003) further stated that food products are rarely consumed in isolation or various types of food are all consumed within one setting. Therefore, consumption context should be considered to increase context validity in sensory evaluation and consumer research.

One approach is to conduct the sensory evaluation in natural environments where consumers are likely to use the product. For example, Danner et al. (2020); Danner et al. (2016) compared different locations such as homes, restaurants, and the sensory laboratory and Holthuysen et al. (2017) examined the sensory differences of aeroplane meals between the laboratory, re-created environment (e.g., immersive environment), and aeroplane environment. Alternatively, to counter the situational fallacy problem, researchers have created different consumption context methods to incorporate in their sensory evaluation in the sensory laboratory. Examples include virtual reality, immersive environment, and evoked context. Virtual reality uses technology to stimulate environments that are similar to the real world while sensory evaluation is carried out (Torrico et al., 2020). For an immersive environment, researchers use visual, auditory, and olfactory cues to represent similar real-life situations in the laboratory setting (Sinesio et al., 2019). However, not all institutions or companies can provide an immersive environment during sensory evaluation due to cost and resource constraints. A possible alternative to virtual reality and immersive environments is evoked context. Evoked context was first systematically introduced into food literature by Hein et al. (2010). Unlike immersive environments, physical objects or virtual reality headsets are not required, evoked context uses participants' experiences and imagination during sensory evaluation. Experiments with evoked context include dry-cured ham (Hersleth et al., 2015), packaged lamb meat (de Andrade et al., 2016), fruit juices (Hein et al., 2010, 2012; Lusk et al., 2015) and beer (Dorado et al., 2016; Nijman et al., 2019).

This research aims to determine which consumption environment (e.g., Asian restaurant or home environment) is the most appropriate place to consume *makgeolli* in New Zealand. The study was conducted in two parts. The first study (referred to as Study 1) was conducted entirely in a sensory laboratory setting using simulated environmental scenarios. The second study (referred to as Study 2) was conducted in three natural environments including an Asian restaurant, home, and the food science laboratory. Changes in mood and emotions, overall liking, and appropriateness of consuming *makgeolli* were measured in both studies. Mood is defined as a long-lasting psychological arousal state that affects the energy, tension, and pleasure of the individual (Köster & Mojet, 2015) while emotions are responses towards a specific situation and are short lasting while the mood is non-specific and require gradual build-up over time (Meiselman, 2015). This study plans to fulfil three objectives: (1) establish the most appropriate consumer environment to consume

*makgeolli* in New Zealand, (2) identify whether participants will experience mood/emotional changes in each environmental setting while consuming *makgeolli*, and (3) determine whether evoked context scenarios or different environments change sensory perception among the participants.

## 6.3 Materials and methods

### 6.3.1 *Makgeolli* samples

The *makgeolli* processing methods were first identified from scientific literature and later categorised into four main processing methods by Wong, Muchangi, et al. (2023). Physicochemical, taste, flavour, and volatile compounds were previously investigated by Wong, Muchangi, et al. (2023); Wong, Owens, et al. (2023); Wong et al. (2024) to identify differences between the *makgeolli* samples. For this research, a single *makgeolli* sample was used across both studies. This sample, which underwent two-stage fermentation (2SF), was chosen as it received the highest-rating among the four different processing methods identified by Wong, Muchangi, et al. (2023). Additionally, it was the most preferred *makgeolli* sample compared to other wine and *makgeolli* products (Wong et al., 2024). All *makgeolli* samples used in Study 1 and Study 2 were prepared in the Food Science Laboratory of Auckland University of Technology, and all materials were purchased from the Auckland CBD area.

Two-stage fermented *makgeolli* (2SF) is a process involving two stages, where a fermentation base is initially produced by fermenting non-glutinous rice with *nuruk*, a traditional Korean fermentation starter. This base is then combined with the glutinous rice for further fermentation. To create the fermentation base, the researcher washed 400 g of non-glutinous rice (Wang Ltd., Korea) with deionised (DI) water until the water ran clear (approximately 10 min of continuous washing), soaked for 3 h, and then drained for 1 h. The soaked rice was pulverised into smaller particles such as rice powder using a blender (Russell Hobbs, UK). The rice powder was then cooked for 15 min with 1.25 L of DI water, cooled to 25 °C, and mixed with 200 g of ground *nuruk* (Wang Ltd., Korea). The mixture was left to ferment at 25 °C for 1 day, then filtered. One litre of the resulting fermentation base was added to the glutinous rice for the second phase. In the second phase, 2 kg of glutinous rice (Wang Ltd, Korea) were washed with deionised (DI) water until the water ran clear (approximately 10 min of continuous washing), soaked for 3 h, and drained for 1 h. The soaked rice was steamed for 120 min, cooled to 25 °C, and combined with 1 L of fermentation base and 1.5 L of DI

water. The mixture was fermented in vessels for 7 days at 25 °C. After fermentation, the 2SF makgeolli was filtered to remove the rice wine mash, and the remaining liquid was stored in amber-coloured bottles in a 4 °C refrigerator until used for sensory evaluation. Samples stored for more than two weeks were discarded and not used for sensory evaluation. **Figure 6.1** demonstrates the process of pouring the fermentation base into the cooled glutinous rice, while **Figure 6.2** illustrates the appearance of the resulting 2SF *makgeolli*.



**Figure 6.1** Photo illustration of fermentation base being poured into the steamed glutinous rice. Once fermentation base was fully incorporated into the glutinous rice creating a glutinous rice mash, the mash was then distributed into different vessels for fermentation.



**Figure 6.2** Photo illustration of the 2SF *makgeolli* sample. Korean rice wine mash was filtered and discarded; the remaining liquid is 2SF *makgeolli*.

### 6.3.2 Study protocol

Advertisements for both studies were carried out on social media such as Facebook, and posters/flyers around the AUT University student announcement walls. Participants from both studies were recruited from the Auckland Metropolitan area and were screened for the following the same criteria set out by Wong, Muchangi, et al. (2023); Wong, Owens, et al. (2023). Participants must satisfy the following criteria to participate in the studies: (1) the participant does not suffer from food allergies such as wheat, rice, and alcohol, (2) the participant is not pregnant or trying to conceive a child, (3) not operating heavy machinery or driving within 2 h after completing the sensory evaluation and lastly (4) the participant must be at least 18 years of age or over to take part in the sensory evaluation (the legal age of consuming alcohol in New Zealand). Both studies were approved by the AUT Ethics Committee, and the application number is 19/241.

Study 1 differed from Study 2 where participants were required to write a statement based on a specific context such as '*afternoon at home friends for a drink*' (referred to as home), '*at an Asian restaurant*' (referred to as Asian restaurant), or no context (e.g., a typical laboratory environment). Study 1 used the sensory evaluation method called evoked context (Hein et al., 2010) while Study 2 used real environments including a local Asian restaurant (Faro, Auckland CBD), the subject's home, and the Food Science Laboratory at AUT City campus.

### 6.3.3 Questionnaire, scale, and sociodemographic

The general structure of the questionnaire was as follows: participants were asked to rate their mood baseline using the Bond-Lader scale (1), evoked context page for participants to write their thoughts (Study 1 only) (2), consume the *makgeolli* sample and rate the overall liking on 9-point hedonic category scale, JAR questions regarding taste, flavour, and appearance of the *makgeolli* sample (3), check or circle the emotional terms that best describe their feeling when drinking *makgeolli* using the BE survey (4), Bond-Lader scale to measure the effects of consuming the *makgeolli* sample in the specified scenario or environment (5), specific questions about the environmental context such as appropriateness and accuracy of the information given (6), need for uniqueness (short version) (7) and lastly, sociodemographic questions (8). The survey questions were all randomised within their specific section to reduce the first-order effect.

The Bond-Lader scale was used in both studies as a measure of mood changes before and after consuming the *makgeolli* sample. Sixteen bi-polar 100 mm line scale questions were presented before the experiments took place and after answering questions regarding overall liking, seven JAR questions, and the participant's emotional state in both studies.

A 9-point hedonic category scale labelled from '*dislike extremely*' to '*like extremely*' was used to determine the overall liking of the *makgeolli* sample. Context appropriateness, compelled something to drink, the vividness of environmental context (Study 1 only), ease of rating their overall liking based on environment, and the accuracy of the information given were also examined on a 9-point category scale for both studies and will be referred to as environmental context questions. Most of the environmental context questions are inspired by Hein et al. (2010, 2012) apart from willingness to consume, willingness to pay, and likelihood of purchase. The context question reads: '*To what extent did this sensory experiment compel you to desire something to drink?*' (1 = 'not at all compelled', 9 = 'very compelled') for compelled something to drink, '*While you taste the rice wine sample, how vivid in your mind was the occasion you imagined?*' (1 = 'not at all vivid, 9 = 'very vivid) for vividness of environmental context (Hein et al., 2012). '*How easy/difficult did you find it to rate your liking/dislike of the rice wine drink?*' (1 = 'very difficult', 9 = very easy) for ease of rating their overall liking based on environment, '*To what extent do you feel that the liking information you have given is accurate?*' (1 = 'not at all accurate', 9 = 'very accurate') are questions designed to measure the suitability of the environmental context (Hein et al., 2012). '*To what extent do you feel appropriate to drink rice wine in this environment?*' (1 = 'not at all appropriate', 9 = 'very appropriate') for context appropriateness while consuming the *makgeolli*. Additional questions such as '*How willing are you going to consume this product?*' (1 = 'not at all willing, 9 = 'very much willing'), '*How likely are you going to buy this product?*' (1 = 'not at all likely', 9 = 'very much likely'), and '*How much are you willing to pay for this product in a 750 ml (normal wine bottle)?*' subjects need to fill in the blank '     NZD per 750 ml normal wine bottle'.

The JAR scale was used in both studies to understand the intensity of the *makgeolli* while being consumed in different contextual environments (Wong, Owens, et al., 2023), attributes including sweetness, sourness, astringency, colour, alcohol strength, fruitiness, and smoothness were examined on a 5-point JAR

scale (1 = Not enough, 3 = Just about right, 5 = Too much). Participants were encouraged to ask the researcher if they did not understand the terms.

The beverage emotional (BE) survey designed by Silva et al. (2016) was used in both studies because this survey has been used in different beverages such as beer, wine, and non-alcoholic beverages. The survey consists of 19 terms: adventurous, amused, calm, comforted, curious, disappointed, energetic, excited, exuberant, free, friendly, good, grumpy, happy, joyful, pleased, relaxed, restless, and sad which was identified by van Zyl (2016). Participants marked the emotions that they perceived using the Check-All-That-Apply method.

The need for uniqueness is a measure of the consumers' desire to pursue differences between individuals via consumption to develop a distinctive shelf and social image (Tian et al., 2001). Both studies use the short version of the Consumers' Need for Uniqueness (CNFU) questionnaire designed by Ruvio et al. (2008), which consists of three dimensions: creative choice, unpopular choice, and avoidance of similarity measured on a 7-point category scale (1 = disagree extremely; 7= agree extremely). CNFU information will be shown as the total sum for each study under **Section 6.3.6** participants of Study 1 and Study 2.

#### **6.3.4 Study 1 experimental design and procedure**

Study 1 was a laboratory experiment whereby participants were randomly assigned to one of three evoked contexts (evoked context: afternoon drinks with friends, Asian restaurant, or none) in a between subject design while consuming *makgeolli*. The evoked context was used to simulate real-life experiences that subjects have while consuming alcoholic beverages. Two written scenarios were developed for this sensory experiment including at home with friends, and at an Asian restaurant. The first evoked context was afternoon drinks with friend(s) where participants were presented with the statement "*Think about an occasion when you are at home with friends having an afternoon drink. Clearly imagine you are experiencing this occasion. Now write a detailed description of the occasion that you are imagining.*" The second statement was Asian restaurant context where participants were presented with "*Think about an occasion when you are at an Asian restaurant, and you are having a sip of your drink. Clearly imagine you are experiencing this occasion. Now write a detailed description of the occasion that you are imagining.*" Throughout the experiment, participants were reminded of the specific scenario by having to read the same

evoked context statement on each questionnaire page. The third condition was no context, where the experiment was carried out without written statements.

Study 1 took place in the Marketing Sensory Laboratory at the AUT city campus with the temperature set at 22 °C and white fluorescent light was used. Before the experiment took place, a researcher explained the nature and purpose of the experiment and the processes of the questionnaire. One *makgeolli* sample was presented when the participant completed the specific question (e.g., after writing the evoked context or finishing the Bond-Lader scale questions for no context) and indicated to the researcher that they were ready to consume the sample. Participants were allowed to request more *makgeolli* samples, and water and crackers were provided as palate cleansers but were not mandatory for the participants to consume. All *makgeolli* samples for Study 1 were prepared at least 2 h before the experiment took place, 40 ml was measured and placed in a transparent 60 ml plastic vessel with a lid. All the *makgeolli* samples were stored in the refrigerator at 4 °C before the experiment took place.

### **6.3.5 Study 2 experimental design and procedure**

Study 2 was a field experiment conducted in three environments including an Asian restaurant, the subject's home, and the Food Science Laboratory in Auckland, New Zealand. Participants were recruited from the wider community and invited to consume *makgeolli* in one of the three environmental contexts. Criteria for the participant's selection were consistent with Study 1.

The Asian restaurant, situated in Auckland's CBD area (see **Figure 6.3**), was chosen as the venue for the experiment. The experiment was conducted on a Tuesday and Wednesday between 17:30 and 19:30 in May 2023, as this was the least disruptive time for the restaurant. During this time frame, a researcher approached diners who had been seated by the restaurant staff and placed their orders to see if they would like to participate in the study. Those who agreed were given a 'sensory pack' containing a 40 ml *makgeolli* sample, sensory questionnaire, consent form, information sheet, pen, and set of instructions. The researcher introduced the research project and informed diners they would receive NZD 15.00 compensation per a person for participating and completing the questionnaire while consuming the *makgeolli*. Once the participant information sheet and consent form had been read and signed, participants were asked to consume the *makgeolli* sample while answering the questionnaire. Participants were encouraged to complete

the experiment before starting their meal and were given the option to do so either individually or with company.



**Figure 6.3** A photo illustration of the Asian restaurant used in Study 2. A local Korean restaurant in the Auckland CBD.

For the Food Science Laboratory, located in Auckland, New Zealand, the experiment took place between 11:00 and 15:00 during university opening hours. The temperature was set to 22.0 °C and white fluorescent light was used in the Food Science Laboratory. Participants were given the same sensory pack as in the Asian restaurant condition, and similar procedures were followed.

In the home environment, there were no restrictions on when participants could complete the experiment or whether they needed to do it alone or with company. It was recommended that participants complete the experiment in the most natural state possible, however, the experiment must be completed in the participant's home environment. Participants received the same sensory pack used in other environmental conditions, and similar procedures were followed. To maintain consistency, participants were instructed to store the *makgeolli* sample in the refrigerator at approximately 4.0°C before the experiment. They collected the sensory pack between 10:00 and 16:00 on a weekday during the university's open hours. Arrangements for both collection and drop off of the sensory pack were made in advance between the participants and researcher via email or phone message.

### 6.3.6 Participants of Study 1 and Study 2

Both Study 1 and Study 2 used convenience sampling within Auckland CBD, New Zealand. Apart from Study 2 in the Asian restaurant environment where diners were approached by the researcher and asked to participate in the sensory evaluation, Study 1 and most of Study 2 were conducted on a pre-arranged basis with the researcher. A general description of the participants is presented in **Table 6.1**. In total, 60 participants (24 female, 35 males, and 1 not recorded) participated in Study 1 with 20 subjects in each evoked context scenario. Around 51.6% of participants were aged between 18 and 29, with one participant's age bracket not being recorded. Sixty-one percent of the participants consumed alcoholic beverages at least once a week or more and 51.7% of participants consumed rice more than once a week. In terms of ethnicity, researchers used the self-prioritisation method as part of the sociodemographic question regarding the participant's ethnicity (Kukutai & Callister, 2009). Participants are asked to only select one ethnic group that they strongly associate themselves with. For ease of interpretation, some ethnic groups were categorised together. New Zealand Europeans are defined as individuals who have strong affiliation with New Zealand such as citizenship or cultural identity with European ancestry.

For Study 2, 30 participants took part in the local Asian restaurant, 35 participants in the Food Science Laboratory, and 48 participated in the home environment. Like Study 1, the self-prioritisation method was used in the sociodemographic questions to determine the participants' ethnic affiliation. The largest ethnic group category identified in Study 2 was East Asian (49.6%) consisting of participants with Chinese, Korean, Filipino, Thai, Vietnamese, and Taiwanese backgrounds followed by New Zealand Europeans (20.4%).

For Consumer's Need for Uniqueness, the overall mean of the three dimensions for Study 1 includes creative choice ( $4.38 \pm 1.37$ ), unpopular choice ( $3.68 \pm 1.58$ ), and avoidance of similarity ( $3.18 \pm 1.39$ ). The overall mean of the three dimensions for Study 2 is  $4.01 \pm 1.33$  for creative choice,  $3.31 \pm 1.52$  for unpopular choice, and  $3.07 \pm 1.59$  for avoidance of similarity on a 7-point scale.

**Table 6.1** Participant’s sociodemographic information with percentages including gender, age, ethnic background, rice consumption frequency, and alcoholic consumption frequency in both studies.

Categories	Different subcategories	Study 1 Sample n (%)	Study 2 Sample n (%)
Gender	Male	35 (58.3%)	48 (42.5%)
	Female	24 (40.0%)	65 (57.5%)
	Not recorded/not disclosed	1 (1.70%)	n/a
Age	18 – 29	31 (51.6%)	51 (45.1%)
	30 – 39	19 (31.7%)	31 (27.4%)
	40 – 49	5 (8.33%)	11 (9.7%)
	50+	4 (6.67%)	20 (17.7%)
	Not recorded/not disclosed	1 (1.70%)	n/a
Ethnicity association	New Zealand European <sup>a</sup>	17 (28.3%)	23 (20.4%)
	East Asian <sup>b</sup>	17 (28.3%)	56 (49.6%)
	South Asian <sup>c</sup>	14 (23.3%)	8 (7.08%)
	African <sup>d</sup>	3 (5.00%)	2 (1.77%)
	Māori/Pasifika <sup>e</sup>	5 (8.33%)	8 (7.08%)
	European <sup>f</sup>	1 (1.7%)	9 (7.96%)
	American <sup>g</sup>	3 (5.00%)	1 (0.88%)
	Middle East	n/a	6 (5.31%)
Rice consumption	More than once week	31 (51.7%)	16 (14.2%)
	At least once a week	12 (20.0%)	6 (5.31%)
	Every second week	3 (5.00%)	12 (10.6%)
	Once a month	3 (5.00%)	21 (18.6%)
	Seldom	10 (16.7%)	57 (50.4%)
	Not recorded/not disclosed	1 (1.70%)	1 (0.89%)
Alcohol consumption	More than once a week	19 (31.7%)	16 (14.2%)
	At least once a week	18 (30.0%)	21 (18.6%)
	Every second week	10 (16.7%)	23 (20.4%)

Once a month	13 (21.7%)	52 (46.0%)
Not recorded/not disclosed	n/a	1 (0.89%)

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Note: Study 1 refers to the first study that was conducted using evoked context to simulate different scenarios (n = 60). Study 2 refers to the second study that used different physical environmental contexts (n = 113).

<sup>a</sup>New Zealand European is defined as individuals who have European ancestry but self-identify with strong affiliation with New Zealand (e.g., New Zealand citizenship or permanently residing in New Zealand).

<sup>b</sup>East Asians category consists of subjects with East or Southeast Asian ancestry, subjects may self-identify as Chinese, Korean, Thai, Taiwanese, Filipino, Vietnamese, or Southeast Asian.

<sup>c</sup>South Asian category consists of subjects with South Asian ancestry, subjects may self-identify as Sri Lankan, Nepalese, or Indian.

<sup>d</sup>African category consists of subjects from the African continent.

<sup>e</sup>Māori/Pasifika category consists of subjects with Māori or Pacific Islander ancestry (e.g., Fijian, Samoan, and Tongan).

<sup>f</sup>European category consists of subject from the European continent and does not self-identify as a New Zealand European such as British, French, Slavic, and Ukrainian.

<sup>g</sup>American category consists of subjects from Northern, Central, Southern of the Americas continent.

### 6.3.7 Statistical analysis

For Study 1, the Shapiro-Wilk test was used to identify whether parametric tests were appropriate for significant testing for the environmental questions. When statistical significance was reached for the Shapiro-Wilk test ( $p \leq 0.05$ ), alternative non-parametric statistics were used e.g., the Kruskal-Wallis  $\chi^2$  test. When statistical significance was reached, the Mann-Whitney U test was used as a post hoc test, a nonparametric version of the Student's t-test.

For Study 2, environmental questions were analysed using a one-way analysis of variance (ANOVA) with the  $p$ -value set at 0.05 for statistical significance. When statistical significance was reported, a post hoc test was performed to identify the degree of difference between the natural environment conditions using Tukey's Honestly Significance Difference test.

From the recommendations by Bond and Lader (1974), Bond-Lader scale bipolar attributes were grouped into three categories: alertness, contentedness, and calmness. Paired Student's t-test was used to compare participants before and after completing the experiment and alpha was set at  $p \leq 0.05$ . For analysing the BE survey, Pearson's  $\chi^2$  test was chosen as the information was presented as count data and statistical significance was reached with alpha set at  $p < 0.05$ . Cochran's Q test was not used as participants only attended to one environment context and participants only consumed one 2SF *makgeolli* sample, therefore, it was considered inappropriate to employ this analysis. For JAR questions, the SensoMineR package was used to determine the penalty and  $p$ -value of the specific sensory attributes signalled by participants while consuming *makgeolli* in different environmental settings (Lê & Husson, 2008). All data were analysed using R version 4.2.0.

A prior power analysis was conducted using G × Power version 3.1.9.7 for both Study 1 and Study 2 to determine the minimum sample size required for hypothesis testing (Faul et al., 2007). Results indicated the required sample size to achieve 80% power for detecting a large effect, a significance criterion of  $\alpha = 0.05$ , was  $n = 66$  for a one-way ANOVA test. Previous research by Wu et al. (2022) showed that different consumer environments strongly affect our sensory perception, therefore effect size was set at large. Sixty participants participated in Study 1 and 113 participants participated in Study 2. Post hoc power analysis was conducted due to the low participation in Study 1, the power was calculated to be 0.776. Additionally, Cohen's  $d$  value was calculated for each context interaction with mood and environmental questions that

reached statistical significance for Study 1 and Study 2. When appropriate, epsilon squared ( $\epsilon^2$ ) statistics were employed to determine the effect size in Study 1.

#### **6.4 Study 1: Results and discussion**

**Table 6.2** is a verbatim example of a written description from participants who participated in Study 1. Each column represents a specific evoked context such as home (left column) and Asian restaurant (right column). Examples were selected at random from subjects #4, #5, and #7 for both specific evoked contexts. Participants that were allocated to the Asian restaurant context noted a lot of celebrations with friends while answering the evoked context question. The variety of Asian restaurants mentioned by participants include Japanese, Thai, and also Korean cuisines. The written description of the specific evoked contexts was not analysed further for Study 1.

**Table 6.2** Participant’s verbatim examples from specific evoked contexts with home (left column) and Asian restaurant (right column). Verbatim examples were selected at random from participant #4, #5, #7 for both specific evoked contexts for Study 1.

Participants	Evoked context condition: Home	Evoked context condition: Asian restaurant
#4	Several French [friends] came over [to] my house, we sat in the garden, talking and enjoying the afternoon.	I imagine a crowded Asian restaurant with my family sitting here trying this new classic wine bought into the market. As my dad takes the first sip and lets us taste the alcohol later. It is a tradition in my Indian culture for the head of the family to try it first then let the sons or daughters try the alcohol and knowing the fact that we would love the taste of this new wine.
#5	I feel very excited and relaxed, I will get a good time with my friend.	Popping edamame out of the shell - it's salty. Voices are loud and I am pressed into a small table with my husband. Cosy and warm, we have just come inside from the cold. The big main meal is coming - something with tofu and eggplant usually. Edamame bites, and I take a sip of warm sake. I've just poured it from the clay container into the little cup and of course, there is a drip, I mop up with a napkin. The little ceramic cup is warm, feels like a thimble in my hand compared to a big wine glass in some Italian restaurant - and as I sip I close my eyes. The drink is sharp, hot - warm and absorbs the soft from the edamame as it goes down. I feel the hot sake through my system and take a quick second sip as I feel my fingers and toes warm. Pure enjoyment.

#7	<p>Having an image of an occasion that occurred last year around April, the surrounding was excellent, food and music were keeping the guest entertained. I can still see how the day went. I was really excited as I was turning "21" big day big number. The only thing I could think of was I am an adult now, I have responsibilities, though I was scared here I am being a graduate paying my own bills and providing for myself.</p>	<p>I like food and I often try different types of cuisines. Once I went to an Asian restaurant in Auckland called Bawarichi Indian Restaurant and ordered a chicken biriyani. The chicken biriyani was very spicy.</p>
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Note: Study 1 refers to the evoked context experiment which simulated the three different scenarios including at home with friends, Asian restaurants, and no context. Participant under no context did not provide a written statement as it was not part of the questionnaire.

Kruskal-Wallis  $\chi^2$  test was selected to analyse the environmental context questions as the Shapiro-Wilk normality test showed that all environmental context questions reached statistical significance at  $p < 0.05$ . From the Kruskal-Wallis  $\chi^2$  test, only context appropriateness was statistically significant ( $p$ -value = 0.03). The effect size was measured using epsilon squared ( $\epsilon^2$ ) statistics, the  $\epsilon^2 = 0.115$  which indicates that the effect size was moderate. Mann-Whitney U test was used to determine the differences between the different evoked context scenarios. The mean score with standard deviation for Asian Restaurant is  $8.00 \pm 1.26$ , followed by home ( $6.85 \pm 2.13$ ) and no context ( $6.35 \pm 2.10$ ). Asian Restaurant was statistically significant compared to home and no context, while no statistical difference was observed between home and no context. Based on the information acquired from the participants present in Study 1, shows that Asian Restaurant was the most appropriate evoked context scenario to consume *makgeolli*. This finding was not surprising as *makgeolli* is not a common alcoholic beverage in the New Zealand market and the Asian restaurant context provides a sense of where the product is from. Statistical significance was not reached for overall liking in *makgeolli* between the different scenarios, showing similar results in the literature (Danner et al., 2016). **Table 6.3** shows the mean score and standard deviation with the  $p$ -value of the environmental questions observed in Study 1 only. Results of the environmental context questions for Study 2 are displayed in **Table 6.4** due to Study 2 using parametric statistics (e.g., one-way ANOVA) compared to non-parametric statistics such as the Kruskal-Wallis  $\chi^2$  test for testing statistical significance in Study 1.

**Table 6.3** Participant's mean responses with standard deviation to the environmental questions in Study 1 using Kruskal-Wallis  $\chi^2$  test for statistical significance (n = 60).

	<u>Significance testing</u>		<u>Evoked context scenarios</u>		
	$\chi^2$ value	p-value	Asian Restaurant (n = 20)	Home (n = 20)	No context (n = 20)
Accuracy	1.78	0.41	7.75 ± 1.21 <sup>a</sup>	8.00 ± 0.97 <sup>a</sup>	7.35 ± 1.46 <sup>a</sup>
Appropriateness	6.78	0.03*	8.00 ± 1.26 <sup>a</sup>	6.85 ± 2.13 <sup>b</sup>	6.35 ± 2.10 <sup>b</sup>
Compelled	1.33	0.51	6.40 ± 2.11 <sup>a</sup>	6.45 ± 2.04 <sup>a</sup>	5.80 ± 2.34 <sup>a</sup>
Likelihood of purchase	4.47	0.11	6.70 ± 2.58 <sup>a</sup>	6.00 ± 2.38 <sup>a</sup>	5.55 ± 1.80 <sup>a</sup>
Rating of difficulty	3.78	0.15	8.15 ± 1.09 <sup>a</sup>	7.10 ± 2.25 <sup>a</sup>	7.25 ± 1.55 <sup>a</sup>
Vividness	0.72	0.40	6.15 ± 1.95 <sup>a</sup>	6.50 ± 2.54 <sup>a</sup>	n/a
Willingness to consume	3.90	0.14	6.90 ± 2.17 <sup>a</sup>	7.00 ± 1.78 <sup>a</sup>	6.15 ± 1.68 <sup>a</sup>
Willingness to pay	1.18	0.55	17.75 ± 8.16 <sup>a</sup>	20.10 ± 8.09 <sup>a</sup>	17.50 ± 6.58 <sup>a</sup>
Overall liking	0.96	0.62	6.80 ± 1.96 <sup>a</sup>	6.50 ± 1.64 <sup>a</sup>	6.90 ± 1.84 <sup>a</sup>

Note: Study 1 refers to the evoked context experiment which simulated the three different scenarios including at home with friends, Asian restaurants, and no context. Statistical significance between different environments is expressed as letters in the column using the Mann-Whitney U test for Post hoc testing. Environmental question regarding vividness was not asked for participants participating in no context for Study 1.

<sup>n.s</sup> Environmental questions that did not reach statistical significance set at 0.05.

\* Statistical significance level  $p < 0.05$  Kruskal-Wallis  $\chi^2$  test

\*\* Statistical significance level  $p < 0.01$  Kruskal-Wallis  $\chi^2$  test

\*\*\* Statistical significance level  $p < 0.001$  Kruskal-Wallis  $\chi^2$  test

**Table 6.4** Participant’s mean responses with standard deviation to the environmental questions in Study 2 using one-way ANOVA test for statistical significance (n = 113).

	<u>Significance testing</u>		<u>Environmental contexts</u>		
	<i>F</i> -value	<i>p</i> -value	Asian Restaurant (n = 30)	Home (n = 48)	Laboratory (n = 35)
Accuracy	0.53	0.59 <sup>n.s.</sup>	7.07 ± 1.76 <sup>a</sup>	7.30 ± 1.59 <sup>a</sup>	6.91 ± 1.79 <sup>a</sup>
Appropriateness	13.03	<0.001 <sup>***</sup>	6.97 ± 1.94 <sup>a</sup>	6.96 ± 1.43 <sup>a</sup>	4.91 ± 2.54 <sup>b</sup>
Compelled	4.12	0.02 <sup>*</sup>	6.20 ± 2.14 <sup>a</sup>	4.70 ± 2.43 <sup>b</sup>	4.91 ± 2.33 <sup>ab</sup>
Likelihood of purchase	1.14	0.32 <sup>n.s.</sup>	5.03 ± 2.20 <sup>a</sup>	4.30 ± 2.32 <sup>a</sup>	4.91 ± 2.49 <sup>a</sup>
Rating of difficulty	0.39	0.68 <sup>n.s.</sup>	6.93 ± 1.84 <sup>a</sup>	6.74 ± 2.20 <sup>a</sup>	6.49 ± 2.01 <sup>a</sup>
Willingness to consume	1.36	0.26 <sup>n.s.</sup>	5.07 ± 2.30 <sup>a</sup>	4.49 ± 2.42 <sup>a</sup>	5.34 ± 2.42 <sup>a</sup>
Willingness to pay	2.38	0.10 <sup>n.s.</sup>	11.37 ± 7.53 <sup>a</sup>	8.86 ± 4.66 <sup>a</sup>	11.33 ± 5.75 <sup>a</sup>
Overall liking	2.11	0.13 <sup>n.s.</sup>	5.20 ± 1.95 <sup>a</sup>	5.81 ± 1.94 <sup>a</sup>	6.17 ± 1.84 <sup>a</sup>

Note: Study 2 refers to the physical environmental contexts including home, Asian restaurant, and laboratory.

<sup>n.s.</sup> Attributes did not reach statistical significance set at 0.05 from the one-way ANOVA.

<sup>\*</sup> Statistical significance level  $p < 0.05$  one-way ANOVA.

<sup>\*\*</sup> Statistical significance level  $p < 0.01$  one-way ANOVA.

<sup>\*\*\*</sup> Statistical significance level  $p < 0.001$  one-way ANOVA.

**Table 6.5** shows the mean mood changes of alertness, contentedness, and calmness before and after consuming *makgeolli* in the evoked context environments including Asian restaurant, home, and no context for Study 1. No difference in the change of mood (e.g., alertness, contentedness, and calmness) is observed in the Asian restaurant environment, however, statistical significance in mood changes is observed for the home environment and no context. Specifically, for the home environment scenario, the key mood that reached statistical significance was alertness ( $p$ -value = 0.002) with a mood change of +14.20 points. This observation from participants was expected, as alertness is often associated with mental clarity, improvement in attention and faster reaction time. The increase of 14.20 points shows that participants were less alert, therefore, the consumption of alcoholic beverages reduced the participant's alertness to be less attentive, energetic, and clear-headedness (Smith, 2013). The effect size was measured using Cohen's  $d$ , for alertness and in the home environment scenario was  $d = 0.96$  indicating the effect size was large. For no context, the key mood that reached statistical significance was contentedness ( $p$ -value < 0.001) with a mood change of -12.86. The negative change from the baseline of contentedness for no context indicates that participants were more content (e.g., happy) after consuming *makgeolli*. Smith (2013) observed similar findings as participants indicated that their hedonic tone increased over time as the participants consumed alcoholic beverages along with reduced anxiety. In comparison with the home environment scenario and alertness, the effect size was moderate according to Cohen's  $d$  for no context and contentedness ( $d = 0.70$ ).

**Table 6.5** Summary of participant's responses for both Study 1 (n = 58) and Study 2 (n = 113) on their mood changes based on the Bond-Lader Scale for different environment contexts

Study 1 (n = 58)							
Environmental contexts	Mood	<i>t</i> -value	df	<i>p</i> -value	Pre-experiment	Post-experiment	Change
Asian restaurant (n = 20)	Alertness	0.919	19	0.370 <sup>n.s</sup>	26.46 ± 16.41	29.84 ± 18.19	3.38
	Contentedness	-0.332	19	0.743 <sup>n.s</sup>	27.25 ± 18.87	26.02 ± 14.28	-1.23
	Calmness	1.156	19	0.262 <sup>n.s</sup>	40.73 ± 24.25	48.40 ± 22.81	7.68
Home (n = 18)	Alertness	3.671	17	0.002**	21.74 ± 9.14	35.94 ± 18.27	14.20
	Contentedness	0.148	17	0.884 <sup>n.s</sup>	31.53 ± 15.58	32.20 ± 14.38	0.67
	Calmness	0.504	17	0.621 <sup>n.s</sup>	33.44 ± 18.65	36.36 ± 21.83	2.92
No context (n = 20)	Alertness	0.281	19	0.782 <sup>n.s</sup>	28.38 ± 14.85	29.14 ± 13.22	0.76
	Contentedness	-6.832	19	<0.001***	40.74 ± 11.98	27.88 ± 13.70	-12.86
	Calmness	1.783	19	0.091 <sup>n.s</sup>	34.25 ± 19.75	41.28 ± 14.20	7.03
Study 2 (n = 113)							
Environmental contexts	Mood	<i>t</i> -value	df	<i>p</i> -value	Pre-experiment	Post-experiment	Change
Asian restaurant	Alertness	0.454	29	0.653 <sup>n.s</sup>	25.78 ± 18.87	27.05 ± 13.63	1.28

(n = 30)

Contentedness	-0.852	29	0.401 <sup>n.s</sup>	25.96 ± 15.49	24.21 ± 16.02	-1.76
Calmness	2.865	29	0.008**	25.17 ± 22.61	38.92 ± 20.09	13.75

Home

Alertness	1.151	47	0.256 <sup>n.s</sup>	30.51 ± 16.70	32.80 ± 16.09	2.29
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(n = 48)

Contentedness	1.443	47	0.156 <sup>n.s</sup>	26.38 ± 13.05	29.29 ± 15.84	2.91
Calmness	0.582	47	0.563 <sup>n.s</sup>	25.77 ± 16.76	27.09 ± 18.70	1.32

Laboratory

Alertness	-0.911	34	0.368 <sup>n.s</sup>	37.45 ± 16.57	35.50 ± 13.14	-1.94
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(n = 35)

Contentedness	-0.178	34	0.860 <sup>n.s</sup>	32.94 ± 16.58	32.54 ± 10.09	-0.40
Calmness	0.032	34	0.975 <sup>n.s</sup>	36.61 ± 18.27	36.70 ± 17.66	0.09

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Note: Study 1 refers to the first study that was conducted using evoked context to simulate different scenarios (n = 60). Study 2 refers to the second study that used different physical environmental contexts (n = 113). Two participants were removed from Study 1 in evoked context scenario of home due to incomplete survey.

<sup>n.s</sup> Statistical significance was not reached with alpha set at 0.05 for the Paired student *t*-test.

\* Statistical significance level  $p < 0.05$  Paired student *t*-test

\*\* Statistical significance level  $p < 0.01$  Paired student *t*-test

All  $\chi^2$  values and  $p$ -values for each emotional term are displayed in **Table 6.6** for both Study 1 and Study 2. Of the emotional terms selected by participants in Study 1 between the three evoked context scenarios, four emotional terms reached statistical significance including comforted ( $p$ -value = 0.04), curious ( $p$ -value = 0.001), energetic ( $p$ -value = 0.03) and free ( $p$ -value = 0.003). Fifty-five percent of participants selected comforted in the home context, while 25% of participants selected comforted in the Asian restaurant context followed by 20% of participants selecting this emotion term in no context. Interestingly, 85% of participants selected curious in no context while consuming the *makgeolli* sample, followed by 40% of participants who selected this emotional term in Asian restaurant and 30% of participants who selected this term in the home context. For energetic, 40% of subjects in the Asian restaurant context selected this emotional term while no context had 25% of participants and 5% of participants in the home context selected this term. For the emotional term for free, both home context and Asian restaurant context had 55% and 40% of participants selected this term respectively.

From the observations of Study 1, there seems to be a correlational relationship between environmental appropriateness and the emotional terms selected while consuming *makgeolli*. Piqueras-Fiszman and Jaeger (2014) observed that context appropriateness was an important aspect of food-emotional research as participants selected more negative terms when there was a mismatch between the food investigated (e.g., chocolate brownie) and the context during consumption (e.g., breakfast, lunch, or dinner). Interestingly, the three emotional terms (e.g., comforted, curious, and free) that reached statistical significance are positive terms and negative emotional terms such as disappointed, grumpy, and sad were hardly selected. Study 1 shows similar findings from previously published work that participants tend to select more positive emotional terms in food-related emotional research than negative terms (Danner et al., 2016; Desmet & Schifferstein, 2008; King & Meiselman, 2010).

**Table 6.6** Summary of subject's responses for both Study 1 (n = 60) and Study 2 (n = 113) on their emotional term selection for different environment contexts.

Emotional terms	Study 1					Study 2				
	Significance testing		Environmental contexts			Significance testing		Environmental contexts		
	$\chi^2$ value	<i>p</i> -value	Asian Restaurant (n = 20)	Home (n = 20)	No context (n = 20)	$\chi^2$ value	<i>p</i> -value	Asian Restaurant (n = 30)	Home (n = 48)	Laboratory (n = 35)
Adventurous	0.62	0.735 <sup>n.s.</sup>	0.35	0.35	0.25	1.03	0.596	0.33	0.25	0.34
Amused	0.75	0.689 <sup>n.s.</sup>	0.30	0.20	0.20	1.41	0.493	0.27	0.40	0.37
Calm	1.67	0.435 <sup>n.s.</sup>	0.30	0.40	0.50	2.31	0.316	0.27	0.44	0.37
Comforted	6.45	0.040*	0.25	0.55	0.20	3.26	0.196	0.10	0.25	0.14
Curious	13.75	0.001**	0.40	0.30	0.85	1.72	0.422	0.47	0.56	0.63
Disappointed	n/a	n/a <sup>n.s.</sup>	0	0	0	3.17	0.205	0.10	0.15	0.03
Energetic	6.89	0.032*	0.40	0.05	0.25	1.63	0.442	0.07	0.04	0.11
Excited	0.00	1.000 <sup>n.s.</sup>	0.30	0.30	0.30	6.30	0.043*	0.37	0.13	0.26
Exuberant	5.67	0.059 <sup>n.s.</sup>	0	0.05	0.20	2.25	0.325	0	0	0.03
Free	11.85	0.003**	0.40	0.55	0.05	1.57	0.457	0.03	0.10	0.11
Friendly	3.75	0.153 <sup>n.s.</sup>	0.50	0.60	0.30	4.41	0.111	0.37	0.17	0.31
Good	0.94	0.626 <sup>n.s.</sup>	0.55	0.40	0.45	4.21	0.122	0.33	0.40	0.57
Grumpy	2.03	0.362 <sup>n.s.</sup>	0	0.05	0	1.37	0.505	0	0.02	0
Happy	1.20	0.549 <sup>n.s.</sup>	0.55	0.55	0.4	1.60	0.449	0.33	0.23	0.34

Joyful	0.95	0.622 <sup>n.s.</sup>	0.45	0.50	0.35	0.20	0.904	0.20	0.17	0.20
Pleased	1.21	0.546 <sup>n.s.</sup>	0.50	0.50	0.35	1.82	0.403	0.37	0.31	0.46
Relaxed	0.48	0.788 <sup>n.s.</sup>	0.75	0.70	0.65	5.94	0.051	0.70	0.56	0.40
Restless	2.03	0.362 <sup>n.s.</sup>	0	0	0.05	1.52	<0.001***	0.03	0.08	0.40
Sad	n/a	n/a <sup>n.s.</sup>	0	0	0	1.37	0.505	0	0.02	0

Note: Study 1 refers to the first study that was conducted using evoked context to simulate different scenarios consisting of home with friends, Asian restaurant, and no context (n = 60). Study 2 refers to the second study that used different physical environmental contexts consisting of home, Asian restaurant, and laboratory (n = 113).

<sup>n.s.</sup> Emotional terms that did not reach statistical significance set at 0.05 using the  $\chi^2$  test.

\* Statistical significance level  $p < 0.05$   $\chi^2$  test

\*\* Statistical significance level  $p < 0.01$   $\chi^2$  test

\*\*\* Statistical significance level  $p < 0.001$   $\chi^2$  test

**Table 6.7** shows the penalty analysis for both Study 1 and Study 2. Overall, four attributes were identified as either being too-much or not enough influencing the low hedonic score of the overall liking of *makgeolli* in all three evoked context scenarios including Asian restaurant, home, and no context in Study 1. The highest penalty score in Study 1 was sweetness being not-enough with an overall score of  $2.11 \pm 0.48$ , indicating some reformulation is required to increase the overall liking of *makgeolli* among New Zealand participants. Kwak et al. (2015) showed that there is a correlation between sweetness and overall liking of Korean rice wine in the United States and Wong, Muchangi, et al. (2023) showed participants having a higher liking of *makgeolli* with a higher concentration of sugars such as maltose and glucose. To increase the hedonic score of *makgeolli* in Western markets, it would be advantageous for manufacturers to reformulate *makgeolli* with higher sweetness such as increasing the sugar content in the final product. Around 25% of subjects noted that smoothness of *makgeolli* was not-enough with a penalty score of  $1.58 \pm 0.57$ . In terms of sourness, participants in Study 1 cited that sourness was too much with a penalty score of  $1.18 \pm 0.47$ , reformulation of *makgeolli* should be considered to optimise the overall hedonic score. Sourness in Korean rice wine tends to be negatively correlated with overall liking (Kwak et al., 2015). Interestingly, subjects in Study 1 indicated that *makgeolli* had both not-enough astringency with a penalty score of  $1.76 \pm 0.62$  and too-much astringency with a penalty score of  $1.47 \pm 0.54$ . Similar to Wong, Owens, et al. (2023) findings, the differences between the perception of astringency such as either too much or not enough are likely due to the different participant groups participating in the experiment. Wong, Owens, et al. (2023) commented that a possible reason is the different cluster groups participating in their study. Four cluster groups were identified from their study, and different defining traits such as age, alcoholic consumption patterns, and different degrees of subjective and objective wine knowledge were observed.

**Table 6.7** Just-about-right (JAR) information from Study 1 and Study 2. Information displays the penalty score  $\pm$  standard deviation and the  $p$ -value for statistical significance.

Attributes	Study 1		Study 2	
	Penalty score	$p$ -value	Penalty score	$p$ -value
Alcohol Strength (not enough)	-0.615 $\pm$ 0.526	0.247 <sup>n.s.</sup>	0.277 $\pm$ 0.529	0.602 <sup>n.s.</sup>
Alcohol strength (too much)	-0.657 $\pm$ 0.685	0.329 <sup>n.s.</sup>	0.013 $\pm$ 0.433	0.976 <sup>n.s.</sup>
Astringency (not enough)	1.760 $\pm$ 0.617	0.006**	0.590 $\pm$ 0.591	0.320 <sup>n.s.</sup>
Astringency (too much)	1.470 $\pm$ 0.535	0.008**	0.599 $\pm$ 0.390	0.128 <sup>n.s.</sup>
Colour (not enough)	0.797 $\pm$ 0.759	0.298 <sup>n.s.</sup>	0.638 $\pm$ 0.496	0.201 <sup>n.s.</sup>
Colour (too much)	0.339 $\pm$ 0.517	0.514 <sup>n.s.</sup>	0.248 $\pm$ 0.433	0.568 <sup>n.s.</sup>
Fruitiness (not enough)	0.806 $\pm$ 0.533	0.136 <sup>n.s.</sup>	1.235 $\pm$ 0.375	0.001**
Fruitiness (too much)	0.402 $\pm$ 0.620	0.519 <sup>n.s.</sup>	0.509 $\pm$ 0.587	0.388 <sup>n.s.</sup>
Smoothness (not enough)	1.575 $\pm$ 0.573	0.008**	0.831 $\pm$ 0.388	0.035*
Smoothness (too much)	0.658 $\pm$ 0.615	0.289 <sup>n.s.</sup>	-0.285 $\pm$ 0.647	0.661 <sup>n.s.</sup>
Sourness (not enough)	1.546 $\pm$ 0.774	0.050 <sup>n.s.</sup>	0.074 $\pm$ 0.554	0.893 <sup>n.s.</sup>
Sourness (too much)	1.179 $\pm$ 0.471	0.015*	1.007 $\pm$ 0.386	0.010*
Sweetness (not enough)	2.110 $\pm$ 0.484	<0.001***	1.144 $\pm$ 0.367	0.002**
Sweetness (too much)	-0.132 $\pm$ 0.616	0.831 <sup>n.s.</sup>	0.883 $\pm$ 0.672	0.191 <sup>n.s.</sup>

Note: Study 1 refers to the first study that was conducted using evoked context to simulate different scenarios consisting of home with friends, Asian restaurant, and no context (n = 60). Study 2 refers to the second study that used different physical environmental contexts consisting of home, Asian restaurant, and laboratory (n = 113).

<sup>n.s</sup> Attributes did not reach statistical significance set at 0.05 from the penalty analysis, \* Statistical significance level  $p < 0.05$  penalty analysis, \*\* Statistical significance level  $p < 0.01$  penalty analysis and \*\*\* Statistical significance level  $p < 0.001$  penalty analysis

## 6.5 Study 2: Results and discussion

Statistical significance was observed for two environmental questions including appropriateness to consuming *makgeolli* ( $p$ -value  $<0.001$ ) and how participants were compelled to consume the rice wine in the specific environments ( $p$ -value = 0.02) including Asian restaurant, home, and laboratory using one-way ANOVA in Study 2. For appropriateness, Tukey's HSD test showed both Asian restaurant ( $6.97 \pm 1.94$ ) and home ( $6.96 \pm 1.43$ ) environments are not statistically significant to each other indicating both environments are appropriate for consuming *makgeolli*, however, both are statistically significant to laboratory ( $4.91 \pm 2.54$ ). The effect size was measured using Cohen's  $d$ ,  $d = 0.993$  between home and laboratory and  $d = 0.909$  between laboratory and Asian restaurant. Both Cohen's  $d$  value indicated that the effect size was large. This finding showed similarities with Study 1 where participants indicated that Asian restaurant and home environments were more appropriate to consume *makgeolli* than no context.

For the question regarding how compelled participants were to consume rice wine, Asian restaurant ( $6.20 \pm 2.14$ ) is significantly different to home ( $4.70 \pm 2.43$ ) but not laboratory ( $4.91 \pm 2.22$ ). Cohen's  $d$  was measured to determine the effect size, and Cohen's  $d$  value indicates that the effect size was moderate with  $d = 0.65$  between home and Asian restaurant and  $d = 0.58$  for laboratory and Asian restaurant. Statistical significance was not observed between home and laboratory in Tukey's HSD test. Participants in Study 2 may feel as though they were compelled to consume *makgeolli* due to external factors such as situational or the cultural setting (Köster, 2009) as the Asian restaurant is a natural environment for customers to purchase and consume their meals. In terms of overall liking of consuming *makgeolli* in different environments, no statistical significance was observed in both Study 1 and Study 2. This result is consistent with other researchers as they concluded that the environment is unlikely to impact the overall liking of food products (Dorado et al., 2016; Torrico et al., 2020).

The only environment that observed statistical difference for mood changes was Asian restaurant, specifically in calmness from  $25.17 \pm 22.61$  to  $38.92 \pm 20.09$  with a measured change of +13.75 as shown in **Table 6.5**. Cohen's  $d$  indicates the effect size for the mood change of calmness in Asian restaurant was moderate ( $d = 0.70$ ). **Table 6.6** shows the emotional terms cited by participants after consuming *makgeolli* in the three environmental contexts. From the participant's responses between Asian restaurant, home, and laboratory, only excited ( $p$ -value = 0.04) and restless ( $p$ -value =  $<0.001$ ) were statistically significant. For excited, 37% of participants cited this emotional term while consuming *makgeolli* at an Asian restaurant and

13% of participants cited being excited at home. Surprisingly, 26% of participants cited the term excited while consuming *makgeolli* in the laboratory environment. This finding may explain the change of mood in participants from a calm state to a rather heightened state on the Bond-Lader mood scale.

For the emotional term restless, 40% of participants cited this emotional term in the laboratory environment while both home and Asian restaurant were relatively low with 8% and 3% citing this term respectively. The results show that participants were more restless in the laboratory environment after consuming *makgeolli* compared to Asian restaurant and home. The results on restless were consistent with Danner et al. (2016) observation as they observed that participants were more fearful/anxious while consuming red wine in the laboratory than home and restaurant. Like Study 1, Study 2 observed that environmental context appropriateness is likely to affect the consumers' emotional responses to food products (Danner et al., 2016; Desmet & Schifferstein, 2008; Piqueras-Fiszman & Jaeger, 2014). The positive and negative emotions are associated with the environmental appropriateness of consuming *makgeolli*. Positive emotion such as excited is cited more in Asian restaurant and home, while negative emotion such as restless is cited more in the laboratory environment.

**Table 6.7** summarises the penalty analysis of Study 2 for the just-about-right (JAR) attributes. Four attributes including fruitiness, smoothness, sourness, and sweetness were identified as either being too much or not-enough which likely impacted the overall hedonic rating of *makgeolli* in different environments in Study 2. The highest penalty score was not-enough fruitiness ( $1.24 \pm 0.38$ ;  $p$ -value = 0.001) followed by not-enough sweetness ( $1.14 \pm 0.37$ ;  $p$ -value = 0.002). The results from Study 2 differed slightly from Study 1 which can be explained by the location where *makgeolli* was consumed. A possible explanation is that participants applied more penalty scores in the laboratory than in natural environments, due to being more analytical while doing the sensory evaluation in a laboratory environment (Shi et al., 2021).

## 6.6 General discussion and limitations

This research extends our understanding of *makgeolli* and investigates whether different environmental contexts change the overall acceptance (e.g., overall liking) of *makgeolli* and whether there is a more appropriate location to consume *makgeolli*. From Study 1 and Study 2, measurable attribute differences such as consumption appropriateness, mood, emotions, taste, and flavour were observed in different evoked context scenarios and environments. The findings from both studies somewhat suggest that

consumption appropriateness may play an important role in food decision or selection rather than the participants' overall liking of the food product. The emotional and mood differences between evoked context scenarios and environments were not surprising in both studies, as previous studies show that perceived physical environments impact the individual's emotions which subsequently affects their behaviour (Liu & Jang, 2009; Ryu & Jang, 2007). Mehrabian and Russell (1974) state that emotions can be characterised into three states (e.g., pleasure, arousal, and dominance) and this determines the individuals' approach or avoidance responses within the environment.

Both studies demonstrate mood and emotion changes in some environments. Most notably mood and the emotions selected in Study 1 (e.g., comforted, curious, energetic, and free) and Study 2 (e.g., excited and restless) are likely to be associated with consumption appropriateness. Piqueras-Fiszman and Jaeger (2014) stated that positive emotions were evoked more when participants deemed the consumption context appropriate, while more negative emotions were evoked when the consumption context was considered less appropriate. Therefore, positioning *makgeolli* in restaurants would be beneficial as participants deemed Asian restaurants as an appropriate environment for the consumption of *makgeolli* while evoking positive emotions.

While both studies yielded interesting results that are consistent with the scientific literature on evoked context and consumption environment, this research has several limitations that should be addressed. First, both studies have relatively small sample sizes. Due to the COVID19 outbreak in 2020, the experimental parameters were shifted to accommodate the situation. Sensory researchers provided various solutions to reduce the spread of COVID-19, including remote testing, driven-in booths, and at home testing, also referred to as home use testing (Dinnella et al., 2022; Park et al., 2023; Seo et al., 2021). Given the circumstances, the researchers in this study opted to employ an evoked context to simulate different consumption environments rather than utilising physical settings, which posed a risk to the participants and was not feasible in 2020.

During Study 1, the experiment ended after two and a half weeks due to the Auckland regional lockdown that occurred in August 2020 (Taylor, 2020). To help overcome some of the limitations associated with a smaller sample size, non-parametric statistics were employed. Non-parametric statistics such as Kruskal-Wallis  $\chi^2$  test do not assume normal data distribution and are less sensitive to outliers, thus considered acceptable for analysing Study 1 data. Other researchers with low participants have also utilised

non-parametric methods or applied statistical adjustments in their analysis (Crofton et al., 2021; Rousta et al., 2021; Zulkarnain et al., 2024). Therefore, we deemed this an appropriate approach to data analysis considering the circumstances.

In Study 2, Auckland City experienced several weather events during the first half of 2023, such as the Auckland Anniversary storm, Cyclone Gabrielle, and the May storm event (Johnson, 2023). The lower participation rate of participants from the restaurant environment can be attributed to the lower consumer turnout at restaurants in Auckland City during this period. In light of the situation, power analysis showed a moderate to large effect size for factors that showed statistical significance. This indicates practical significance (e.g., the meaningfulness of the observed data) from both studies which can be applied to real-world situations (Kirk, 1996; Peeters, 2016).

Although we used a combination of field and laboratory studies to examine different environmental contexts impact on the consumption of *makgeolli* and Study 2 had a larger sample than Study 1, future research should replicate the findings of our studies with larger samples. While Study 2 displayed a more balanced age distribution compared to Study 1, a limitation of our research lies in its concentration on the perceptions of *makgeolli* and the environmental appropriateness among younger consumers. The younger sample is likely due to the nature of the experiment relying on a convenience sampling method. Also, given the lack of evidence regarding the primary consumer demographics of *makgeolli* in the Western context, it remains challenging to ascertain whether the inclusion of a younger sample restricts the scope of our research. Consequently, future work with *makgeolli* could determine the age groups most attracted to the consumption and purchase of *makgeolli*, with additional studies recruiting more subjects over the age of 30.

Another limitation was the methods used for measuring mood and emotions. Currently, there is no standardised measure for mood and emotions in food product testing, therefore, both scales (e.g., Bond-Lader scale and the BE survey) were borrowed from psychology and wine research. Finally, some supplementary information was not collected in Study 2 that may be useful for other researchers such as the time of day that the *makgeolli* experiment was conducted and whether the subjects were completing the experiment as an individual or group. Future research within consumption environments should collect this information as part of the sensory survey to identify potential biases and to control for these potentials confounds.

## 6.7 Conclusion

This study demonstrated that different environments both scenario and natural environments are likely to evoke different moods and emotions while consuming *makgeolli*. While no statistical differences were observed in overall liking for both studies, it was evident that subjects considered consuming *makgeolli* in Asian restaurants to be more appropriate. Another interesting observation was the association between environmental appropriateness versus mood and emotions. There is likely a positive association between environmental appropriateness and positive emotions. Negative emotion terms were selected more in environments that participants deemed inappropriate to consume the *makgeolli*. Overall, this research enhances our understanding of how different environments including evoked context and real environments impact our understanding of mood and emotions while consuming *makgeolli*.

## Chapters 7. Overall conclusion and future research directions

The overall aim of this research was to expand our understanding of the different *makgeolli* processing methods and to quantify its physicochemical and sensory attributes within a Western context such as New Zealand. From this thesis, four studies were conducted to achieve the four objectives listed in Chapter 1. These objectives include (1) exploring whether New Zealand consumers can discriminate/differentiate different types of *makgeolli* based on their processing methods, (2) understanding the physicochemical properties of *makgeolli* based on their processing methods, (3) comparing the flavour and sensory attributes of different *makgeolli* samples using chemical analysis and sensory evaluation, lastly (4) to understand the consumer acceptance of *makgeolli* among New Zealand consumers. Each chapter fulfils at least one or more of the objectives stated and it was conducted in a manner to further expand our understanding of the physicochemical and sensory properties of the different processing methods to produce *makgeolli*. Below is a summary of each experimental chapter:

### 7.1 Summary and implications of Chapter 3

Four methods of preparing *makgeolli*, a traditional Korean turbid rice wine, were reported in this study. The four processing routes include single-stage simultaneous saccharification and fermentation of glutinous rice with *nuruk* – a Korean starter culture (1SF-N), single-stage fermentation with *nuruk* and yeast (1SF-YN), two-stage fermentation (2SF) and three-stage fermentation (3SF). Chemical analysis was used to determine how the different processing routes could affect the rice wine's properties in terms of alcohol content, pH, colour, mineral content, proximate composition, antioxidant activity, total phenolic content, sugar, free amino acid, and organic acid profile. Sensory analysis using polarised projective mapping (PPM) and 62 participants found that sweetness is the most desirable attribute for *makgeolli* among New Zealand participants with sourness and bitterness as less desirable. The 2SF *makgeolli* sample had the highest concentration of glucose (8.2 mg/mL) and maltose (107 mg/mL) and in the PPM experiment was the most preferred out of the four processing methods. The 1SF-N *makgeolli* sample had the highest alcohol (13% ABV), crude protein (4.9%), antioxidant activity, total phenolic (621 mg GAE/L) and free amino acids content, however, it was the least overall liked *makgeolli* sample. Overall, the novelty of this research

includes formulating a traditional Korean turbid rice wine in a Western country environment and evaluating consumer perception of *makgeolli* beyond the normal clientele in South Korea. From these results, it is suggested that the properties of *makgeolli* can be manipulated via processing to suit the brewer's sensory needs that best fit the consumer market.

The purpose of **Chapter 3** is to systematically evaluate the different *makgeolli* processing methods and to identify the physicochemical properties of each of the *makgeolli* samples. Food manufacturers and researchers can select the appropriate processing method or tailor the *makgeolli* towards their consumer market. Although it is evident that 2SF is the most overall liked and 1SF-N is the least liked *makgeolli* sample, all samples of *makgeolli* showed relatively low consumer acceptance from the PPM experiment. Additional ingredients, alternations to ingredients, and changes in processing methods of *makgeolli* should be considered to increase overall acceptance among consumers in New Zealand.

## **7.2 Summary and implications of Chapter 4**

This study seeks to identify sensory descriptors that best describe *makgeolli* among New Zealand consumers. Chemical analysis and sensory evaluation were carried out to establish the different sensory and flavour properties of the four different *makgeolli* samples. Chemical analysis using SPME-GC-MS was employed to understand the volatile compounds present in the four *makgeolli* samples, while two sensory tests were carried out simultaneously using Check-All-That-Apply (CATA) and Just-About-Right (JAR). A total of 45 volatile compounds were identified using SPME-GC-MS, and examples of major volatiles include 2-methyl-1-propanol (alcoholic flavour), limonene (citrus-like flavour), and hexanal (green/grass-like flavour). One hundred and twenty-nine subjects (n = 68 females) completed the sensory evaluation and were analysed for this study. Female subjects tend to rate overall acceptance of *makgeolli* higher than male subjects; both subjects preferred 1SF-YN with the highest mean hedonic score, and the least preferred *makgeolli* was 1SF-N. From CATA, attributes such as apple, apricot, peach, sweet taste, and bubbly texture were statistically significant when describing *makgeolli*. For JAR, a high proportion of subjects indicated that sourness was too much in three of the four *makgeolli* samples.

Research on rice wine in Western markets such as New Zealand is limited, and this study gives insight into how New Zealand consumers perceive Korean rice wine (*makgeolli*). Sensory participants in this study indicated that *makgeolli* is too sour and lacks sufficient sweetness in the majority of the samples examined. When launching *makgeolli* to the New Zealand market, practitioners need to optimise sweetness and reduce sourness to increase overall liking. Sensory terms used by subjects describing *makgeolli* include cider, apple, and sour.

### 7.3 Summary and implications of Chapter 5

This study aims to investigate the product categorisation and characterisation of *makgeolli* among beer and wine samples. Projective mapping with ultra-flash profiling (PM with UFP) ( $n = 68$ ) was conducted with 12 alcoholic beverage samples, including wines, beers, and *makgeolli*, and showed that participants characterised wine based on fruitiness, beer on bitterness, and *makgeolli* on sourness. Study 1 showed that PM with UFP had a combined explained variance of 47.4% with beer, wine, and *makgeolli* grouped separately. However, when participants were separated based on wine knowledge, low wine knowledge participants placed Shiraz close to *makgeolli* indicating participants were using a different metric in grouping the alcoholic beverage samples. When participants were tasked with using (Study 2) polarised sensory positioning ( $n = 91$ ) to characterise *makgeolli* and wines, participants regardless of wine knowledge showed that wine and *makgeolli* had unique sensory traits and thus should be categorised differently.

Based on the categorisation theory, it is important to position the product properly in the food and beverage categories as consumers may use the category cues to evaluate *makgeolli* and use products such as beer or wine within the same category as price anchors for *makgeolli*'s price in the market. The results showed that participants categorise *makgeolli* differently compared to wine and beer; therefore, it would be beneficial to position *makgeolli* separately. Practical applications may include creating a separate section on a restaurant beverage menu, a webpage on an alcoholic beverage seller's website, or a small sub-section on the retail store shelf. Placing *makgeolli* in the wine section as previously suggested is not recommended.

## 7.4 Summary and implications of Chapter 6

This study examined the relationships in how different environments affect the participants' attitudes, behaviour, and perception while consuming Korean rice wine (*makgeolli*) in New Zealand. Two studies were conducted in the Auckland metropolitan area. Study 1 (n = 60) was carried out in a laboratory setting using the evoked context method to simulate a context scenario. The context scenario includes consuming a beverage at home with friends, at an Asian restaurant, and no context with n = 20 in each scenario. For Study 2 (n = 113), participants evaluated the *makgeolli* sample in three natural environments. These natural environments include home (n = 48), a local Asian restaurant (n = 30), and the Food Science Laboratory (n = 35). Mood was evaluated before and after the experiment using the Bond-Lader scale, while emotions were evaluated using the Check-All-That-Apply method on specific terms. From both studies, context appropriateness indicated that the Asian restaurant was an appropriate location to consume *makgeolli*. For emotions, it was evident that there was a positive association between context appropriateness and positive emotional terms such as *energetic* and *excited* for Asian restaurant for both studies. In terms of flavour and taste perception, there were differences between the studies, this may suggest that subjects may be hypersensitive in laboratory settings while evaluating *makgeolli*. Overall liking was not affected by the different scenarios or environmental contexts. Therefore, context appropriateness may be an important factor in consumers' decision-making when consuming food products.

The experiments from both Study 1 and Study 2 show that participants' attitudes, behaviour, and perceptions are likely to change depending on the environment. Although we did not notice statistical differences in overall liking in different scenarios and environments, both studies show that context-appropriate matter of where *makgeolli* should be consumed. Therefore, it would be advantageous to position *makgeolli* in restaurant settings. Another aspect of scientific inquiry that should be investigated is the consumer perception of taste and flavour in different scenarios and environments. More attributes e.g., sweetness, sourness, smoothness, and astringency were noted to be either too-much or not-enough in laboratory setting than natural environments.

## 7.5 Future direction of the research

The sensory evaluation methods conducted in this thesis were relatively cost-effective and required minimal training from the participants (**Chapters 3, 4, and 5**). In addition, acceptance testing (**Chapters 3, 4, and 6**) was carried out to establish to what degree the *makgeolli* samples were liked. The benefit of minimal training is that sensory evaluation can be easily conducted, however, results are likely to have higher variation and require high amounts of participants to compensate for the variation. Future direction of research on *makgeolli* may consider carrying out a descriptive analysis or quantitative descriptive analysis (QDA®) to identify the intensity of specific attributes that make *makgeolli* unique. Results from **Chapters 3, 4, and 5** can aid the process of generating sensory terms and attributes that are likely to be important in the descriptive analysis process. Additionally, researchers may consider combining sensory data with physicochemical data to establish correlations between these two factors.

Secondly, physicochemical and sensory evaluation were conducted on the *makgeolli* samples and other factors such as shelf-life and packaging were not included in this thesis because it was beyond the scope of the research. Researchers may consider the effects of pasteurisation on *makgeolli* or how packaging is likely to affect consumer's attitudes, perceptions, and behaviour in New Zealand. *Makgeolli* packaging is not transparent in New Zealand and other countries such as the United States have introduced certain varieties of *makgeolli* in cans.

Thirdly, the sensory evaluation methods used in **Chapters 3, 4, 5, and 6** are established methods within sensory research. These methods include Check-All-That-Apply, Just-About-Right, polarised sensory positioning, projective mapping, and evoked context are methods that have been used in a variety of food products. All methods stated are easy to administrate and used by the participants. However, the methods assume that sensory attributes are static but in reality, sensory perception of food and beverages is dynamic. Methods such as temporal dominance of sensation should be considered as flavour, taste, and aroma of *makgeolli* are likely to change over time during consumption. Researchers can evaluate how sensory attributes change over time for *makgeolli* and compare them between the different processing methods.

Finally, like many aspects of life, food is an integral part of our culture and humans tend to have a complex relationship with food. Our selection of food can also be used as a sense of self-expression, cultural identity, and a sense of belonging. Research on ethnic food products in foreign countries should continue as

it provides essential information to researchers and manufacturers regarding the consumers' attitudes and behaviour towards ethnic food products. It is also important to document how consumers perceive and respond to these ethnic food products. If consumers respond positively to ethnic food products, manufacturers can foster new opportunities by providing these ethnic food products to the market.

## Reference list

- Aaker, D. A., & Shansby, J. G. (1982). Positioning your product. *Business Horizons*, 25(3), 56-62. [https://doi.org/10.1016/0007-6813\(82\)90130-6](https://doi.org/10.1016/0007-6813(82)90130-6)
- Ahn, H., & Kim, I.-D. (2020). Influence of Ulmi (*Ulmus macrocarpa* Hance) Cortex on Quality Characteristics and Antioxidant activity of Korean Traditional Wine, Takju. *International Journal of Sciences*, 9(06), 9-12. <https://doi.org/10.18483/ijSci.2333>
- Ailer, Š., Valšíková, M., Jedlička, J., Mankovecký, J., & Baroň, M. (2020). Influence of sugar and ethanol content and color of wines on the sensory evaluation: From wine competition "Nemcinany Wine Days" in Solvack Republic (2013–2016). *Erwerbs-Obstbau*, 62, 9-16. <https://doi.org/10.1007/s10341-020-00486-x>
- Akaike, M., Miyagawa, H., Kimura, Y., Terasaki, M., Kusaba, Y., Kitagaki, H., & Nishida, H. (2020). Chemical and bacterial components in sake and sake production process. *Current Microbiology*, 77, 632-637. <https://doi.org/10.1007/s00284-019-01718-4>
- Alencar, N. M. M., Ribeiro, T. G., Barone, B., Barros, A. P. A., Marques, A. T. B., & Behrens, J. H. (2019). Sensory profile and check-all-that-apply (CATA) as tools for evaluating and characterizing syrah wines aged with oak chips. *Food Research International*, 124, 156-164. <https://doi.org/10.1016/j.foodres.2018.07.052>
- Ali, M. M., & Hashim, N. (2024). Exploring Nutritional Composition, Volatile Compounds, Health Benefits, Emerging Processing Technologies, and Potential Food Products of Glutinous Rice: A Review. *Rice Science*. <https://doi.org/10.1016/j.rsci.2024.02.002>
- Antalick, G., Perello, M.-C., & De Revel, G. (2014). Esters in wines: New insight through the establishment of a database of French wines. *American Journal of Enology and Viticulture*, 65(3), 293-304. <https://doi.org/10.5344/ajev.2014.13133>
- Ares, G., Antúnez, L., de Saldamando, L., & Giménez, A. (2018). Polarized Sensory Positioning. In S. E. Kemp, J. Hort, & T. Hollowood (Eds.), *Descriptive analysis in sensory evaluation* (pp. 561-577). John Wiley & Sons Ltd. <https://doi.org/10.1002/9781118991657.ch16>
- Ares, G., Antúnez, L., Oliveira, D., Alcaire, F., Giménez, A., Berget, I., Næs, T., & Varela, P. (2015). Pole selection in polarized sensory positioning: insights from the cognitive aspects behind the task. *Food Quality and Preference*, 46, 48-57. <https://doi.org/10.1016/j.foodqual.2015.07.003>
- Ares, G., de Andrade, J. C., Antúnez, L., Alcaire, F., Swaney-Stueve, M., Gordon, S., & Jaeger, S. R. (2017). Hedonic product optimisation: CATA questions as alternatives to JAR scales. *Food Quality and Preference*, 55, 67-78. <https://doi.org/10.1016/j.foodqual.2016.08.011>
- Ares, G., de Saldamando, L., Vidal, L., Antúnez, L., Giménez, A., & Varela, P. (2013). Polarized projective mapping: Comparison with polarized sensory positioning approaches. *Food Quality and Preference*, 28(2), 510-518. <https://doi.org/10.1016/j.foodqual.2013.01.003>
- Bae, S. H., Choi, J. W., Ra, K. S., Yu, K. W., Shin, K. S., Park, S. S., & Suh, H. J. (2012). Anti-complementary activity of enzyme-treated traditional Korean rice wine (Makgeolli) hydrolysates. *Journal of the Science of Food and Agriculture*, 92(8), 1765-1770. <https://doi.org/10.1002/jsfa.5543>
- Bae, S. H., Jung, E. Y., Kim, S. Y., Shin, K. S., & Suh, H. J. (2010). Antioxidant and immuno-modulating activities of Korean traditional rice wine, Takju. *Journal of Food Biochemistry*, 34, 233-248. <https://doi.org/10.1111/j.1745-4514.2009.00327.x>

- Bal, J., Yun, S.-H., Song, H.-Y., Yeo, S.-H., Kim, J. H., Kim, J.-M., & Kim, D.-H. (2014). Mycoflora dynamics analysis of Korean traditional wheat-based nuruk. *Journal of Microbiology*, *52*, 1025-1029. <https://doi.org/10.1007/s12275-014-4620-0>
- Ballester, J., Abdi, H., Langlois, J., Peyron, D., & Valentin, D. (2009). The odor of colors: can wine experts and novices distinguish the odors of white, red, and rosé wines? *Chemosensory Perception*, *2*, 203-213. <https://doi.org/10.1007/s12078-009-9058-0>
- Barton, A., Hayward, L., Richardson, C. D., & McSweeney, M. B. (2020). Use of different panellists (experienced, trained, consumers and experts) and the projective mapping task to evaluate white wine. *Food Quality and Preference*, *83*. <https://doi.org/10.1016/j.foodqual.2020.103900>
- Bautista, R. C., & Counce, P. A. (2020). An overview of rice and rice quality. *Cereal Foods World*, *65*(5). <https://doi.org/10.1094/CFW-65-5-0052>
- Benzie, I. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: the FRAP assay. *Analytical Biochemistry*, *239*(1), 70-76. <https://doi.org/10.1006/abio.1996.0292>
- Bicsak, R. C. (2020). Comparison of Kjeldahl method for determination of crude protein in cereal grains and oilseeds with generic combustion method: collaborative study. *Journal of AOAC International*, *76*(4), 780-786. <https://doi.org/10.1093/jaoac/76.4.780>
- Bond, A., & Lader, M. (1974). The use of analogue scales in rating subjective feelings. *British Journal of Medical Psychology*, *47*(3), 211-218. <https://doi.org/10.1111/j.2044-8341.1974.tb02285.x>
- Boutrolle, I., Arranz, D., Rogeaux, M., & Delarue, J. (2005). Comparing central location test and home use test results: Application of a new criterion. *Food Quality and Preference*, *16*(8), 704-713. <https://doi.org/10.1016/j.foodqual.2005.03.015>
- Bruwer, J., Chrysochou, P., & Lesschaeve, I. (2017). Consumer involvement and knowledge influence on wine choice cue utilisation. *British Food Journal*, *119*(4), 830-844. <https://doi.org/10.1108/BFJ-08-2016-0360>
- Buggenhout, J., Brijs, K., & Delcour, J. A. (2014). Soaking conditions during brown rice parboiling impact the level of breakage-susceptible rice kernels. *Cereal Chemistry*, *91*(6), 554-559. <https://doi.org/10.1094/CCHEM-03-14-0038-R>
- Byeon, Y. S., Heo, J., Kwak, H. S., Baek, H. H., Lee, Y. s., & Kim, S. S. (2023). Does sensory quality assessed by beverage experts fit consumer acceptability? A study on cheongju. *Journal of Sensory Studies*, *38*(5), e12853. <https://doi.org/10.1111/joss.12853>
- Cai, H., Zhang, Q., Shen, L., Luo, J., Zhu, R., Mao, J., Zhao, M., & Cai, C. (2019). Phenolic profile and antioxidant activity of Chinese rice wine fermented with different rice materials and starters. *LWT*, *111*, 226-234. <https://doi.org/10.1016/j.lwt.2019.05.003>
- Cai, H., Zhang, T., Zhang, Q., Luo, J., Cai, C., & Mao, J. (2018). Microbial diversity and chemical analysis of the starters used in traditional Chinese sweet rice wine. *Food Microbiology*, *73*, 319-326. <https://doi.org/10.1016/j.fm.2018.02.002>
- Campbell, H. (2000). The glass phallus: Pub(lic) masculinity and drinking in rural New Zealand. *Rural Sociology*, *65*(4), 562-581. <https://doi.org/10.1111/j.1549-0831.2000.tb00044.x>
- Cha, J., Park, S.-E., Kim, E.-J., Seo, S.-H., Cho, K.-M., Kwon, S. J., Lee, M.-H., & Son, H.-S. (2023). Effects of saccharification agents on the microbial and metabolic profiles of Korean rice wine (makgeolli). *Food Research International*, *172*, 113367. <https://doi.org/10.1016/j.foodres.2023.113367>

- Chakkaravarthi, A., Lakshmi, S., Subramanian, R., & Hegde, V. (2008). Kinetics of cooking unsoaked and presoaked rice. *Journal of Food Engineering*, 84(2), 181-186. <https://doi.org/10.1016/j.jfoodeng.2005.11.011>
- Champagne, E. T. (2008). Rice aroma and flavor: a literature review. *Cereal Chemistry*, 85(4), 445-454. <https://doi.org/10.1094/CCHEM-85-4-0445>
- Chen, G.-M., Huang, Z.-R., Wu, L., Wu, Q., Guo, W.-L., Zhao, W.-H., Liu, B., Zhang, W., Rao, P.-F., & Lv, X.-C. (2021). Microbial diversity and flavor of Chinese rice wine (Huangjiu): An overview of current research and future prospects. *Current Opinion in Food Science*, 42, 37-50. <https://doi.org/10.1016/j.cofs.2021.02.017>
- Chen, L., Ren, L., Li, D., & Ma, X. (2021). Analysis of microbiomes in three traditional starters and volatile components of the Chinese rice wines. *Food Science and Biotechnology*, 30, 87-96. <https://doi.org/10.1007/s10068-020-00839-y>
- Chen, L., Wang, S., Ren, L., Li, D., Ma, X., & Rong, Y. (2021). Flavour characteristics of rice wine fermented with mixed starter by moulds and yeast strains. *International Journal of Food Science & Technology*, 56(11), 5791-5798. <https://doi.org/10.1111/ijfs.15126>
- Chen, T., Wu, F., Guo, J., Ye, M., Hu, H., Guo, J., & Liu, X. (2020). Effects of glutinous rice protein components on the volatile substances and sensory properties of Chinese rice wine. *Journal of the Science of Food and Agriculture*, 100(8), 3297-3307. <https://doi.org/10.1002/jsfa.10343>
- Chessum, K. J., Chen, T., Hamid, N., & Kam, R. (2022). A comprehensive chemical analysis of New Zealand honeydew honey. *Food Research International*, 157. <https://doi.org/10.1016/j.foodres.2022.111436>
- Chocarro Eguaras, R., Elorz Domezain, M., & Miguel Múgica Grijalba, J. (2012). Consumers' internal categorization structures: an additive tree analysis. *European Journal of Marketing*, 46(6), 760-789. <https://doi.org/10.1108/03090561211214591>
- Chocarro, R., Cortiñas, M., & Elorz, M. (2009). The impact of product category knowledge on consumer use of extrinsic cues—A study involving agrifood products. *Food Quality and Preference*, 20(3), 176-186. <https://doi.org/10.1016/j.foodqual.2008.09.004>
- Choe, S. Y., & Hong, J. H. (2018). Can information positively influence familiarity and acceptance of a novel ethnic food? A case study of Korean traditional foods for Malaysian consumers. *Journal of Sensory Studies*, 33(3), e12327. <https://doi.org/10.1111/joss.12327>
- Choi, H.-C., Hong, H.-C., Kim, Y.-G., & Nahm, B.-H. (1999). Varietal variations in physicochemical characteristics and amylopectin structure of grain in glutinous rice. *Korean Journal of Crop Science*, 44(3), 207-213.
- Choi, J.-S., Seo, H. J., Lee, Y.-R., Kwon, S.-J., Moon, S. H., Park, S.-M., & Sohn, J. H. (2014). Characteristics and in vitro anti-diabetic properties of the Korean rice wine, makgeolli fermented with *Laminaria japonica*. *Preventive Nutrition and Food Science*, 19(2), 98. <https://doi.org/10.3746/pnf.2014.19.2.098>
- Choi, J. S., Jeong, S. T., Lee, H. S., Lee, B.-H., & Kim, S. M. (2019). Biogenic amine production of makgeollis with controlled alcohol concentrations. *Food Science and Biotechnology*, 28(3), 923-930. <https://doi.org/10.1007/s10068-018-0517-8>
- Choi, K.-T., Lee, S.-H., Kim, Y.-J., Choi, J.-S., & Lee, S.-B. (2024). Improvement of volatile aromatic compound levels and sensory quality of distilled soju derived from *Saccharomyces cerevisiae* and *Wickerhamomyces anomalus* co-fermentation. *Food Chemistry: X*, 101368. <https://doi.org/10.1016/j.fochx.2024.101368>

- Choi, Y.-J., Dhungana, S. K., & Kim, I.-D. (2018). Eastern Prickly Pear (*Opuntia humifusa* Raf.) Power Enhanced the Quality of Korean Traditional Wine, Takju. *International Journal of Sciences*, 7(07), 12-16. <https://doi.org/10.18483/ijSci.1750>
- Chow, P. S., & Landhäusser, S. M. (2004). A method for routine measurements of total sugar and starch content in woody plant tissues. *Tree Physiology*, 24(10), 1129-1136. <https://doi.org/10.1093/treephys/24.10.1129>
- Crofton, E., Murray, N., & Botinestean, C. (2021). Exploring the effects of immersive virtual reality environments on sensory perception of beef steaks and chocolate. *Foods*, 10(6). <https://doi.org/10.3390/foods10061154>
- Danner, L., Johnson, T. E., Ristic, R., Meiselman, H. L., & Bastian, S. E. (2020). Consumption context effects on fine wine consumer segments' liking and emotions. *Foods*, 9(12), 1798. <https://doi.org/10.3390/foods9121798>
- Danner, L., Ristic, R., Johnson, T. E., Meiselman, H. L., Hoek, A. C., Jeffery, D. W., & Bastian, S. E. (2016). Context and wine quality effects on consumers' mood, emotions, liking and willingness to pay for Australian Shiraz wines. *Food Research International*, 89, 254-265. <https://doi.org/10.1016/j.foodres.2016.08.006>
- Das, T., Subramanian, R., Chakkaravarthi, A., Singh, V., Ali, S., & Bordoloi, P. (2006). Energy conservation in domestic rice cooking. *Journal of Food Engineering*, 75(2), 156-166. <https://doi.org/10.1016/j.jfoodeng.2005.04.005>
- Davis, M. A., Signes-Pastor, A. J., Argos, M., Slaughter, F., Pendergrast, C., Punshon, T., Gossai, A., Ahsan, H., & Karagas, M. R. (2017). Assessment of human dietary exposure to arsenic through rice. *Science of the Total Environment*, 586, 1237-1244. <https://doi.org/10.1016/j.scitotenv.2017.02.119>
- de Andrade, J. C., Nalério, É. S., Giongo, C., de Barcellos, M. D., Ares, G., & Deliza, R. (2016). Influence of evoked contexts on rating-based conjoint analysis: Case study with lamb meat. *Food Quality and Preference*, 53, 168-175. <https://doi.org/10.1016/j.foodqual.2016.06.013>
- De Beer, D., Joubert, E., Gelderblom, W. C., & Manley, M. (2003). Antioxidant activity of South African red and white cultivar wines: free radical scavenging. *Journal of Agricultural and Food Chemistry*, 51(4), 902-909. <https://doi.org/10.1021/jf026011o>
- De Saldamando, L., Antúnez, L., Torres-moreno, M., Giménez, A., & Ares, G. (2015). Reliability of polarized projective mapping with consumers. *Journal of Sensory Studies*, 30(4), 280-294. <https://doi.org/10.1111/joss.12156>
- Desmet, P. M., & Schifferstein, H. N. (2008). Sources of positive and negative emotions in food experience. *Appetite*, 50(2-3), 290-301. <https://doi.org/10.1016/j.appet.2007.08.003>
- Diep, T. T., Yoo, M. J. Y., Pook, C., Sadooghy-Saraby, S., Gite, A., & Rush, E. (2021). Volatile components and preliminary antibacterial activity of tamarillo (*Solanum betaceum* Cav.). *Foods*, 10(9). <https://doi.org/10.3390/foods10092212>
- Dinnella, C., Pierguidi, L., Spinelli, S., Borgogno, M., Toschi, T. G., Predieri, S., Lavezzi, G., Trapani, F., Tura, M., & Magli, M. (2022). Remote testing: Sensory test during Covid-19 pandemic and beyond. *Food Quality and Preference*, 96. <https://doi.org/10.1016/j.foodqual.2021.104437>
- Dorado, R., Chaya, C., Tarrega, A., & Hort, J. (2016). The impact of using a written scenario when measuring emotional response to beer. *Food Quality and Preference*, 50, 38-47. <https://doi.org/10.1016/j.foodqual.2016.01.004>

- Durand, R., & Khaire, M. (2017). Where do market categories come from and how? Distinguishing category creation from category emergence. *Journal of Management*, 43(1), 87-110. <https://doi.org/10.1177/0149206316669812>
- Ellis, D., & Caruana, A. (2018). Consumer wine knowledge: Components and segments. *International Journal of Wine Business Research*, 30(3), 277-291. <https://doi.org/10.1108/IJWBR-03-2017-0016>
- Ellis, D., & Mattison Thompson, F. (2018). The effect of wine knowledge type on variety seeking behavior in wine purchasing. *Journal of Wine Research*, 29(2), 71-86. <https://doi.org/10.1080/09571264.2018.1471393>
- Eom, J.-E., Kwon, S.-C., & Moon, G.-S. (2012). Detection of 1, 4-dihydroxy-2-naphthoic acid from commercial *Makgeolli* products. *Preventive Nutrition and Food Science*, 17(1), 83-86. <https://doi.org/10.3746/pnf.2012.17.1.083>
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G\* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39(2), 175-191. <https://doi.org/10.3758/BF03193146>
- Fleming, E. E., Ziegler, G. R., & Hayes, J. E. (2015). Check-all-that-apply (CATA), sorting, and polarized sensory positioning (PSP) with astringent stimuli. *Food Quality and Preference*, 45, 41-49. <https://doi.org/10.1016/j.foodqual.2015.05.004>
- Flynn, L. R., & Goldsmith, R. E. (1999). A short, reliable measure of subjective knowledge. *Journal of Business Research*, 46(1), 57-66. [https://doi.org/10.1016/S0148-2963\(98\)00057-5](https://doi.org/10.1016/S0148-2963(98)00057-5)
- Forbes, S. L., Cohen, D. A., & Dean, D. L. (2008, 17-19 July). *An assessment of wine knowledge amongst global consumers* 4th International Conference of the Academy of Wine Business Research, Siena, Italy.
- Freire, A. L., Ramos, C. L., da Costa Souza, P. N., Cardoso, M. G. B., & Schwan, R. F. (2017). Nondairy beverage produced by controlled fermentation with potential probiotic starter cultures of lactic acid bacteria and yeast. *International Journal of Food Microbiology*, 248, 39-46. <https://doi.org/10.1016/j.ijfoodmicro.2017.02.011>
- Gambetta, J. M., Bastian, S. E., Cozzolino, D., & Jeffery, D. W. (2014). Factors influencing the aroma composition of chardonnay wines. *Journal of Agricultural and Food Chemistry*, 62(28), 6512-6534. <https://doi.org/10.1021/jf501945s>
- Golledge, R. (1963). The New Zealand brewing industry. *New Zealand Geographer*, 19(1), 7-24. <https://doi.org/10.1111/j.1745-7939.1963.tb00081.x>
- Goode, M. R., Dahl, D. W., & Moreau, C. P. (2013). Innovation aesthetics: The relationship between category cues, categorization certainty, and newness perceptions. *Journal of Product Innovation Management*, 30(2), 192-208. <https://doi.org/10.1111/j.1540-5885.2012.00995.x>
- Green, J. A., Parr, W. V., Breitmeyer, J., Valentin, D., & Sherlock, R. (2011). Sensory and chemical characterisation of Sauvignon blanc wine: Influence of source of origin. *Food Research International*, 44(9), 2788-2797. <https://doi.org/10.1016/j.foodres.2011.06.005>
- Gregan-Paxton, J., Hibbard, J. D., Brunel, F. F., & Azar, P. (2002). "So that's what that is": Examining the impact of analogy on consumers' knowledge development for really new products. *Psychology & Marketing*, 19(6), 533-550. <https://doi.org/10.1002/mar.10023>
- Guerrini, L., Corti, F., Angeloni, G., Masella, P., Spadi, A., Calamai, L., & Parenti, A. (2022). The effects of destemming/crushing and pressing conditions in rose wine production. *Australian Journal of Grape and Wine Research*, 2022. <https://doi.org/10.1155/2022/9853264>

- Guo, L., Zhang, J., Hu, J., Li, X., & Du, X. (2015). Susceptibility of glutinous rice starch to digestive enzymes. *Carbohydrate Polymers*, *128*, 154-162. <https://doi.org/10.1016/j.carbpol.2015.04.008>
- Hazelwood, L. A., Daran, J.-M., Van Maris, A. J., Pronk, J. T., & Dickinson, J. R. (2008). The Ehrlich pathway for fusel alcohol production: a century of research on *Saccharomyces cerevisiae* metabolism. *Applied and Environmental Microbiology*, *74*(8), 2259-2266. <https://doi.org/10.1128/AEM.02625-07>
- Hein, K. A., Hamid, N., Jaeger, S. R., & Delahunty, C. M. (2010). Application of a written scenario to evoke a consumption context in a laboratory setting: Effects on hedonic ratings. *Food Quality and Preference*, *21*(4), 410-416. <https://doi.org/10.1016/j.foodqual.2009.10.003>
- Hein, K. A., Hamid, N., Jaeger, S. R., & Delahunty, C. M. (2012). Effects of evoked consumption contexts on hedonic ratings: A case study with two fruit beverages. *Food Quality and Preference*, *26*(1), 35-44. <https://doi.org/10.1016/j.foodqual.2012.02.014>
- Heo, J., Kwak, H. S., Kim, M., Kim, J.-H., Baek, H. H., Shin, H., Lee, Y.-s., Lee, S., & Kim, S. S. (2020). Major sensory attributes and volatile compounds of Korean rice liquor (yakju) affecting overall acceptance by young consumers. *Foods*, *9*(6). <https://doi.org/10.3390/foods9060722>
- Hernández, L., Afonso, D., Rodríguez, E. M., & Díaz, C. (2011). Phenolic compounds in wheat grain cultivars. *Plant Foods for Human Nutrition*, *66*, 408-415. <https://doi.org/10.1007/s11130-011-0261-1>
- Hersleth, M., Monteleone, E., Segtnan, A., & Næs, T. (2015). Effects of evoked meal contexts on consumers' responses to intrinsic and extrinsic product attributes in dry-cured ham. *Food Quality and Preference*, *40*, 191-198. <https://doi.org/10.1016/j.foodqual.2014.10.002>
- Holthuysen, N. T., Vrijhof, M. N., de Wijk, R. A., & Kremer, S. (2017). "Welcome on board": Overall liking and just-about-right ratings of airplane meals in three different consumption contexts—laboratory, re-created airplane, and actual airplane. *Journal of Sensory Studies*, *32*(2), e12254. <https://doi.org/10.1111/joss.12254>
- Hong, J., Park, H., Chung, S., Chung, L., Cha, S., Lê, S., & Kim, K. (2014). Effect of familiarity on a cross-cultural acceptance of a sweet ethnic food: a case study with Korean traditional cookie (Yackwa). *Journal of Sensory Studies*, *29*(2), 110-125. <https://doi.org/10.1111/joss.12087>
- Hopfer, H., & Heymann, H. (2013). A summary of projective mapping observations—The effect of replicates and shape, and individual performance measurements. *Food Quality and Preference*, *28*(1), 164-181. <https://doi.org/10.1016/j.foodqual.2012.08.017>
- Horita, C., Esmerino, E., Vidal, V., Farah, J., Amaral, G., Bolini, H., Cruz, A., & Pollonio, M. (2017). Sensory profiling of low sodium frankfurter containing garlic products: Adequacy of Polarized Projective Mapping compared with trained panel. *Meat Science*, *131*, 90-98. <https://doi.org/10.1016/j.meatsci.2017.05.002>
- Ivanišová, E., Kačániová, M., Petrová, J., Frančáková, H., & Tokár, M. (2016). The evaluation of antioxidant and antimicrobial effect of *Tussilago farfara* L. and *Cetraria islandica* L. *Scientific Papers Animal Science and Biotechnologies*, *49*(2), 46-46.
- Jaeger, S. R., Cardello, A. V., Chheang, S. L., Beresford, M. K., Hedderley, D. I., & Pineau, B. (2017). Holistic and consumer-centric assessment of beer: A multi-measurement approach. *Food Research International*, *99*, 287-297. <https://doi.org/10.1016/j.foodres.2017.05.004>
- Jaeger, S. R., Danaher, P. J., & Brodie, R. J. (2009). Wine purchase decisions and consumption behaviours: Insights from a probability sample drawn in Auckland, New Zealand. *Food Quality and Preference*, *20*(4), 312-319. <https://doi.org/10.1016/j.foodqual.2009.02.003>

- Jaeger, S. R., & Porcherot, C. (2017). Consumption context in consumer research: Methodological perspectives. *Current Opinion in Food Science*, 15, 30-37. <https://doi.org/10.1016/j.cofs.2017.05.001>
- Jaeger, S. R., Worch, T., Phelps, T., Jin, D., & Cardello, A. V. (2020). Preference segments among declared craft beer drinkers: Perceptual, attitudinal and behavioral responses underlying craft-style vs. traditional-style flavor preferences. *Food Quality and Preference*, 82, 103884. <https://doi.org/10.1016/j.foodqual.2020.103884>
- Jaeger, S. R., Xia, Y., Le Blond, M., Beresford, M. K., Hedderley, D. I., & Cardello, A. V. (2019). Supplementing hedonic and sensory consumer research on beer with cognitive and emotional measures, and additional insights via consumer segmentation. *Food Quality and Preference*, 73, 117-134. <https://doi.org/10.1016/j.foodqual.2018.11.015>
- Jang, S. H., Kim, M. J., Lim, J., & Hong, J. H. (2016). Cross-cultural comparison of consumer acceptability of kimchi with different degree of fermentation. *Journal of Sensory Studies*, 31(2), 124-134. <https://doi.org/10.1111/joss.12198>
- Jeon, B. Y., Seo, H. N., Yun, A., Lee, I. H., & Park, D. H. (2010). Effect of glasswort (*Salicornia herbacea* L.) on *Nuruk*-making process and *Makgeolli* quality. *Food Science and Biotechnology*, 19(4), 999-1004. <https://doi.org/10.1007/s10068-010-0140-9>
- Jeon, E. B., Song, M. G., Kim, S. H., Choi, J. S., Lee, J. S., & Park, S. Y. (2023). Quality characteristics and antioxidant activities of Korean traditional rice and quinoa-based wine “Makgeolli”. *Cereal Chemistry*, 100(2), 473-483. <https://doi.org/10.1002/cche.10626>
- Jeong, Y.-H. (2011). Physicochemical and microbial properties of Korean traditional rice wine, makgeolli, supplemented with black garlic extracts during fermentation. *Journal of Food Science and Nutrition*, 16, 142-149. <https://doi.org/10.3746/jfn.2011.16.2.142>
- Johnson, K. (2023). *Auckland storm event 9 May 2023, rapid analysis*. Auckland Council. <https://knowledgeauckland.org.nz/publications/auckland-storm-event-9-may-2023-rapid-analysis/>
- Johnson, T. E., Hasted, A., Ristic, R., & Bastian, S. E. (2013). Multidimensional scaling (MDS), cluster and descriptive analyses provide preliminary insights into Australian Shiraz wine regional characteristics. *Food Quality and Preference*, 29(2), 174-185. <https://doi.org/10.1016/j.foodqual.2013.03.010>
- Josse, J., Pagès, J., & Husson, F. (2008). Testing the significance of the RV coefficient. *Computational Statistics & Data Analysis*, 53(1), 82-91. <https://doi.org/10.1016/j.csda.2008.06.012>
- Juliano, B. O., & Perez, C. M. (1983). Major factors affecting cooked milled rice hardness and cooking time. *Journal of Texture Studies*, 14(3), 235-243. <https://doi.org/10.1111/j.1745-4603.1983.tb00346.x>
- Jung, H., Lee, S.-J., Lim, J. H., Kim, B. K., & Park, K. J. (2014). Chemical and sensory profiles of makgeolli, Korean commercial rice wine, from descriptive, chemical, and volatile compound analyses. *Food Chemistry*, 152, 624-632. <https://doi.org/10.1016/j.foodchem.2013.11.127>
- Kang, B. S., Lee, J.-E., & Park, H.-J. (2014a). Electronic tongue-based discrimination of Korean rice wines (makgeolli) including prediction of sensory evaluation and instrumental measurements. *Food Chemistry*, 151, 317-323. <https://doi.org/10.1016/j.foodchem.2013.11.084>
- Kang, B. S., Lee, J. E., & Park, H. J. (2014b). Qualitative and quantitative prediction of volatile compounds from initial amino acid profiles in Korean rice wine (makgeolli) model. *Journal of Food Science*, 79(6), C1106-C1116. <https://doi.org/10.1111/1750-3841.12489>

- Kang, H.-R., Hwang, H.-J., Lee, J. E., & Kim, H. R. (2016). Quantitative analysis of volatile flavor components in Korean alcoholic beverage and Japanese sake using SPME-GC/MS. *Food Science and Biotechnology*, 25(4), 979-985. <https://doi.org/10.1007/s10068-016-0159-7>
- Kang, J.-E., Choi, H.-S., Kim, J.-W., Kim, C.-W., Yeo, S.-W., & Jung, S.-T. (2016). Quality characteristics of yakju with nuruk extracts. *Korean Journal of Food Science and Technology*, 48(3), 223-230. <https://doi.org/10.9721/KJFST.2016.48.3.223>
- Kang, M.-Y., Rico, C. W., & Lee, S.-C. (2010). Physicochemical properties of eight popular glutinous rice varieties in Korea. *Plant Production Science*, 13(2), 177-184. <https://doi.org/10.1626/pps.13.177>
- Kang, S.-., Kwon, Y.-s., Jeong, S.-t., Choi, H.-s., Im, B.-r., Yeo, S.-h., & Kang, J.-e. (2020). Physicochemical characteristics of beer with rice nuruk. *Journal of Applied Biological Chemistry*, 63(3), 229-234. <https://doi.org/10.3839/jabc.2020.031>
- Kennedy, J. (2010). Evaluation of replicated projective mapping of granola bars. *Journal of Sensory Studies*, 25(5), 672-684. <https://doi.org/10.1111/j.1745-459X.2010.00302.x>
- Kim, D., Park, S.-E., Kim, E.-J., Kim, H.-W., Seo, S.-H., Whon, T. W., Roh, S. W., & Son, H.-S. (2023). Effects of sediment and temperature on the long-term aging process of rice wine: Microbial and metabolic insights. *Food Research International*, 174, 113604. <https://doi.org/10.1016/j.foodres.2023.113604>
- Kim, E., Chang, Y. H., Ko, J. Y., & Jeong, Y. (2013). Physicochemical and microbial properties of the Korean traditional rice wine, Makgeolli, supplemented with banana during fermentation. *Preventive Nutrition and Food Science*, 18(3), 203-209. <https://doi.org/10.3746/pnf.2013.18.3.203>
- Kim, H.-R., Lee, A. R., Kim, J.-H., & Ahn, B.-H. (2012). Microbial dynamics of commercial makgeolli depending on the storage temperature. *Journal of Microbiology and Biotechnology*, 22(8), 1101-1106. <https://doi.org/10.4014/jmb.1112.12063>
- Kim, J. Y., Kim, D., Park, P., Kang, H.-I., Ryu, E. K., & Kim, S. M. (2011). Effects of storage temperature and time on the biogenic amine content and microflora in Korean turbid rice wine, Makgeolli. *Food Chemistry*, 128(1), 87-92. <https://doi.org/10.1016/j.foodchem.2011.02.081>
- Kim, M.-O., Kim, I.-D., Dhungana, S. K., Lee, J.-W., & Shin, D.-H. (2015). Influence of blueberry and black rice powders on quality characteristics of the Korean traditional rice wine Takju. *Food Science and Biotechnology*, 24(2), 439-444. <https://doi.org/10.1007/s10068-015-0058-3>
- Kim, M.-R., Kim, K.-P., & Chung, S.-J. (2019). Utilizing hedonic frame for projective mapping: A case study with Korean fermented soybean paste soup. *Food Quality and Preference*, 71, 279-285. <https://doi.org/10.1016/j.foodqual.2018.07.014>
- Kim, S., Yun, S., Jeon, S., Kim, N., Kim, H., Cho, T., Lee, S., Hwang, I., & Rhee, M. (2015). Microbial composition of turbid rice wine (Makgeolli) at different stages of production in a real processing line. *Food Control*, 53, 1-8. <https://doi.org/10.1016/j.foodcont.2015.01.002>
- Kim, Y.-S., & Kim, Y.-S. (2015). Biometrics analysis and evaluation on Korean Makgeolli using brainwaves and taste biological sensor system. *BioMed Research International*, 2015. <https://doi.org/10.1155/2015/918631>
- King, S. C., & Meiselman, H. L. (2010). Development of a method to measure consumer emotions associated with foods. *Food Quality and Preference*, 21(2), 168-177. <https://doi.org/10.1016/j.foodqual.2009.02.005>
- Kirk, R. E. (1996). Practical significance: A concept whose time has come. *Educational and Psychological Measurement*, 56(5), 746-759. <https://doi.org/10.1177/0013164496056005002>

- Kondrashov, A., Ševčík, R., Benáková, H., Košťířová, M., & Štípek, S. (2009). The key role of grape variety for antioxidant capacity of red wines. *e-SPEN, the European e-Journal of Clinical Nutrition and Metabolism*, 4(1), e41-e46. <https://doi.org/10.1016/j.eclnm.2008.10.004>
- Köster, E. P. (2003). The psychology of food choice: some often encountered fallacies. *Food Quality and Preference*, 14(5-6), 359-373. [https://doi.org/10.1016/S0950-3293\(03\)00017-X](https://doi.org/10.1016/S0950-3293(03)00017-X)
- Köster, E. P. (2009). Diversity in the determinants of food choice: A psychological perspective. *Food Quality and Preference*, 20(2), 70-82. <https://doi.org/10.1016/j.foodqual.2007.11.002>
- Köster, E. P., & Mojet, J. (2015). From mood to food and from food to mood: A psychological perspective on the measurement of food-related emotions in consumer research. *Food Research International*, 76, 180-191. <https://doi.org/10.1016/j.foodres.2015.04.006>
- Kuehn, K. M., & Parker, S. (2021). One of the blokes: Brewsters, branding and gender (in) visibility in New Zealand's craft beer industry. *Journal of Consumer Culture*, 21(3), 519-538. <https://doi.org/10.1177/1469540518806956>
- Kuijken, B., Gemser, G., & Wijnberg, N. M. (2017). Categorization and willingness to pay for new products: The role of category cues as value anchors. *Journal of Product Innovation Management*, 34(6), 757-771. <https://doi.org/10.1111/jpim.12414>
- Kukutai, T., & Callister, P. (2009). A "main" ethnic group? Ethnic self-prioritisation among New Zealand youth. *Social Policy Journal of New Zealand*(36), 16-31.
- Kustos, M., Gambetta, J. M., Jeffery, D. W., Heymann, H., Goodman, S., & Bastian, S. E. (2020). A matter of place: Sensory and chemical characterisation of fine Australian Chardonnay and Shiraz wines of provenance. *Food Research International*, 130. <https://doi.org/10.1016/j.foodres.2019.108903>
- Kwak, H. S., Ahn, B. H., Kim, H. R., & Lee, S. Y. (2015). Identification of sensory attributes that drive the likeability of Korean rice wines by American panelists. *Journal of Food Science*, 80(1), S161-S170. <https://doi.org/10.1111/1750-3841.12739>
- Kwon, S.-J., & Sohn, J.-H. (2012). Analysis of microbial diversity in Nuruk using PCR-DGGE. *Journal of Life Science*, 22(1), 110-116. <https://doi.org/10.5352/JLS.2012.22.1.110>
- Lakshmi, S., Chakkaravarthi, A., Subramanian, R., & Singh, V. (2007). Energy consumption in microwave cooking of rice and its comparison with other domestic appliances. *Journal of Food Engineering*, 78(2), 715-722. <https://doi.org/10.1016/j.jfoodeng.2005.11.011>
- Lam, H., & Proctor, A. (2003). Milled rice oxidation volatiles and odor development. *Journal of Food Science*, 68(9), 2676-2681. <https://doi.org/10.1111/j.1365-2621.2003.tb05788.x>
- Law, R. (1997). Masculinity, place, and beer advertising in New Zealand: The Southern Man campaign. *New Zealand Geographer*, 53(2), 22-28. <https://doi.org/10.1111/j.1745-7939.1997.tb00495.x>
- Lawless, H., & Glatter, S. (1990). Consistency of multidimensional scaling models derived from odor sorting. *Journal of Sensory Studies*, 5(4), 217-230. <https://doi.org/10.1111/j.1745-459X.1990.tb00492.x>
- Lawless, H. T. (2013). *Quantitative Sensory Analysis: Psychophysics, Models and Intelligent Design*. John Wiley & Sons.
- Lawless, H. T., & Heymann, H. (2010). Introduction. In *Sensory Evaluation of food: Principles and practices* (pp. 1-18). Springer Science & Business Media. [https://doi.org/10.1007/978-1-4419-6488-5\\_1](https://doi.org/10.1007/978-1-4419-6488-5_1)

- Lê, S., & Husson, F. (2008). Sensominer: A package for sensory data analysis. *Journal of Sensory Studies*, 23(1), 14-25. <https://doi.org/10.1111/j.1745-459X.2007.00137.x>
- Lê, S., Josse, J., & Husson, F. (2008). FactoMineR: an R package for multivariate analysis. *Journal of Statistical Software*, 25(1), 1-18. <https://doi.org/10.18637/jss.v025.i01>
- Lee, C.-H. (2022). The History and Manufacture of Traditional Korean Alcoholic Drinks. In C.-H. Lee (Ed.), *Korean Food and Foodways: The Root of Health Functional Food* (pp. 207-240). Springer. [https://doi.org/10.1007/978-981-19-0023-5\\_9](https://doi.org/10.1007/978-981-19-0023-5_9)
- Lee, C. W., & Lves, M. (2022). *This ancient brew has retro appeal in South Korea*. <https://www.nytimes.com/2022/01/20/world/asia/south-korea-makgeolli-rice-wine.html>
- Lee, H.-G. (1996). History of Traditional Korean Alcoholic Drinks. *Koreana*, 10(4), 4-9.
- Lee, J.-E., & Kim, J.-H. (2017). Concept of Nuruk on Brewing Technology. In M. Kanauchi (Ed.), *Brewing Technology* (pp. 123-134). IntechOpen. <https://doi.org/10.5772/intechopen.69380>
- Lee, J.-E., Lee, A. R., Kim, H., Lee, E., Kim, T. W., Shin, W. C., & Kim, J. H. (2017). Restoration of traditional Korean Nuruk and analysis of the brewing characteristics. *Journal of Microbiology and Biotechnology*, 27(5), 896-908. <https://doi.org/10.4014/jmb.1610.10039>
- Lee, J., Lee, Y., Ha, J., Yoo, M., & Jang, H. W. (2018). Simultaneous determination of four bioactive compounds in Korean rice wine (*makgeolli*) by solvent extraction coupled with gas chromatography-mass spectrometry. *International Journal of Food Properties*, 21(1), 139-146. <https://doi.org/10.1080/10942912.2017.1414841>
- Lee, K. Y., Han, Q. X., & Lee, H. G. (2022). Comparison of microbial inactivation and quality characteristics of Korean turbid rice wine, Makgeolli pasteurized with conventional and ohmic heating. *Journal of Food Measurement and Characterization*, 16(4), 3216-3225. <https://doi.org/10.1007/s11694-022-01431-0>
- Lee, M. G., Ham, T. H., Song, S. H., Chung, D. H., & Yoon, W. B. (2016). Effects of the high pressure homogenization on the viability of yeast cell and volatile components in non-pasteurized rice wine. *Food Science and Biotechnology*, 25(4), 1073-1080. <https://doi.org/10.1007/s10068-016-0173-9>
- Lee, N. G. (2020). Physicochemical characteristics and antioxidant activity of makgeolli. *The Journal of the Convergence on Culture Technology*, 6(4), 739-745. <https://doi.org/10.17703/JCCT.2020.6.4.739>
- Lee, S.-J., Kwon, Y.-H., Kim, H.-R., & Ahn, B.-H. (2007). Chemical and sensory characterization of Korean commercial rice wines (yakju). *Food Science and Biotechnology*, 16(3), 374-380.
- Lee, S.-m., Shin, K.-J., & Lee, S.-J. (2016). Exploring nuruk aroma; identification of volatile compounds in commercial fermentation starters. *Food Science and Biotechnology*, 25(2), 393-399. <https://doi.org/10.1007/s10068-016-0054-2>
- Lee, S., Kwak, H. S., Jung, J. y., Kim, S. S., & Lee, Y. (2021). Identifying drivers of liking for Korean traditional rice wine (Yakju) across different age groups by penalty analysis based on the CATA method. *Journal of the Institute of Brewing*, 127, 286-295. <https://doi.org/10.1002/jib.649>
- Lee, S., Kwak, H. S., Kim, S. S., & Lee, Y. (2021). Combination of the Check-All-That-Apply (CATA) Method and Just-About-Right (JAR) Scale to Evaluate Korean Traditional Rice Wine (*Yakju*). *Foods*, 10(8). <https://doi.org/10.3390/foods10081895>
- Lee, S., Yoo, M., & Shin, D. (2015). The identification and quantification of biogenic amines in Korean turbid rice wine, Makgeolli by HPLC with mass spectrometry detection. *LWT-Food Science and Technology*, 62(1), 350-356. <https://doi.org/10.1016/j.lwt.2015.01.016>

- Lee, S. J., & Lee, K. G. (2008). Understanding consumer preferences for rice wines using sensory data. *Journal of the Science of Food and Agriculture*, 88(4), 690-698. <https://doi.org/10.1002/jsfa.3137>
- Lee, Y., Kim, H., Eom, T., Kim, S.-H., Choi, G. P., Kim, M., Yu, S., & Jeong, Y. (2013). Quality characteristics of Korean traditional rice wine with glutinous rice. *Journal of the Korean Society of Food Science and Nutrition*, 42(11), 1829-1836. <https://doi.org/10.3746/JKFN.2013.42.11.1829>
- Legras, J.-L., Merdinoglu, D., Cornuet, J.-M., & Karst, F. (2007). Bread, beer and wine: *Saccharomyces cerevisiae* diversity reflects human history. *Molecular Ecology*, 16(10), 2091-2102. <https://doi.org/10.1111/j.1365-294X.2007.03266.x>
- Lelièvre, M., Chollet, S., Abdi, H., & Valentin, D. (2008). What is the validity of the sorting task for describing beers? A study using trained and untrained assessors. *Food Quality and Preference*, 19(8), 697-703. <https://doi.org/10.1016/j.foodqual.2008.05.001>
- Lentz, M. (2018). The impact of simple phenolic compounds on beer aroma and flavor. *Fermentation*, 4(1). <https://doi.org/10.3390/fermentation4010020>
- Lezaeta, A., Bordeu, E., Næs, T., & Varela, P. (2017). Exploration of consumer perception of Sauvignon Blanc wines with enhanced aroma properties using two different descriptive methods. *Food Research International*, 99, 186-197. <https://doi.org/10.1016/j.foodres.2017.05.003>
- Li, H., Yang, J., Gao, M., Wang, J., & Sun, B. (2019). Washing rice before cooking has no large effect on the texture of cooked rice. *Food Chemistry*, 271, 388-392. <https://doi.org/10.1016/j.foodchem.2018.07.172>
- Li, Y. Y., Lee, K. Y., & Lee, H. G. (2022). Effects of roasting conditions on Korean rice wine (Makgeolli) with licorice (*Glycyrrhiza uralensis* Fischer). *Food Science and Biotechnology*, 31(3), 323-332. <https://doi.org/10.1007/s10068-022-01032-z>
- Lina, G., & Min, Z. (2022). Formation and release of cooked rice aroma. *Journal of Cereal Science*, 107. <https://doi.org/10.1016/j.jcs.2022.103523>
- Lingua, M. S., Fabani, M. P., Wunderlin, D. A., & Baroni, M. V. (2016). In vivo antioxidant activity of grape, pomace and wine from three red varieties grown in Argentina: Its relationship to phenolic profile. *Journal of Functional Foods*, 20, 332-345. <https://doi.org/10.1016/j.jff.2015.10.034>
- Liu, A., Yang, X., Guo, Q., Li, B., Zheng, Y., Shi, Y., & Zhu, L. (2022). Microbial communities and flavor compounds during the fermentation of traditional Hong Qu glutinous rice wine. *Foods*, 11(8). <https://doi.org/10.3390/foods11081097>
- Liu, K., Zheng, J., & Chen, F. (2018). Effects of washing, soaking and domestic cooking on cadmium, arsenic and lead bioaccessibilities in rice. *Journal of the Science of Food and Agriculture*, 98(10), 3829-3835. <https://doi.org/10.1002/jsfa.8897>
- Liu, Y., & Jang, S. S. (2009). The effects of dining atmospherics: An extended Mehrabian–Russell model. *International Journal of Hospitality Management*, 28(4), 494-503. <https://doi.org/10.1016/j.ijhm.2009.01.002>
- Louw, L., Malherbe, S., Naes, T., Lambrechts, M., van Rensburg, P., & Nieuwoudt, H. (2013). Validation of two Napping® techniques as rapid sensory screening tools for high alcohol products. *Food Quality and Preference*, 30(2), 192-201. <https://doi.org/10.1016/j.foodqual.2013.05.016>
- Lucas, C., Iobbi, A., de Matos, A. D., & Tomasino, E. (2023). Understanding the relationship between tropical fruit aroma, acceptance, and emotional response in chardonnay wines. *Food Research International*, 174. <https://doi.org/10.1016/j.foodres.2023.113496>

- Luo, Y., Kong, L., Xue, R., Wang, W., & Xia, X. (2020). Bitterness in alcoholic beverages: The profiles of perception, constituents, and contributors. *Trends in Food Science & Technology*, *96*, 222-232. <https://doi.org/10.1016/j.tifs.2019.12.026>
- Lusk, K. A., Hamid, N., Delahunty, C. M., & Jaeger, S. R. (2015). Effects of an evoked refreshing consumption context on hedonic responses to apple juice measured using best–worst scaling and the 9-pt hedonic category scale. *Food Quality and Preference*, *43*, 21-25. <https://doi.org/10.1016/j.foodqual.2015.01.007>
- Macdonald, J. V. (2017). *Makgeolli in Seoul: Why this speciality liquor is only at its best in the South Korean capital*. Independent. <https://www.independent.co.uk/travel/asia/makgeolli-south-korea-seoul-milky-liquor-alcohol-probiotic-bars-brewery-tours-festivals-a7881366.html>
- Maeda, Y., Okuda, M., Hashizume, K., Joyo, M., Mikami, S., & Goto-Yamamoto, N. (2011). Analyses of peptides in sake mash: Forming a profile of bitter-tasting peptides. *Journal of Bioscience and Bioengineering*, *112*(3), 238-246. <https://doi.org/10.1016/j.jbiosc.2011.05.006>
- Mehrabian, A., & Russell, J. A. (1974). A verbal measure of information rate for studies in environmental psychology. *Environment and Behavior*, *6*(2), 233. <https://doi.org/10.1177/001391657400600205>
- Meiselman, H. L. (1996). The contextual basis for food acceptance, food choice and food intake: the food, the situation and the individual. In H. L. Meiselman & H. J. H. MacFie (Eds.), *Food choice, acceptance and consumption* (pp. 239-263). [https://doi.org/10.1007/978-1-4613-1221-5\\_6](https://doi.org/10.1007/978-1-4613-1221-5_6)
- Meiselman, H. L. (2015). A review of the current state of emotion research in product development. *Food Research International*, *76*, 192-199. <https://doi.org/10.1016/j.foodres.2015.04.015>
- Mervis, C. B., & Rosch, E. (1981). Categorization of natural objects. *Annual Review of Psychology*, *32*(1), 89-115. <https://doi.org/10.1146/annurev.ps.32.020181.000513>
- Mogilner, C., Rudnick, T., & Iyengar, S. S. (2008). The mere categorization effect: How the presence of categories increases choosers' perceptions of assortment variety and outcome satisfaction. *Journal of Consumer Research*, *35*(2), 202-215. <https://doi.org/10.1086/588698>
- Mohidem, N. A., Hashim, N., Shamsudin, R., & Che Man, H. (2022). Rice for food security: Revisiting its production, diversity, rice milling process and nutrient content. *Agriculture*, *12*(6). <https://doi.org/10.3390/agriculture12060741>
- Monsoor, M., & Proctor, A. (2002). Effect of water washing on the reduction of surface total lipids and FFA on milled rice. *Journal of the American Oil Chemists' Society*, *79*, 867-870. <https://doi.org/10.1007/s11746-002-0571-x>
- Mouret, M., Monaco, G. L., Urdapilleta, I., & Parr, W. V. (2013). Social representations of wine and culture: A comparison between France and New Zealand. *Food Quality and Preference*, *30*(2), 102-107. <https://doi.org/10.1016/j.foodqual.2013.04.014>
- Munteanu, I. G., & Apetrei, C. (2021). Analytical methods used in determining antioxidant activity: A review. *International Journal of Molecular Sciences*, *22*(7). <https://doi.org/10.3390/ijms22073380>
- Murray, J., Delahunty, C., & Baxter, I. (2001). Descriptive sensory analysis: past, present and future. *Food Research International*, *34*(6), 461-471. [https://doi.org/10.1016/S0963-9969\(01\)00070-9](https://doi.org/10.1016/S0963-9969(01)00070-9)
- Murray, W. E., & Overton, J. (2016). Fictive clusters: Crafty strategies in the New Zealand beer industry. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography*, *70*(3), 176-189. <https://doi.org/10.1080/00291951.2016.1177587>

- Muthayya, S., Sugimoto, J. D., Montgomery, S., & Maberly, G. F. (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences*, 1324(1), 7-14. <https://doi.org/10.1111/nyas.12540>
- Narayanan, P., Chinnasamy, B., Jin, L., & Clark, S. (2014). Use of just-about-right scales and penalty analysis to determine appropriate concentrations of stevia sweeteners for vanilla yogurt. *Journal of Dairy Science*, 97(6), 3262-3272. <https://doi.org/10.3168/jds.2013-7365>
- Navas-Acien, A., & Nachman, K. E. (2013). Public Health Responses to Arsenic in Rice and Other Foods. *JAMA Internal Medicine*, 175(15), 1395-1396. <https://doi.org/10.1001/jamainternmed.2013.6405>
- Nestrud, M. A., & Lawless, H. T. (2008). Perceptual mapping of citrus juices using projective mapping and profiling data from culinary professionals and consumers. *Food Quality and Preference*, 19(4), 431-438. <https://doi.org/10.1016/j.foodqual.2008.01.001>
- Nijman, M., James, S., Dehrmann, F., Smart, K., Ford, R., & Hort, J. (2019). The effect of consumption context on consumer hedonics, emotional response and beer choice. *Food Quality and Preference*, 74, 59-71. <https://doi.org/10.1016/j.foodqual.2019.01.011>
- Nile, S. H. (2015). The nutritional, biochemical and health effects of makgeolli—a traditional Korean fermented cereal beverage. *Journal of the Institute of Brewing*, 121(4), 457-463. <https://doi.org/10.1002/jib.264>
- Okuda, M. (2019). Rice used for Japanese sake making. *Bioscience, Biotechnology, and Biochemistry*, 83(8), 1428-1441. <https://doi.org/10.1080/09168451.2019.1574552>
- Oladokun, O., Tarrega, A., James, S., Smart, K., Hort, J., & Cook, D. (2016). The impact of hop bitter acid and polyphenol profiles on the perceived bitterness of beer. *Food Chemistry*, 205, 212-220. <https://doi.org/10.1016/j.foodchem.2016.03.023>
- Ozanne, J. L., Brucks, M., & Grewal, D. (1992). A study of information search behavior during the categorization of new products. *Journal of Consumer Research*, 18(4), 452-463. <https://doi.org/10.1086/209273>
- Özyürek, M., Güçlü, K., & Apak, R. (2011). The main and modified CUPRAC methods of antioxidant measurement. *TrAC Trends in Analytical Chemistry*, 30(4), 652-664. <https://doi.org/10.1016/j.trac.2010.11.016>
- Pagès, J. (2005). Collection and analysis of perceived product inter-distances using multiple factor analysis: Application to the study of 10 white wines from the Loire Valley. *Food Quality and Preference*, 16(7), 642-649. <https://doi.org/10.1016/j.foodqual.2005.01.006>
- Pagès, J., Cadoret, M., & Lê, S. (2010). The sorted napping: A new holistic approach in sensory evaluation. *Journal of Sensory Studies*, 25(5), 637-658. <https://doi.org/10.1111/j.1745-459X.2010.00292.x>
- Park, E. H., Jeon, E. B., & Park, S. Y. (2024). Quality Characteristics and Antioxidant Activity of the Korean Traditional Rice-Oat Wine “Makgeolli” Supplemented with *Codium fragile*, a Green Seaweed. <https://doi.org/10.20944/preprints202401.0353.v1>
- Park, H.-J., Lee, S. M., Song, S. H., & Kim, Y.-S. (2013). Characterization of volatile components in Makgeolli, a traditional Korean rice wine, with or without pasteurization, during storage. *Molecules*, 18, 5317-5325. <https://doi.org/10.3390/molecules18055317>
- Park, H.-Y., Choi, I., Oh, S. K., Woo, K. S., Yoon, S. D., Kim, H.-J., Sim, E.-Y., & Jeong, S. T. (2015). Effects of different cultivars and milling degrees on quality characteristics of barley Makgeolli. *Journal of the Korean Society of Food Science and Nutrition*, 44(12), 1839-1846. <https://doi.org/10.3746/jkfn.2015.44.12.1839>

- Park, H. J., Ko, J. M., Lim, J., & Hong, J. H. (2020). American consumers' perception and acceptance of an ethnic food with strong flavor: a case study of Kimchi with varying levels of red pepper and fish sauce. *Journal of the Science of Food and Agriculture*, 100(6), 2348-2357. <https://doi.org/10.1002/jsfa.10106>
- Park, J.-S., Song, S. H., Choi, J. B., Kim, Y.-S., Kwon, S.-H., & Park, Y.-S. (2014). Physicochemical properties of Korean rice wine (Makgeolli) fermented using yeasts isolated from Korean traditional nuruk, a starter culture. *Food Science and Biotechnology*, 23(5), 1577-1585. <https://doi.org/10.1007/s10068-014-0214-1>
- Park, S., Heo, J., Oh, J., Chung, S.-J., & Kwak, H. S. (2023). Consumer testing away from a sensory facility: Application of home-use test and no-contact home-use test. *Food Quality and Preference*, 109, 104905. <https://doi.org/10.1016/j.foodqual.2023.104905>
- Parr, W. V., Green, J. A., White, K. G., & Sherlock, R. R. (2007). The distinctive flavour of New Zealand Sauvignon blanc: Sensory characterisation by wine professionals. *Food Quality and Preference*, 18(6), 849-861. <https://doi.org/10.1016/j.foodqual.2007.02.001>
- Peeters, M. J. (2016). Practical significance: Moving beyond statistical significance. *Currents in Pharmacy Teaching and Learning*, 8(1), 83-89. <https://doi.org/10.1016/j.cptl.2015.09.001>
- Piggott, J., Morrison, W., & Clyne, J. (1991). Changes in lipids and in sensory attributes on storage of rice milled to different degrees. *International Journal of Food Science & Technology*, 26(6), 615-628. <https://doi.org/10.1111/j.1365-2621.1991.tb02007.x>
- Piqueras-Fiszman, B., & Jaeger, S. R. (2014). The impact of evoked consumption contexts and appropriateness on emotion responses. *Food Quality and Preference*, 32, 277-288. <https://doi.org/10.1016/j.foodqual.2013.09.002>
- Pires, E. J., Teixeira, J. A., Brányik, T., & Vicente, A. A. (2014). Yeast: The soul of beer's aroma—A review of flavour-active esters and higher alcohols produced by the brewing yeast. *Applied Microbiology and Biotechnology*, 98, 1937-1949. <https://doi.org/10.1007/s00253-013-5470-0>
- Poitevin, E. (2019). Official methods for the determination of minerals and trace elements in infant formula and milk products: A Review. *Journal of AOAC International*, 99(1), 42-52. <https://doi.org/10.5740/jaoacint.15-0246>
- Pramudya, R. C., & Seo, H.-S. (2018). Using Check-All-That-Apply (CATA) method for determining product temperature-dependent sensory-attribute variations: A case study of cooked rice. *Food Research International*, 105, 724-732. <https://doi.org/10.1016/j.foodres.2017.11.075>
- Quinde-Axtell, Z., & Baik, B.-K. (2006). Phenolic compounds of barley grain and their implication in food product discoloration. *Journal of Agricultural and Food Chemistry*, 54(26), 9978-9984. <https://doi.org/10.1021/jf060974w>
- Reed, M. O., Ai, Y., Leutcher, J. L., & Jane, J. I. (2013). Effects of cooking methods and starch structures on starch hydrolysis rates of rice. *Journal of Food Science*, 78(7). <https://doi.org/10.1111/1750-3841.12165>
- Rice-Evans, C., Miller, N., & Paganga, G. (1997). Antioxidant properties of phenolic compounds. *Trends in Plant Science*, 2(4), 152-159. [https://doi.org/10.1016/S1360-1385\(97\)01018-2](https://doi.org/10.1016/S1360-1385(97)01018-2)
- Rinaldi, A., Vecchio, R., & Moio, L. (2021). Differences in astringency subqualities evaluated by consumers and trained assessors on Sangiovese wine using check-all-that-apply (CATA). *Foods*, 10(2), 218. <https://doi.org/10.3390/foods10020218>

- Rousta, N., Hellwig, C., Wainaina, S., Lukitawesa, L., Agnihotri, S., Rousta, K., & Taherzadeh, M. J. (2021). Filamentous fungus *Aspergillus oryzae* for food: From submerged cultivation to fungal burgers and their sensory evaluation—A pilot study. *Foods*, *10*(11). <https://doi.org/10.3390/foods10112774>
- Rudnitskaya, A., Nieuwoudt, H. H., Muller, N., Legin, A., Du Toit, M., & Bauer, F. F. (2010). Instrumental measurement of bitter taste in red wine using an electronic tongue. *Analytical and Bioanalytical Chemistry*, *397*, 3051-3060. <https://doi.org/10.1007/s00216-010-3885-3>
- Ruvio, A., Shoham, A., & Brenčič, M. M. (2008). Consumers' need for uniqueness: short-form scale development and cross-cultural validation. *International Marketing Review*, *25*(1), 33-53. <https://doi.org/10.1108/02651330810851872>
- Ryu, K., & Jang, S. S. (2007). The effect of environmental perceptions on behavioral intentions through emotions: The case of upscale restaurants. *Journal of Hospitality & Tourism Research*, *31*(1), 56-72. <https://doi.org/10.1177/1096348006295506>
- Saerens, S., Delvaux, F., Verstrepen, K., Van Dijck, P., Thevelein, J., & Delvaux, F. (2008). Parameters affecting ethyl ester production by *Saccharomyces cerevisiae* during fermentation. *Applied and Environmental Microbiology*, *74*(2), 454-461. <https://doi.org/10.1128/AEM.01616-07>
- Salazar, C., Armenta, J. M., & Shulaev, V. (2012). An UPLC-ESI-MS/MS assay using 6-aminoquinolyl-N-hydroxysuccinimidyl carbamate derivatization for targeted amino acid analysis: application to screening of *Arabidopsis thaliana* mutants. *Metabolites*, *2*(3), 398-428. <https://doi.org/10.3390/metabo2030398>
- Schlich, P., & Guichard, E. (1989). Selection and classification of volatile compounds of apricot using the RV coefficient. *Journal of Agricultural and Food Chemistry*, *37*(1), 142-150.
- Seo, H.-S., Buffin, K., Singh, A., Beekman, T. L., & Arroyo, S. E. J. (2021). Stay safe in your vehicle: Drive-in booths can be an alternative to indoor booths for laboratory sensory testing. *Food Quality and Preference*, *94*. <https://doi.org/10.1016/j.foodqual.2021.104332>
- Seo, S.-H., Park, S.-E., Yoo, S.-A., Lee, K. I., Na, C.-S., & Son, H.-S. (2016). Metabolite profiling of Makgeolli for the understanding of yeast fermentation characteristics during fermentation and aging. *Process Biochemistry*, *51*(10), 1363-1373. <https://doi.org/10.1016/j.procbio.2016.08.005>
- Shi, M., Stelick, A., Licker, S., & Dando, R. (2021). On the validity of longitudinal comparisons of central location consumer testing results prior to COVID-19 versus home use testing data during the pandemic. *Journal of Food Science*, *86*(10), 4668-4677. <https://doi.org/10.1111/1750-3841.15905>
- Shin, H. M., Lim, J. W., Shin, C. G., & Shin, C. S. (2017). Comparative characteristics of rice wine fermentations using *Monascus koji* and rice nuruk. *Food Science and Biotechnology*, *26*, 1349-1355. <https://doi.org/10.1007/s10068-017-0187-y>
- Silva, A. P., Jager, G., Van Bommel, R., Van Zyl, H., Voss, H.-P., Hogg, T., Pintado, M., & De Graaf, C. (2016). Functional or emotional? How Dutch and Portuguese conceptualise beer, wine and non-alcoholic beer consumption. *Food Quality and Preference*, *49*, 54-65. <https://doi.org/10.1016/j.foodqual.2015.11.007>
- Sinesio, F., Moneta, E., Porcherot, C., Abbà, S., Dreyfuss, L., Guillamet, K., Bruyninckx, S., Laporte, C., Henneberg, S., & McEwan, J. A. (2019). Do immersive techniques help to capture consumer reality? *Food Quality and Preference*, *77*, 123-134. <https://doi.org/10.1016/j.foodqual.2019.05.004>
- Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In L. Packer (Ed.),

*Methods in Enzymology* (Vol. 299, pp. 152-178). Academic Press. [https://doi.org/10.1016/S0076-6879\(99\)99017-1](https://doi.org/10.1016/S0076-6879(99)99017-1)

- Smart, K. F., Aggio, R. B., Van Houtte, J. R., & Villas-Bôas, S. G. (2010). Analytical platform for metabolome analysis of microbial cells using methyl chloroformate derivatization followed by gas chromatography–mass spectrometry. *Nature Protocols*, 5(10), 1709-1729. <https://doi.org/10.1038/nprot.2010.108>
- Smith, A. P. (2013). Effects of caffeine and alcohol on mood and performance changes following consumption of lager. *Psychopharmacology*, 227, 595-604. <https://doi.org/10.1007/s00213-013-2991-2>
- Solms, J. (1969). Taste of amino acids, peptides, and proteins. *Journal of Agricultural and Food Chemistry*, 17(4), 686-688. <https://doi.org/10.1021/jf60164a016>
- Son, E. Y., Lee, S. M., Kim, M., Seo, J.-A., & Kim, Y.-S. (2018). Comparison of volatile and non-volatile metabolites in rice wine fermented by Koji inoculated with *Saccharomycopsis fibuligera* and *Aspergillus oryzae*. *Food Research International*, 109, 596-605. <https://doi.org/10.1016/j.foodres.2018.05.008>
- Song, S. H., Lee, C., Lee, S., Park, J. M., Lee, H.-J., Bai, D.-H., Yoon, S.-S., Choi, J. B., & Park, Y.-S. (2013). Analysis of microflora profile in Korean traditional nuruk. *Journal of Microbiology and Biotechnology*, 23(1), 40-46. <https://doi.org/10.4014/jmb.1210.10001>
- Song, Y.-R., Lim, B.-U., & Baik, S.-H. (2022). Microbial Diversity and Volatile Flavor Changes during Gayangju Fermentation, a Traditional Korean House Rice Wine. *Foods*, 11(17), 2604. <https://doi.org/10.3390/foods11172604>
- Styger, G., Prior, B., & Bauer, F. F. (2011). Wine flavor and aroma. *Journal of Industrial Microbiology and Biotechnology*, 38(9). <https://doi.org/10.1007/s10295-011-1018-4>
- Sujan, M., & Bettman, J. R. (1989). The effects of brand positioning strategies on consumers' brand and category perceptions: Some insights from schema research. *Journal of Marketing Research*, 26(4), 454-467. <https://doi.org/10.1177/002224378902600407>
- Tak, H.-J., Lee, N.-R., Yang, S., Kim, S.-Y., & Lee, C.-H. (2024). Qualitative and Quantitative Metabolite Comparison of Korean Traditional Alcoholic Beverages: Takju, Yakju, and Traditional-Soju. *Foods*, 13(6), 956. <https://doi.org/10.3390/foods13060956>
- Tamura, M. (2023). Cooking of Rice. In J. Tian, Y. Ogawa, J. Singh, & L. Kaur (Eds.), *Science of Rice Chemistry and Nutrition* (pp. 129-165). Springer. [https://doi.org/10.1007/978-981-99-3224-5\\_8](https://doi.org/10.1007/978-981-99-3224-5_8)
- Tamura, M., Kumagai, C., Kaur, L., Ogawa, Y., & Singh, J. (2021). Cooking of short, medium and long-grain rice in limited and excess water: Effects on microstructural characteristics and gastro-small intestinal starch digestion in vitro. *LWT*, 146. <https://doi.org/10.1016/j.lwt.2021.111379>
- Tangsrianugul, N., Wongsagonsup, R., & Suphantharika, M. (2019). Physicochemical and rheological properties of flour and starch from Thai pigmented rice cultivars. *International Journal of Biological Macromolecules*, 137, 666-675. <https://doi.org/10.1016/j.ijbiomac.2019.06.196>
- Taylor, P. (2020). 'Here we go again': Auckland fears a long lockdown as coronavirus returns. The Guardian. <https://www.theguardian.com/world/2020/aug/13/here-we-go-again-auckland-fears-a-long-lockdown-as-coronavirus-returns>
- Teillet, E. (2015). Polarized sensory positioning (PSP) as a sensory profiling technique. In J. Delarue, J. B. Lawlor, & M. Rogeaux (Eds.), *Rapid Sensory Profiling Techniques* (pp. 215-225). Woodhead Publishing. <https://doi.org/10.1533/9781782422587.2.215>

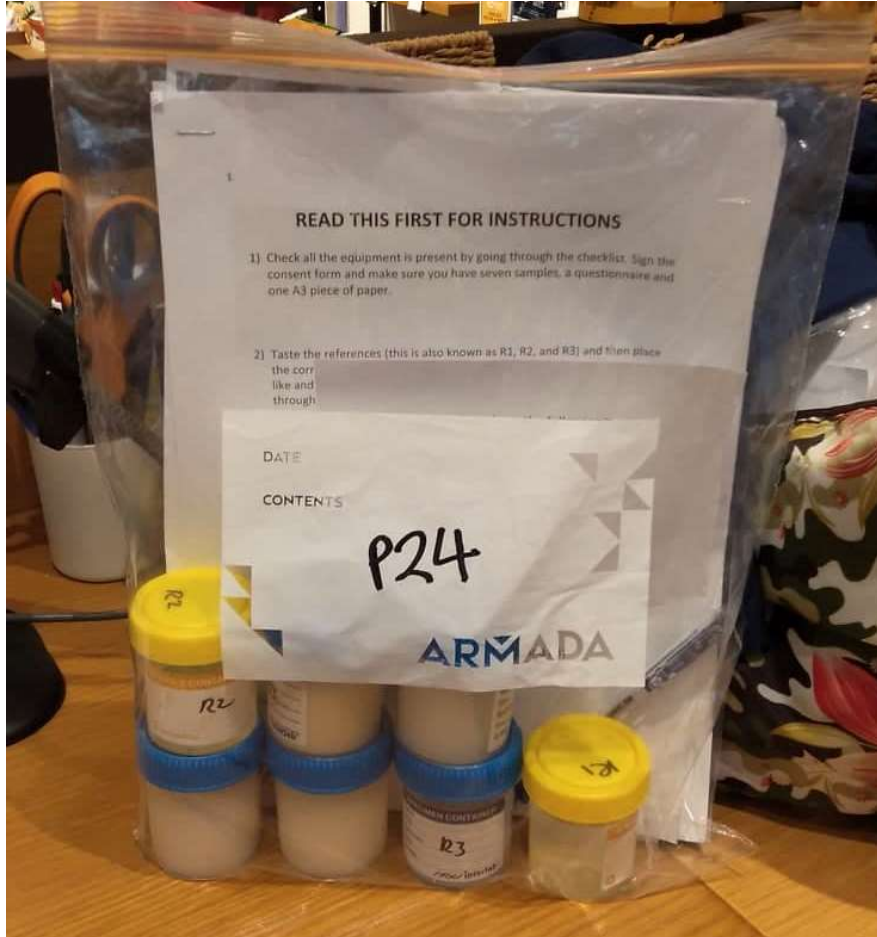
- Teillet, E., Schlich, P., Urbano, C., Cordelle, S., & Guichard, E. (2010). Sensory methodologies and the taste of water. *Food Quality and Preference*, 21(8), 967-976. <https://doi.org/10.1016/j.foodqual.2010.04.012>
- Thiex, N., Anderson, S., & Gildemeister, B. (2019). Crude fat, hexanes extraction, in feed, cereal grain, and forage (Randall/Soxtec/submersion method): Collaborative study. *Journal of AOAC International*, 86(5), 899-908. <https://doi.org/10.1093/jaoac/86.5.899>
- Thiex, N., Novotny, L., & Crawford, A. (2019). Determination of ash in animal feed: AOAC official method 942.05 revisited. *Journal of AOAC International*, 95(5), 1392-1397. <https://doi.org/10.5740/jaoacint.12-129>
- Thomas, A., & Pickering, G. (2003). Behavioural segmentation: a New Zealand wine market application. *Journal of Wine Research*, 14(2-3), 127-138. <https://doi.org/10.1080/09571260410001677941>
- Thuengtung, S., Matsushita, Y., & Ogawa, Y. (2019). Comparison between microwave-cooking and steam-cooking on starch properties and in vitro starch digestibility of cooked pigmented rice. *Journal of Food Process Engineering*, 42(6), e13150. <https://doi.org/10.1111/jfpe.13150>
- Thuengtung, S., & Ogawa, Y. (2020). Comparative study of conventional steam cooking and microwave cooking on cooked pigmented rice texture and their phenolic antioxidant. *Food Science & Nutrition*, 8(2), 965-972. <https://doi.org/10.1002/fsn3.1377>
- Tian, K. T., Bearden, W. O., & Hunter, G. L. (2001). Consumers' need for uniqueness: Scale development and validation. *Journal of Consumer Research*, 28(1), 50-66. <https://doi.org/10.1086/321947>
- Torri, L., Dinnella, C., Recchia, A., Naes, T., Tuorila, H., & Monteleone, E. (2013). Projective Mapping for interpreting wine aroma differences as perceived by naïve and experienced assessors. *Food Quality and Preference*, 29(1), 6-15. <https://doi.org/10.1016/j.foodqual.2013.01.006>
- Torrico, D. D., Han, Y., Sharma, C., Fuentes, S., Gonzalez Viejo, C., & Dunshea, F. R. (2020). Effects of context and virtual reality environments on the wine tasting experience, acceptability, and emotional responses of consumers. *Foods*, 9(2), 191. <https://doi.org/10.3390/foods9020191>
- Valentin, D., Chollet, S., Lelièvre, M., & Abdi, H. (2012). Quick and dirty but still pretty good: A review of new descriptive methods in food science. *International Journal of Food Science & Technology*, 47(8), 1563-1578. <https://doi.org/10.1111/j.1365-2621.2012.03022.x>
- Valentin, D., Chollet, S., Nestrud, M., & Abdi, H. (2018). Projective mapping & sorting tasks. In S. E. Kemp, J. Hort, & T. Hollowood (Eds.), *Descriptive analysis in sensory evaluation* (pp. 535-559). John Wiley & Sons Ltd. <https://doi.org/10.1002/9781118991657.ch15>
- van Zyl, H. (2016). Emotion in beverages. In H. L. Meiselman (Ed.), *Emotion Measurement* (pp. 473-499). Woodhead Publishing. <https://doi.org/10.1016/B978-0-08-100508-8.00019-9>
- Varela, P. (2022). Thinking outside the booth: when Covid-19 pushed sensory testing to remote options. *Food Quality and Preference*, 99, 104549. <https://doi.org/10.1016/j.foodqual.2022.104549>
- Wang, Q. J., & Spence, C. (2019). Drinking through rosé-coloured glasses: Influence of wine colour on the perception of aroma and flavour in wine experts and novices. *Food Research International*, 126. <https://doi.org/10.1016/j.foodres.2019.108678>
- Watman, A. (2023). *An Ancient Korean Libation Gets Transformed for the Modern Drinker*. WIRED. <https://www.wired.com/story/makku-makgeolli/#:~:text=An%20Ancient%20Korean%20Libation%20Gets,Koreans%E2%80%94into%20the%20American%20market>

- Wilson, C., Brand, J., du Toit, W., & Buica, A. (2018). Polarized projective mapping as a rapid sensory analysis method applied to South African Chenin Blanc wines. *LWT*, *92*, 140-146. <https://doi.org/10.1016/j.lwt.2018.02.022>
- Wilson, M. M., & Goddard, R. W. (2004). Creating value in the New Zealand wine industry. *International Journal of Wine Marketing*, *16*(2), 62-73. <https://doi.org/10.1108/eb008773>
- Wong, B., Muchangi, K., Quach, E., Chen, T., Owens, A., Otter, D., Phillips, M., & Kam, R. (2023). Characterisation of Korean rice wine (*makgeolli*) prepared by different processing methods. *Current Research in Food Science*, *6*, 100420. <https://doi.org/10.1016/j.crfs.2022.100420>
- Wong, B., Owens, A., Phillips, M., & Kam, R. (2023). Identifying sensory attributes of Korean rice wine (*makgeolli*) using sensory evaluation and chemical analysis. *Journal of Food Science*, *88*(10), 4247-4261. <https://doi.org/10.1111/1750-3841.16762>
- Wong, B., Phillips, M., & Kam, R. (2024). Product categorization of Korean rice wine (*makgeolli*) compared to beer and wine using sensory evaluation methods. *Journal of Sensory Studies*, *39*(2), e12904. <https://doi.org/10.1111/joss.12904>
- Wu, C., Zhu, H., Huang, C., Liang, X., Zhao, K., Zhang, S., He, M., Zhang, W., & He, X. (2022). Does a beautiful environment make food better-The effect of environmental aesthetics on food perception and eating intention. *Appetite*, *175*, 106076. <https://doi.org/10.1016/j.appet.2022.106076>
- Xia, D., Tan, X., Wang, L., Li, Z., Hou, A., Zhu, Y., Lai, L., & Wang, Y. (2023). GC-MS coupled with Rate-All-That-Apply (RATA) to analyse the volatile flavor substances of yellow wine during fermentation. *Foods*, *12*(10). <https://doi.org/10.3390/foods12101992>
- Yan, H., Chang, E.-C., Chou, T.-J., & Tang, X. (2015). The over-categorization effect: How the number of categorizations influences shoppers' perceptions of variety and satisfaction. *Journal of Business Research*, *68*(3), 631-638. <https://doi.org/10.1016/j.jbusres.2014.08.008>
- Yang, J. (2023). *Korea's Kooksoondang sees its makgeolli exports surpass \$10 mn mark*. The Korea Economic Daily. <https://www.kedglobal.com/korean-food/newsView/ked202303210020>
- Yang, S., Lee, J., Kwak, J., Kim, K., Seo, M., & Lee, Y.-W. (2011). Fungi associated with the traditional starter cultures used for rice wine in Korea. *Journal of the Korean Society for Applied Biological Chemistry*, *54*, 933-943. <https://doi.org/10.3839/jksabc.2011.141>
- Yu, H., Xie, T., Xie, J., Ai, L., & Tian, H. (2019). Characterization of key aroma compounds in Chinese rice wine using gas chromatography-mass spectrometry and gas chromatography-olfactometry. *Food Chemistry*, *293*, 8-14. <https://doi.org/10.1016/j.foodchem.2019.03.071>
- Yu, H., Zhao, J., Li, F., Tian, H., & Ma, X. (2015). Characterization of Chinese rice wine taste attributes using liquid chromatographic analysis, sensory evaluation, and an electronic tongue. *Journal of Chromatography B*, *997*, 129-135. <https://doi.org/10.1016/j.jchromb.2015.05.037>
- Yu, L., Turner, M., Fitzgerald, M., Stokes, J., & Witt, T. (2017). Review of the effects of different processing technologies on cooked and convenience rice quality. *Trends in Food Science & Technology*, *59*, 124-138. <https://doi.org/10.1016/j.tifs.2016.11.009>
- Zandstra, E. H., Kaneko, D., Dijksterhuis, G. B., Vennik, E., & De Wijk, R. A. (2020). Implementing immersive technologies in consumer testing: Liking and Just-About-Right ratings in a laboratory, immersive simulated café and real café. *Food Quality and Preference*, *84*, 103934. <https://doi.org/10.1016/j.foodqual.2020.103934>

- Zhang, H., Jang, S.-G., Lar, S. M., Lee, A.-R., Cao, F.-Y., Seo, J., & Kwon, S.-W. (2021). Genome-wide identification and genetic variations of the starch synthase gene family in rice. *Plants*, *10*(6). <https://doi.org/10.3390/plants10061154>
- Zulkarnain, A. H. B., Cao, X., Kókai, Z., & Gere, A. (2024). Self-Assessed Experience of Emotional Involvement in Sensory Analysis Performed in Virtual Reality. *Foods*, *13*(3), 375. <https://doi.org/10.3390/foods13030375>

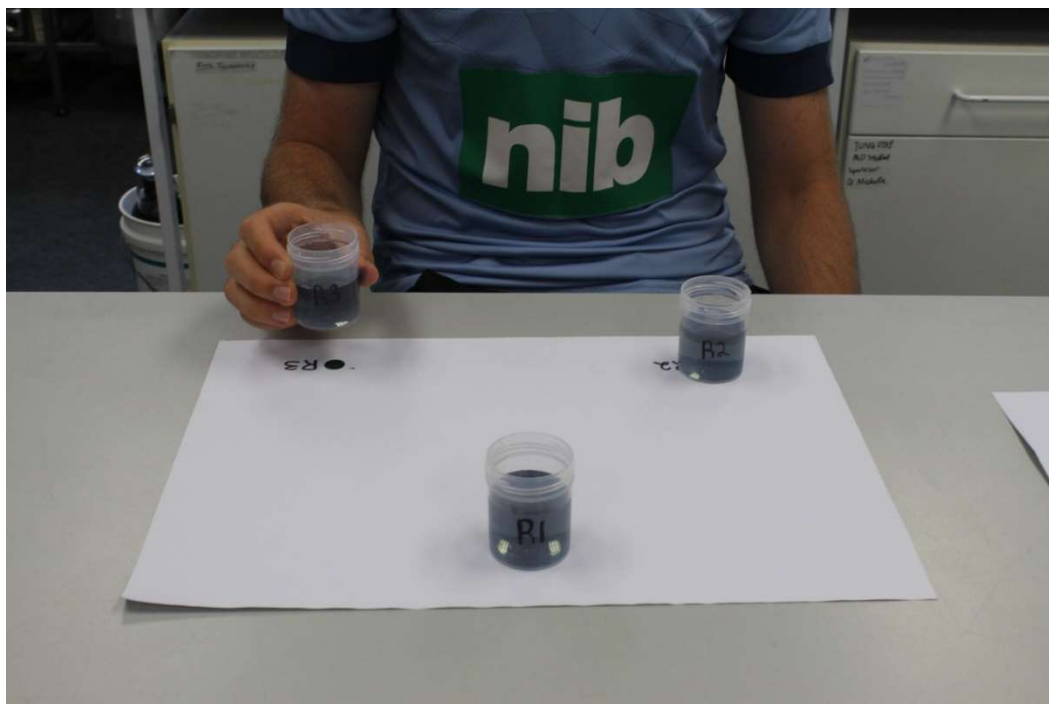
## Appendix A. A photo of the sensory test kit

A photo of the sensory test kit that was sent out to participants for the PPM sensory experiment.



## Appendix B. A photo demonstration of the PPM experiment

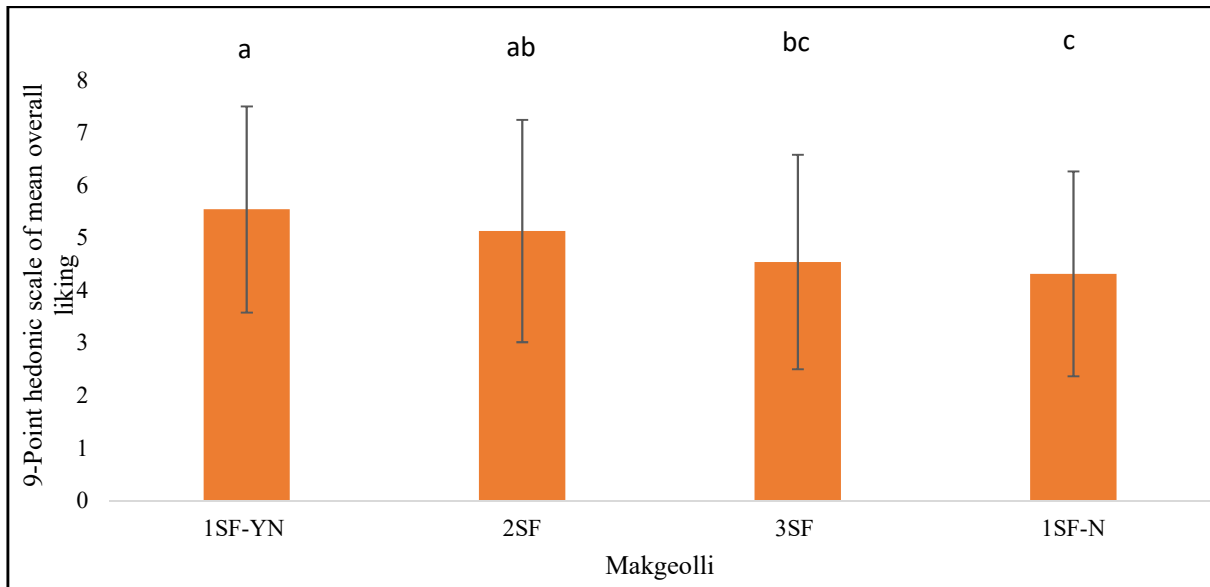
A photo demonstration of the location of the three poles, the colour is used to highlight the solution only and was not presented in the experiment.





## Appendix D. The overall liking of *makgeolli*

The overall liking of *makgeolli* including mean and standard deviation on a 9-point hedonic scale.



Note: Letters represent the level of statistical significance between each *makgeolli* sample.

## Appendix E. ANOVA results of the overall liking of *makgeolli*.

One-way ANOVA results of the overall liking of *makgeolli* among all participants.

	Df	Sum Sq	Mean Sq	Pr(>F)
Sample	3	120.30	40.09	2.54e-06***
Residuals	512	2084.40	4.07	

## Appendix F. The overall liking of *makgeolli* between male and female participants.

The overall liking of *makgeolli* including mean and standard deviation on a 9-point hedonic category scale between male and female participants.

Male	Sample	Mean	SD	HSD test
	1SF-N	4.40	2.07	bc
	1SF-YN	5.48	1.96	ab
	2SF	5.02	2.05	abc
	3SF	4.54	2.00	bc
Female	Sample	Mean	SD	HSD test
	1SF-N	4.26	1.85	c
	1SF-YN	5.60	1.97	a
	2SF	5.24	2.19	abc
	3SF	4.54	2.10	bc

Note: Letters represent the level of statistical significance between each *makgeolli* sample.

**Appendix G. ANOVA results of the overall liking of *makgeolli* between male and female participants.**

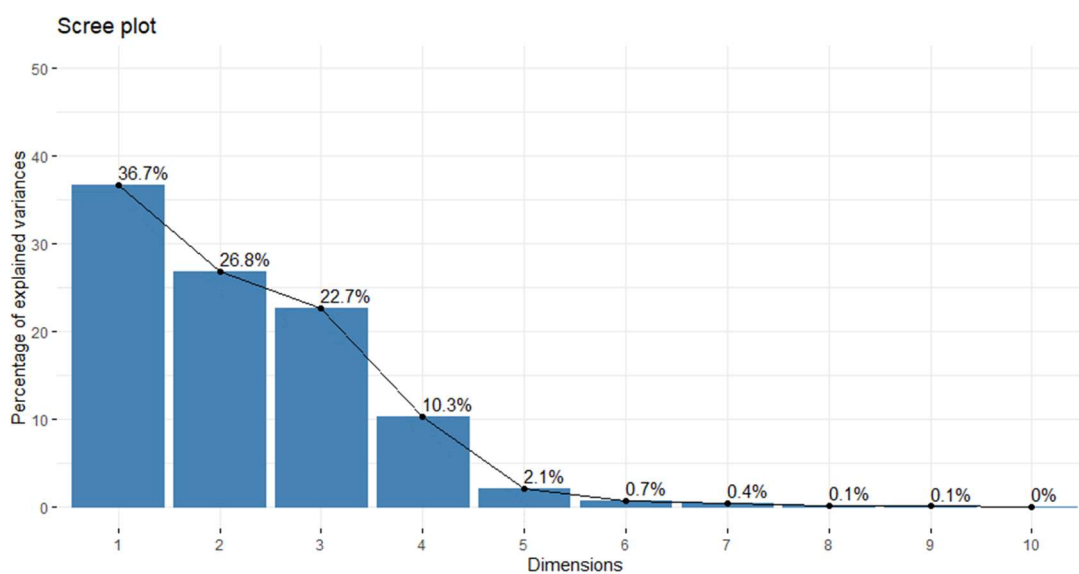
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	Df	Sum Sq	Mean Sq	Pr(>F)
Gender	7	122.73	17.53	0.00013111***
Residuals	508	2082.29	4.10	

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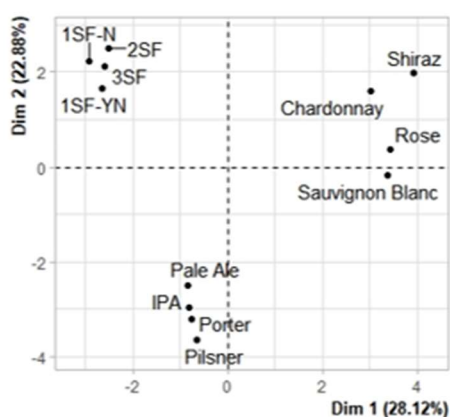
## Appendix H. Scree plot of the PCA

Scree plot of the PCA conducted from the *makgeolli* sample using SPME-GC-MS.

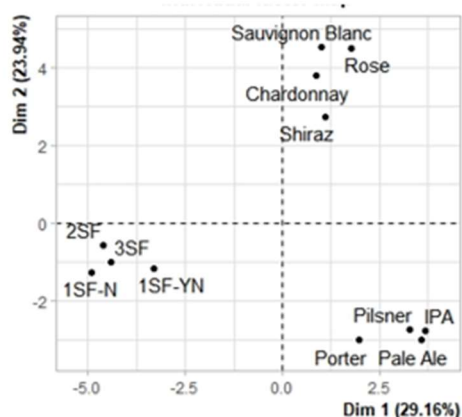


## Appendix I. The MFA map of different cluster groups from PM with UFP

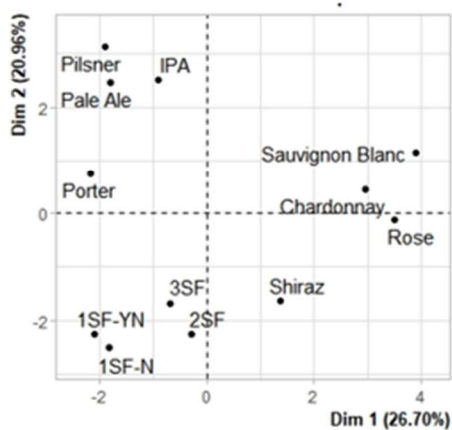
The MFA map of the four different cluster groups from the projective mapping with ultra-flash profiling experiment. A) Cluster 1 from the PM experiment explained the total variance of 51.0%, B) Cluster 2 from the PM experiment explained the total variance of 53.1%, C) Cluster 3 from the PM experiment explained the total variance of 47.7%, and D) Cluster 4 from the PM experiment explained the total variance of 42.1%.



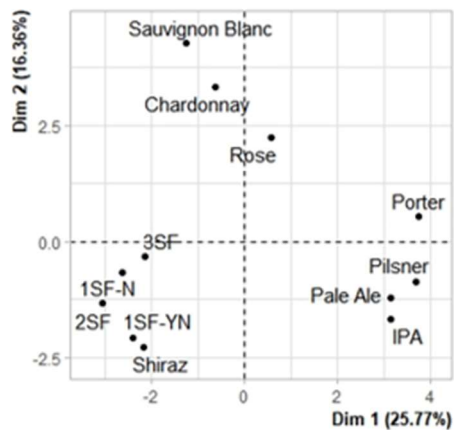
(A)



(B)



(C)



(D)

Based on the subjective wine knowledge results reported by participants, four clusters were identified using hierarchical cluster analysis (HCA). Cluster 1 consists of 22.7% of the total participants who took part in the PM with UFP experiments. Eighty-six percent of the participants in Cluster 1 indicate that they consume alcoholic beverages at least once a week and over 66.7% of participants are below 35 ages old. In terms of the subjective wine knowledge questions, Cluster 1 tends to rate their subjective wine knowledge

higher than the other cluster groups. For example, '*Among my circle of friends, I'm one of the experts on wines*' with  $4.9 \pm 0.9$  and '*I am quite familiar with wine*'  $5.5 \pm 0.5$  on a 7-point category scale from "disagree strongly" to "agree strongly". Cluster 2 consists of 34.8% of the participant group, where majority of the participants in this cluster is male (65.2%), and all indicate that they consume alcohol at least once a week or more. Compared to Cluster 1, Cluster 2 indicates that they are familiar with wine ( $4.0 \pm 1.3$ ) but rated high for the question '*I do not feel very knowledgeable about wines*' ( $5.6 \pm 0.9$ ) and believes that '*compared to most other people, I know less about wine*' ( $4.7 \pm 1.5$ ). The PM with UFP MFA map based on the Cluster 1 participant's results, explained 51.0% of the total variance (Dimension 1 = 28.12%, Dimension 2 = 22.88%) while the Cluster 2 participant's results explained 53.1% of the total variance (Dimension 1 = 29.2%, Dimension 2 = 23.9%) (see supplementary information **SI.1** for the MFA map of Cluster 1 – 4).

Cluster 3 consists of 16.7% of the participant group and 81.8% of them are females, all participants in Cluster 3 are below the age of 34. Participants from Cluster 3 tend to consume alcoholic beverages less than the other cluster groups, with 72.7% of participants stating that they consume alcoholic beverages once a month and the other 27.3% consume alcoholic beverages every second week for Cluster 3 participants. From the subjective wine knowledge questions, Cluster 3 participants indicated that they are not familiar with wine ( $2.5 \pm 0.8$ ) and rated  $5.7 \pm 1.0$  on a 7-point category scale for the question '*I do not feel very knowledgeable about wines*'. Finally, 25.8% of participants are classified in Cluster 4, with East Asian (35.3%) and South Asian (29.4%) making most of the ethnic makeup in this cluster group. Interestingly, Cluster 4 participants indicated that they are familiar with wine ( $4.5 \pm 1.6$ ), but they do not feel knowledgeable about wine ( $4.5 \pm 1.8$ ). For Cluster 3, the MFA results explain 47.7% (Dimension 1 = 26.7%, Dimension 2 = 21.0%) of the total variance, while Cluster 4 explains 42.1% (Dimension 1 = 25.8%, Dimension 2 = 16.4%) of the total variance of their PM with UFP MFA map. From the PM with UFP MFA map in **Appendix I**, Cluster 3 and Cluster 4 grouped Shiraz closer to *makgeolli* samples and it is important to note that the total explained variance is relatively lower compared to Cluster 1 and Cluster 2. The grouping of alcoholic beverages for Cluster 3 and Cluster 4 is more spread out on the PM with UFP MFA map than Cluster 1 and Cluster 2, suggesting that criteria for sorting the 12 alcoholic beverages are not consistent. The results show that the level of knowledge such as wine subjective knowledge will affect the categorization of alcoholic beverages.

## Appendix J. Cluster comparison between overall PM-MFA (Global) and the four cluster groups.

Cluster comparison of the results from the perceptual maps created from the projective mapping tasks (based on the first two dimensions) between overall PM-MFA (Global) and the four cluster groups.

PM Global versus specific cluster groups	RV values
PM Global versus PM Cluster 1 <sup>c</sup>	0.937
PM Global versus PM Cluster 2 <sup>c</sup>	0.983
PM Global versus PM Cluster 3 <sup>c</sup>	0.916
PM Global versus PM Cluster 4 <sup>c</sup>	0.796

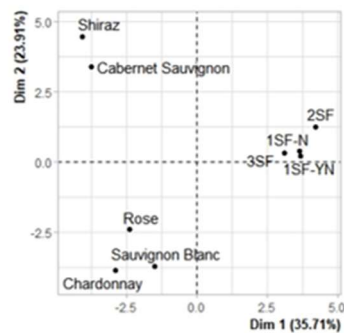
<sup>a</sup> Statistical significance level  $p < 0.05$

<sup>b</sup> Statistical significance level  $p < 0.01$

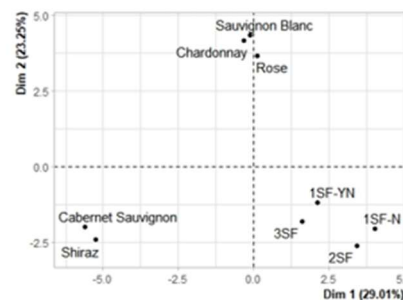
<sup>c</sup> Statistical significance level  $p < 0.001$

## Appendix K. The MFA map of cluster groups from PSP experiment

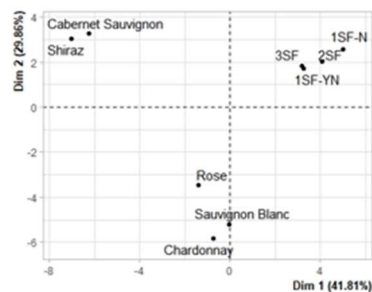
The MFA map of the four different cluster groups from the polarized sensory positioning (PSP) experiment. A) Cluster 1 from the PSP experiment explained the total variance of 59.6%, B) Cluster 2 from the PSP experiment explained the total variance of 52.3%, C) Cluster 3 from the PSP experiment explained the total variance of 71.7%, and D) Cluster 4 from the PSP experiment explained the total variance of 62.3%.



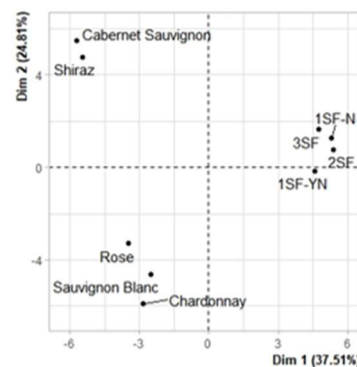
(A)



(B)



(C)



(D)

From hierarchical cluster analysis (HCA), based on the objective and subjective wine knowledge results given by PSP participants, four cluster groups were identified. Cluster 1 represents 19.8% of the total PSP participant group, with all the participants in the cluster below the age of 39 or younger and most of the participants indicating that they only consume alcoholic beverages once a month (61.1%). Cluster 1 tended to perform poorly on the objective wine knowledge questions, and the majority of the participants stated that they had limited knowledge of wine. Cluster 2 consists of 22.0% of the total PSP participants. The alcoholic beverage consumption behavior of Cluster 2 is evenly distributed among the four categories of ‘once a

month', 'every second week', 'at least once a week', and 'more than once a week'. Although Cluster 2 scored the objective wine knowledge questions relatively low but higher than Cluster 1, Cluster 2 participants rated their subjective wine knowledge higher than Cluster 1. Around 25.3% of PSP participants were categorized in Cluster 3, where the majority of the participants in Cluster 3 are New Zealand/Australian Europeans (39.1%) followed by East Asians (30.4%), and South Asians (17.4%). Cluster 3 scored high in the objective wine knowledge with more correct answers than other cluster groups identified among the PSP participants. From the subjective wine knowledge questions, Cluster 3 is self-aware that their knowledge is higher than other individuals. Cluster 4 contains the largest groups of participants (32.9%) with the majority of the participants between the ages of 21 to 34 (80.0%). Cluster 4's performance on the objective wine knowledge was moderate compared to Cluster 3 but better than Cluster 1 and Cluster 2. From the subjective wine knowledge, Cluster 4 participants were self-aware that they had higher knowledge about wine but tended to score themselves as having lower knowledge about wine than their peers (e.g., friends).

The following part of this section will be discussing the total variance explained and the RV coefficient of each cluster group, as shown in **SI.3** for the visualization of the PSP multiple factor analysis (MFA) map. The PSP MFA map based on Cluster 1 participant's results explained 56.2% of the total variance (Dimension 1 = 35.7%, Dimension 2 = 23.9%) where all the wine samples are placed in the negative values and *makgeolli* samples placed in the positive values for Dimension 1. For Cluster 2, the total variance explained 52.3% (Dimension 1 = 29.01%, Dimension 2 = 23.25%), the grouping of the alcoholic beverages is similar to Cluster 1, however, the rotation is slightly different. Cluster 3 had the highest total explained variance 71.7% (Dimension 1 = 41.8%, Dimension 2 = 29.9%). The high total explained variance can be explained by the high degree of objective wine knowledge (e.g., correctly answering the questions in the PSP experiment on the objective wine knowledge survey) and also having a high awareness of their wine knowledge compared to others. Cluster 4 has a high total explained variance of 62.3% (Dimension 1 = 37.5%, Dimension 2 = 24.8%), compared to Cluster 1 and Cluster 2, this is likely because participants consume more alcoholic beverages than the first two clusters. Cluster 4 participants indicated that at least 66.7% of participants consume alcoholic beverages once a week or more.

## Appendix L. Cluster comparison between overall PSP-MFA (Global) and the four cluster groups.

Cluster comparison of the results from the perceptual maps created from the projective mapping tasks (based on the first two dimensions) between overall PSP-MFA (Global) and the four cluster groups.

PSP Global versus different cluster groups	RV
PSP Global versus Cluster 1 <sup>c</sup>	0.986
PSP Global versus Cluster 2 <sup>c</sup>	0.976
PSP Global versus Cluster 3 <sup>c</sup>	0.993
PSP Global versus Cluster 4 <sup>c</sup>	0.992

<sup>a</sup> Statistical significance level  $p < 0.05$

<sup>b</sup> Statistical significance level  $p < 0.01$

<sup>c</sup> Statistical significance level  $p < 0.001$