Influence of hygiene practices through microbiological monitoring of craft beer production processes in Midlands Meander Breweries, Pietermaritzburg

by

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DECLARATION OF INDEPENDENT WORK

I, NONHLAKANIPHO VUYISWA ZULU, do hereby declare that this research project submitted to the Central University of Technology, Free State, for the degree MASTER of HEALTH SCIENCES IN ENVIRONMENTAL HEALTH is my own work and has not been submitted before to any institution by myself or any other person in fulfilment of the requirements for the attainment of any qualification.

SIGNATURE OF STUDENT: ______________ **DATE: 15/10/2025**

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"In this beautiful world anything is possible, but when we believe wholeheartedly and try, we will achieve success."

-Mohith Agadi-

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ABSTRACT

Introduction

Good beer is made with a lot of thought dedicated to processes of hygiene. The prevention of microbiological contamination of beer needs consideration by understanding the microorganisms that exist within a craft brewery establishment and the control of microbial contamination on surfaces.

Aims and Objectives

The study strove to ascertain hygiene practices in two breweries, Brewery A and Brewery B, and to compare these practices using three assessments. These comprehensive assessments involved using observational screening, the evaluation of employee practices, and swab analyses collected from key surfaces in the selected craft breweries in the Pietermaritzburg Midlands Meander area. The study proposes effective controls and urges the need for relevant targeted training programs for the establishment of hygiene protocols in these and possibly similar beer breweries.

Material and Methods

Two craft beer breweries, referred to as Brewery A and Brewery B, were selected, as study sites. Samples were collected from these sites and evaluated. Employees (n=15) from both sites were also surveyed to determine their knowledge and understanding of hygienic practices in the craft beer brewery setting. Mixed methods (qualitative and quantitative) were employed which involved using a five-step sequential flow of purposive sampling during the brewing process and a survey. Upon site visitation a standard checklist was used which formed part of the qualitative methods. Measuring instruments included onsite inspection using an audit checklist sourced from the Food Regulations 638 of June 22, 2018 (Department of Health, 2018) to assess compliance with regulations within the two sites. In addition, as part of quantitative methods self-administered survey questionnaires were administered to the employees to determine their personal hygiene

practices as food handlers in the two establishments. Finally, sampling of surfaces was conducted using the protocol for laboratory analysis which involved using the sausage agar method and Lin's Wild Yeast method. During the first and last week of each determined month, data were collected from the selected craft breweries which formed part of the quantitative methods. This occurred during COVID-19 restrictions during allocated time periods with specific intervals as determined by the craft brewery owners so as not to disturb production processes. The data were recorded on an excel spreadsheet. Data were analysed using the SPSS version 28 (IBM Corporation®, New York, USA) for Windows Version 17.0 software program. Trend analyses, descriptive statistics, and paired tests including the chi-square test were conducted to compare operations and practices in the breweries using the one-way Anova P-test.

Results

Brewery A adhered to better hygiene practices compared to Brewery B, especially in behaviours such as wearing personal protective clothing and removal of jewellery. The proportional test results indicated statistically significant differences for "Removal of jewellery when brewing" ($p = 0.003$) and "Hand washing during brewing stages" ($p = 0.028$), where Brewery A showed more positive results. These findings suggest that Brewery B could benefit from additional focus on these specific practices to align with the safety standards observed by Brewery A. Results of observational analysis of comparison between the two craft breweries also revealed that Brewery A employed well-implemented systems (HACCP) while Brewery B had infrastructural defects such as cracked floors, damaged ablution facilities, old paint, and dirty sinks, which suggested that the infrastructure in Brewery B required much more attention and improvement than in Brewery A. It was evident that craft beer Brewery B had a lesser advanced hygiene system and poorer overall structural development than Brewery A; hence, the recommendation that it should fully align with food establishment regulations. Microbial data indicated that there was high consistency of CFU/cm^2 levels of microbial growth from swabs taken in Brewery B after sampling of different surfaces across all critical points.

However, a further display of variable trends with an increase and decrease in microbial contamination between certain time points was noted. Brewery A showed relatively stable CFU/cm^2 levels that were statically significant ($p<0.05$) over time with slight fluctuations, indicating good sanitisation practices. The chi-square test demonstrated a significant association between the premises and their respective hygiene statuses (χ2=26.32\chi^2 = 26.32χ2=26.32, *p*=0.01), indicating that Brewery A and Brewery B differed significantly in their proportions of satisfactory, good, and unsatisfactory hygiene statuses.

Conclusions

This study highlights the significance of good application of hygiene practices and protocol implementation of hygiene systems within craft beer breweries. A lack of adherence to these practices and standards creates room for microbial growth that ultimately poses a threat to product safety. The analyses revealed substantial differences in microbial contamination levels between Brewery A and Brewery B across time points, with Brewery B demonstrating higher microbial loads in both the swab and beer samples. These findings highlighted the importance of adherence to sanitation protocols in breweries, particularly in areas with a tendency for higher contamination, such as work surfaces. It is important to ensure that continuous monitoring is prioritized by craft beer brewery operational managers in collaboration with the local municipality as a key role-player in ensuring compliance with safety standards in breweries for the benefit of consumers. Recommendations for the two sites include frequent training programmes for employees and suitable training venues on site. Furthermore, regular in-house scheduled inspections must be conducted to ensure regulatory compliance, particularly in meeting hygiene standards.

DEFINITIONS OF KEY TERMS

Craft beer: A traditional beer brewed in small quantities in craft beer breweries (Baiano, 2020).

Craft brewery: An independent brewery producing craft beer on a small scale (Brewers association, 2020).

Contamination: Unwanted pollutants or substances present in food that can cause harm or illness (Ciont et al., 2022).

Fermentation: A chemical process in which a substance such as yeast is broken down into a simpler substance (Briggs, 2004).

Hygiene: Routine behaviour to maintain a clean and healthy environment (Douglas, 2020).

Microbes: Microorganisms such as bacteria responsible for causing spoilage and illness. internationally to dictate and to control hazards found in and to ensure food safety (Obi, 2017).

Microbiological sampling: The process of collecting and analysing samples of food products and swabs of food production surfaces to identify the presence of harmful microorganisms (Priest, 2006).

Coliforms: Bacteria that are rod-shaped, Gram-negative and don't have the potential to form. Normally found in environmental surroundings, including in faecal waste of all warm-blooded animals (Bonnet et al., 2020)

Microbial data index: A tool used in Microbiology to characterize and quantify microbial microbes with set standards (Viro, 2019).

Sanitisation: A method of cleaning to reduce or eliminate pathogenic agents on a surface (Manzano et al., 2011).

ISO 22000: A standard for management of food safety which was developed (ISO 22000:2018)

Foreign material: is defined as non-food, foreign bodies that may cause illness or injury to the consumer, and materials that are not typically part of the food product (Payne et al., 2023)

LIST OF ABBREVIATIONS

CGMPs: Current Good Manufacturing Practices

HACCP: Hazard Analysis and Critical Control Points

HPCSA: Health Profession Council of South Africa

PPE: Personal Protective Equipment

CIP: Clean-in-place

QMS: Quality Management System

CFD: Computational Fluid Dynamics

RIMS: Research Information Management System

HSREC: Health Sciences Ethics Committee

FAO: Food and Agriculture Organization

LWYM: Lin's Wild Yeast Medium

CFU: Colony Forming Unit

CBASA: Craft Beer Association of South Africa

TABLE OF CONTENTS

Central University of
Technology, Free State

LIST OF FIGURES

Central University of Technology, Free State

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Background

A definition of a craft brewery is offered by the Brewers Association of the United States of America, that defines it as a beer brewing industry with a capacity smaller than six million barrels (704 million litres) of beer produced annually. These industries are commonly independent as not higher than 25% of the company share is retained by the industrial brewery (Brewers Association, 2020). Another definition describes a craft beer brewery as a small, independent establishment where traditional beer is produced, focusing on a flavour appeal for the localized market (Mascia et al., 2016). Research globally has shown that craft beer is often prone to microbial spoilage; hence, hygiene practices in craft beer establishments are of paramount importance (Rodríguez-Saavedra et al., 2020). Beer is generally known to be a safe product due to its pH value (3.8–4.7) that limits the thriving of pathogens, and this lack of threat is supported by the filtration process and a low storage temperature (Rodhouse and Carbonero, 2017). However, the potential for microbial growth exists, mainly in yeast and on surfaces. According to Wray (2025), craft beers do not normally go through a pasteurization or sterile filtering process, and this makes them more susceptible to spoilage than regular beer. South Africa has been shown to contribute 4.5% of the global craft beer market share and is named among other key leading players like North America (46%) and Europe (43%) (Baiano, 2021). The latter regions have shown that a growing consumer stream is usually health conscious, is looking for new flavours, and prefers locally sourced products (Calvo-Porral, 2019). Research in South Africa on the craft beer industry has shown that these beers are often sold in tourist hubs and they therefore play an important role in the tourism economy (Rogerson, 2019).

Over the years, there has been ongoing initiatives globally to implement the International Organization for Standardization-ISO9001, or ISO 9002, in breweries. Additional to the Hazard Analysis and Critical Control Points (HACCP) guidelines, it is another system of food management for food safety. This practice stems from control measures to ensure that an effective total quality management system is achieved in breweries (Singh et al., 2018; Onescu, 2020). According to Erica (2017), most breweries spend the early years merely on learning to clean the site where the beer will be brewed. Although beer is a relatively safe beverage, uncontrolled growth of microorganisms such as *Saccharomyces cerevisiae var. diastaticus* is commonly the reason for beer spoilage. An effective functional way to stop spoilage in beer is by applying health and safety practices that include adequate cleaning and sanitation techniques that ensure a safe product for the consumer (Manzano et al., 2011). Furthermore, there are many advantages associated with brewery establishments that enforce hygiene standards and put effective control measures in place to reduce contamination caused by a lack of deep cleaning.

Another common concern when it comes to the craft brewery establishment is the negligent of the employees towards removal of accessories such as jewellery when handling beer, which tends to posse's danger on the product by introducing foreign objects/material that may result in contamination of the product. Although well-developed craft breweries have an advantage of identifying foreign objects/material during the brewing stages as they rely on machine dictators, where as in other craft breweries it is still a challenge and it requires employees to adhere to good practices. This makes contamination of the product a persistent problem that affects the production process and calls for improvement on food safety systems (Payne et al., 2023).

This study aimed to determine the hygiene practices in two craft beer breweries, referred to as Brewery A and Brewery B, using three measuring instruments, namely observational screening, the evaluation of employee practices, and the analysis of swabs collected from the selected craft breweries in the Pietermaritzburg Midlands Meander area. Based on the outcomes of this investigation, the study proposes the implementation of effective controls and relevant targeted training programs for these and other similar establishments. The selected craft breweries were situated in a key tourism location in the KwaZulu-Natal province and were significant for this study as they operated using the craft beer production steps, or protocols.

1.2 The Future of the Craft Beer Industry

The topmost ingested alcohol beverage in the world is beer, which has been brewed and consumed since ancient times (Damjanović and Varga, 2021). Various scholars globally have highlighted the increasing interest in the craft beer market, and many have indicated a growing research interest in publication outputs on this topic (Durán-Sánchez et al., 2022; Bimbo et al., 2023). These scholars allude to the fact that more research is needed to better understand and manage the craft beer revolution within the beer industry.

According to Rogerson (2016), the sub-Saharan African region is deemed the least developed region for craft beer research due to limited research publication outputs. As there is a growing need for craft beer production using indigenous ingredients, this research gap must be closed. Hence, this study aimed to heed this call by contributing to research outcomes on hygiene and safety practices within local craft beer establishments. In modern times, customers and connoisseurs have been searching for unique, authentic, distinctive craft beer products that are of high-quality. Most such breweries are very small and cater for local or regional markets. In response, brewers of craft beer have created an innovative blend of raw or malted cereals and have added fruit, spices, and other ingredients to alter the flavour profiles of their beers (Villacreces, Blanco and Caballero, 2022).

Growth in the craft beer market has been influenced by a rising demand for a wider variety of beers, a rise in income, a desire to be locally rooted, and diverse beer styles and flavours (Faganel and Rižnar, 2023). However, the primary obstacles that have been observed are related to the growing use of alternatives, the scarcity of certified brewers, and tax laws. A strong financial opportunity and the growing desire to explore a diversified local beer experience by consumers have become the primary driving forces behind the establishment of craft beer breweries (Pokrivak et al., 2019). Moreover, the home brew movement has been a vital factor in the development of craft beer and microbrew pubs, and it is continuing to take market share away from macro beer makers and full-service restaurants globally (Murray and O'neill, 2012). Globally, there are now more than 3 400 craft brewers because of the craft beer industry's exponential rise in recent years. Some regional craft breweries have grown exponentially and have spread their beer over a large geographic area. However, most of these businesses are still small and cater for local markets (D'Aversa, 2016). Conversely, it has also been noted that the reduction of transportation costs to farther-flung customers have encouraged the establishment of new operations with larger enterprises that have given rise to expanding markets at regional level (Cantwell, 2013). This is arguably the start of a long-term trend where the domination of these large craft breweries will form part of the distribution area for smaller craft breweries that are new in the market. This will ensure a balance within the craft beer industry across the world, and communities may be able to draw these larger craft brewers to their areas to benefit economically from having craft beers produced locally (Reid and Gatrell, 2015).

The latter argument was an important consideration for this study as the two study sites in the Midlands Meander are located in a vibrant tourist area in South Africa. Various recent studies have also supported the narrative of beer tourism, giving it a thrust of authenticity for consumers who want to interact with the production side of this market (Reid and Gatrell, 2015). According to Aschbrenner (2015), geographical requirements are essential for setting up local craft beer breweries, arguing that if relevant criteria are considered when establishing a brewery, more opportunities can be explored. Furthermore, the establishment of brewery sites is an opportunity to boost local tourism which has a direct impact on the local economy.

In 1983, the Mitchell's Brewery at Knysna opened for business as the first artisan brewery in South Africa (Sidubi, 2017). This observable trend is similar to that in Australia and the Netherlands (1981), and it predates the establishment of the first Italian brewery pub in 1988 (Garavaglia and Swinnen, 2017). The beer range of South African Breweries Ltd. (SAB) has been a market leader that has dominated the country's beer industry for decades. However, the country has seen a slow but steady influx of new craft beer outlets during the 1990s, particularly after its democratic transition in 1994, with around nine microbreweries operating by 2003 (Pier, 2015). After 2008, there has been an increase in the number of new breweries launched, with the period 2013–2016 experiencing the highest growth in this industry in South Africa.

African microbrewery start-ups occurred across the country (Rogerson, 2016). A nationwide audit conducted in 2016 revealed that there were 187 licensed craft micro-breweries in the country, serving as the backbone of the growing craft beer tourism industry (Rogerson and Collins, 2015). It is against this backdrop that this study aimed to outline the significance of hygiene practices for craft breweries as this market is envisaged to increase incrementally. Figure 1.1 provides a pictorial view of the South African craft beer landscape country-wide.

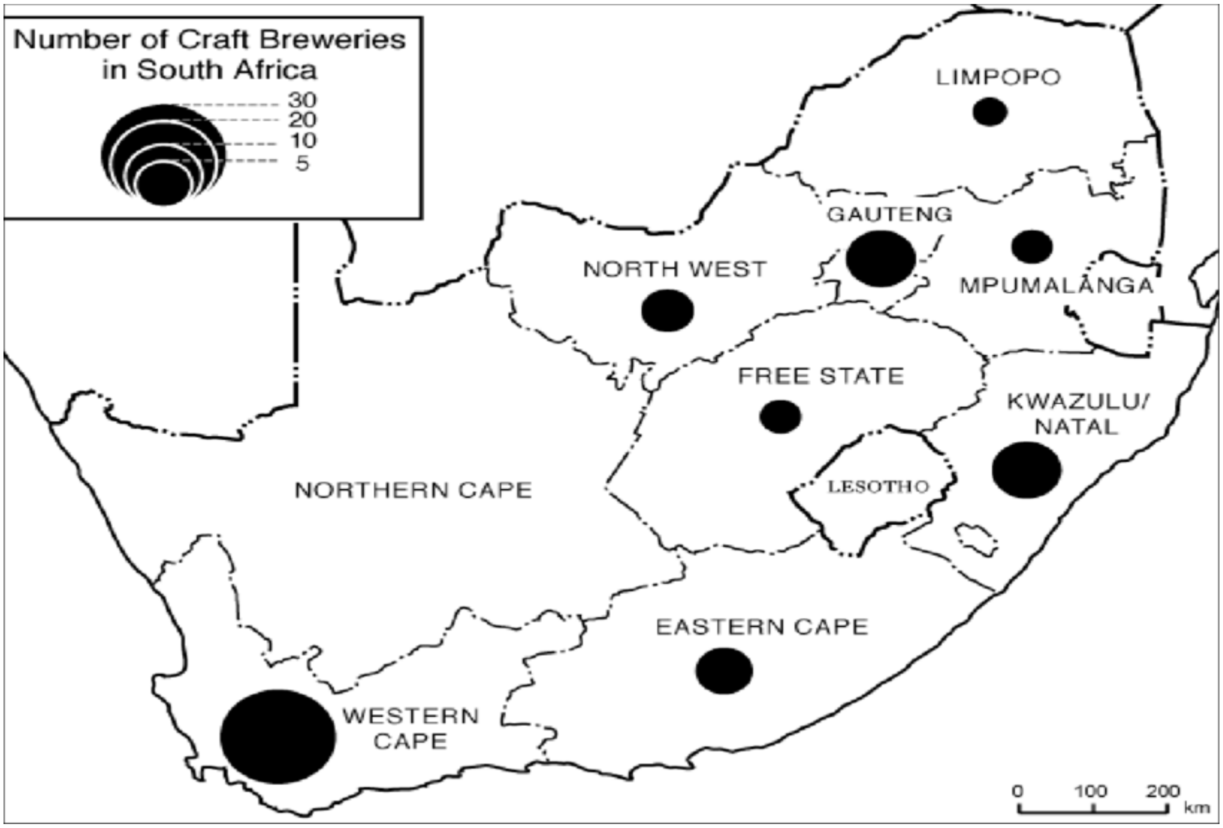


Figure 1.1 Location of craft beer breweries in South Africa by Province

Source: Rogerson, 2016

The general geographic distribution of the country's craft breweries is scattered among 8 of the nine provinces, indicating the size of the nation's microbrewery industry that is predominantly located in the Western Cape, Gauteng, and Kwa-Zulu-Natal (KZN) metropolitan cities that are major population centres preferred by entrepreneurs.

Figure 1.1 illustrates that KZN province (situated along the east coast of South Africa) is a significant player in the market compared to its neighbouring provinces. The prevalence of craft breweries in the province is also linked to South Africa's expanding tourism industry (Rogerson, 2016). Some of the small-town tourist spots include Clarens in the Free State and Hermanus in the Western Cape provinces, which are both home to numerous craft breweries (Rogerson and Collins, 2019). According to the Craft Brewery

Association South Africa, there are more than 200 craft breweries in the country (Rogerson, 2016).

1.3 Trends in Microbiological Control in the Craft Beer Industry in South Africa

As mentioned in the literature, South Africa has shown a growing rise in the craft beer industry. Its production process uses 100% natural ingredients, and consumers' taste buds are becoming more health conscious and flavour orientated, and these trends pose exciting challenges for creative craft beer brewers. A Standard Bank Report (2015) predicted that the market growth for beer would be 2.1% from 2016 to 2017, which translated to the equivalent to 18 million litres.

However, despite this rosy picture, research has also shown that the growing craft beer industry poses a threat to beer safety due to possible microbial instability during the initial production process (Ciont et al., 2022). The increased presence of these beer spoilage microorganisms poses a serious problem for economic growth in the brewing industry as its impacts on brands and rising cost implications may threaten product stability (Obi, 2017). A study in Italy examined the management process of brewery production amongst Italian micro-breweries, and revealed that lactic acid bacteria were discovered in the end product (Farber and Barth, 2025). These authors urge cleaning and sanitising during critical control points of the beer production process as vital control measures.

According to Bokulich and Bamforth (2013), even though limited changes have occurred in the beer development process for many breweries, there have been increasing options for the industry to introduce automated systems for quality assurance, which is a measure that will restrict human contact with the product.

1.4 Controversies Related to the South African Craft Beer Industry

The international craft beer industry has reportedly been affected by social ills such as racism and sexism, which were reported in the South-Eastern part of the United States.

Racism and sexism are underscored by the notion that women do not have the skills men have, and they are therefore discriminated against in the craft beer industry, particularly if they are of African American origin. Moreover, the growing trend of craft beer consumption among the youth as part of a more modern lifestyle has been linked to a negative impact on drinking behaviours, particularly as criminal incidents associated with beer consumption have been on the increase (Room et al., 2021). Conversely, the brewing industry has gradually grown under the patronage of a much more representative gender approach, which has made it an attractive business opportunity for everyone, including all racial groups, regardless of the negative implications among the youth (Rogerson, 1994). On the negative side, an alarming statement made by a respected South African brewer was the following: “Some craft beer is not good and people trying to brew beer do not have skills; [they] have no work ethics and never clean their beer kegs” (Steinhobel, 2023). This statement is concerning as it highlights the threat of dirty kegs that can contaminate an entire batch of beer and threaten human health. Hence, adherence to sound hygiene practices is of the utmost importance in any beer brewing establishment. Moreover, such negative claims pertaining to craft beer operations need to be explored, validated, and addressed if true.

1.5 Microbiological Risks Associated with Craft Beer

1.5.1 The impact of beer spoilage organisms

Contaminants present in breweries that can cause brewery products to degrade are commonly known as microbes. The lines of bottling and canning in breweries are commonly regarded as open production equipment due to the inherent exposure of the filling process to the environment (Moretti, 2013). This process makes beer susceptible to contamination from the environment and other external sources (Priest and Stewart, 2020). A significant problem faced by breweries is the requirement to produce beer of high quality and sustaining this quality. As noted by Moretti (2013), it is an undeniable fact that breweries, large and small, produce a product that is highly vulnerable to microorganisms that may cause spoilage and degradation of the organoleptic properties in the beer. This not only poses a risk to the health of potential buyers, but it also affects the quality of the product which will ultimately compromise the brand and the associated brewery's name.

Nowadays, beer is in great demand and therefore it is essential to be mindful of the possibility of toxins in the product that can be harmful to customers' health. Beer is not always the best medium for microbes to grow, but some species can grow in beer, changing its characteristics and resulting in poor flavour and turbidity. Furthermore, due to their lower likelihood of pasteurization or sterile filtering, craft beers have a more likely potential to deteriorate than beer produced in large-scale breweries (Mallett et al., 2018).

As the spoiling microbes can access the brewing stage at any given time, it may compromise the end product's microbiological stability from an early stage, and this often leads to substantial waste and financial loss (Obi, 2017). Although brewery cleanliness has advanced significantly since the early years of brewing beer in Africa, secondary contamination is still responsible for a growing percentage of microbiologically damaged beer. Microorganisms can filter from the air onto surfaces and are further recirculated into the environment by air turbulence. It has also been affirmed that microorganisms are continuously travelling within canning and bottling areas (Wynne and Wilson, 2021). Therefore, this is an essential and critical control point that should be handled with caution through the implementation of effective controls.

The presence of beer spoilage organisms can be detected by microbiological investigation of the ambient air in breweries, while the development and survival of airborne microbes can be directly impacted by environmental circumstances that include temperature, humidity, and airspeed (Obi, 2017). If the process is compromised, the beer will not be safe and profitable for the brewer. This may happen if the machinery, bottles, cans, or ingredients (particularly yeast) are microbiologically contaminated and there is no control to minimize risk (Bokulich and Bamforth, 2013). According to Sakamoto and

Konings (2003), most organisms that brewers are concerned about result in off-flavours in beer. This is a critical issue as beer quality is paramount, hence undesirable microorganisms should be detected and managed effectively.

Yeast is a critical component in the beer brewing process. It is important to stress that yeast belongs to numerous genera and species with a huge range of physiologies. Moreover, the organisms' predominance of unicellular presentation is their only common trait (Maicas, 2020). Yeast is defined as an oval single celled organism which has a potential to convert sugars into alcohol and carbon dioxide This definition also covers non-brewing yeasts that can be found excessively in raw materials or the air, as well as in brewing strains employed for various types of beer. These can lead to the transfer of micro-organisms within the brewery (Maicas, 2020). Many yeast species have a semi-filamentous lifestyle and may develop mycelia in a variety of environmental settings. Most microorganisms are killed during the boiling process of wort,[1] and are then inoculated by adding yeast to wort for fermentation. There are other types of undesired yeasts that are still able to enter the beer during fermentation, and these are referred to as 'wild yeasts' (Priest and Stewart, 2020). Normally, wild yeasts are not fully controlled and are not intentionally employed. According to Boulton et al., (2001), the term 'wild yeasts' is ambiguous, but such yeasts are commonly classified into saccharomyces and non-saccharomyces for ease of usage.

A study that was conducted in a British city where pitching yeasts were analysed, found that 41% of beer contained wild yeasts. The lager beers were contaminated with wild yeast and had an off-flavour. Beers with unusually low present gravities and super attenuated wort results of diastatic yeast contamination during fermentation were

[1] In beer brewing, wort is a sweet liquid extracted from the mashing process, which involves steeping grains (usually malted barley) in hot water to convert starches into sugars. It's essentially the unfermented precursor to beer, containing sugars, proteins, and other compounds that will be transformed by yeast into alcohol and flavour. The wort is then boiled with hops and other ingredients before fermentation.

observed, and they were referred to as ‘light’ beers made with diastatic yeasts (Boulton and Quian, 2013).

Another threat is high carbon dioxide concentrations in beer that can arise from the contamination of beer bottles that are unpasteurized and beer has diastatic yeast. If this happens, there is a strong possibility of the bottles exploding. This poses a risk for human health and safety, and therefore measures to detect bottling issues must be effectively applied (Hough et al., 1982; Ciont et al., 2022).

The most frequent contaminant found in wine and beer is *Pichia Membranifaciens* (He and Bayen, 2020). It is significant to be aware that the *Brettanomyces* and *Dekkera* species formed by acetic acid typically do not pose a hazard to the processes of brewing as it is difficult for them to thrive in anaerobic environments (Priest and Stewart, 2020). However, some bacteria that cause pollution, such as those in the genus *Zymomonas*, have a special way of breaking down their food because they produce ethanol, and this is not used to produce drinkable alcohol. However, the bacterium has been linked to primed conditioning ale spoiling and is resistant to ethanol up to roughly 10% by volume (Priest and Stewart, 2020).

Zymomonasmobilis is a species that potentially deteriorates beer. It is oxidase-negative, catalase-positive, and Gram-negative. It is common that these bacteria are either completely or partially anaerobic, and they grow into bacilliform or are short with rounded ends. They typically occur alone or in pairs, although larger agglomerates can also occasionally form (Moretti, 2013). While it can survive oxygen, *Zymomonasmobilis* requires anaerobic environments to flourish and it does not ferment maltose, but ferments glucose and fructose. It is also able to withstand ethanol, unlike the majority of Enterobacteriaceae. It has been shown to survive magnitude gravity fermentations that produce 12–13% v/v ethanol and its ideal growing temperature is 25 ± 3°C, which is considered a high temperature (Moretti, 2013).

1.5.2 Primary and secondary sources of contamination in craft beer breweries

Sources of contamination in a craft brewery site can occur at varying degrees. Each one is important to understand to effectively manage contamination levels. Scholars who have investigated contamination sources have classified them into two categories. Contamination source one is primary contamination that originates from yeast, wort, the fermentation process, and from pressure tanks. Limited published data are available on breweries related to recycle pitching yeast as a major source of contamination. Some reported cases revealed that soiled equipment was a significant origin of the contamination in breweries (Obi, 2017). Contamination can also possibly occur during the stage when the hot wort is cooled within the plate heat exchangers, which can occur as a result of leaking plates, lack of cleaning the plates, and wort aeration (Wagner et al., 2021). Contamination source two is secondary contamination which originates from bottling (exposure to air), kegging, or canning. In the bottling section, about 50% of microbial contamination incidents have been associated with secondary contamination (Obi, 2017). The outcomes of primary contamination are more intense than secondary contamination and may lead to higher levels of contamination. The beer microbes may be present during any stage of a brewing process, where the indirect micro-organisms responsible for spoilage (*Obesumbacterium Proteus*) are mainly primary contaminants (Paradh, 2015). For example, the yeast in brewing should be regarded as a contaminant after filtration (Lindemann, 2009).

Airborne contamination of beer is also significant in breweries where it can occur at any stage, but particularly in the filling or bottling department. Also, it can occur in the course of the transportation of the bottles that are open, beginning with the bottle washer up to the filler and including the last step involving sealing the bottles. The dispensation of the microbes in the air relies on humidity, temperature, and atmospheric or air pressure. An inflated amount of the beer spoilage microbes in the air can be linked to the microbial spoilage of the bottled beer (Haikara and Henriksson, 1992).

Microbiological control is a regulatory system to safeguard and guarantee the quality of beer by preventing and minimizing any microbial contamination. This is vital as the brewing procedural steps are not aseptic and impurities can frequently be present, which can impact the final product's quality due to a lack of cleanliness of the equipment, vessels, and other surfaces during operations. Lack of proper control, such as leaving the brewery, kegs of beer, and the dispensing system microbiologically uncontrolled poses a huge risk. Moreover, the open tap and keg practice renders the distribution/dispense system prone to germs that may be prevalent in a brewery. It has been discovered that the organisms present in draft beer from the tap differ from those commonly found in craft breweries, which indicates that other contaminant sources may be present in breweries (Devolli et al., 2016).

1.6 Strategies to Ensure Safe Beer Production in Craft Beer Breweries

1.6.1 Hygiene system design

Even though beer is known to be a relatively safe product, the potential for spoilage by microorganisms is a real threat. A common measure to stop beer spoilage is by controlling brewery pollutants with sufficient application of sanitation and proper cleaning. A 2016 study that was conducted in Italy evaluated the microbiological growth present at the beginning and at the end of the hygiene implementation processes during craft beer production (Baiano, 2020). It was found that hygiene practices were neglected and not taken seriously, and it demonstrated a high rate of beer spoilage resulting in product wastage (Donadini and Porretta, 2017). Therefore, the level of contamination in this establishment impacted the characteristics of the beer product which caused negative implications and the entire batch of beer going to waste, impacting sales volumes. It was then concluded that a consistent hygienic system was necessary as this brewery experienced a trend in product waste. In another study, it was noted that staff attitudes towards hygiene practices were essential, as a negative or careless attitude had cost implications coupled with a degrading reputation of the business. Other negative effects from this experience included the impact this had on service delivery and the customers. The authors therefore proposed a clean-in-place (CIP) method to prevent the microbiological contamination of the beer (Li,2019; Oldham and Held, 2023).

The above experiences suggest that a basic hygiene training and awareness programme should be implemented to ensure that each brewery handler understands the significance of good hygiene practices and the need to enforce compliance (Atwell, 2016b). It has been shown that training will result in a positive change within a brewery and an improved system of work, thus resulting in the production of beer of good quality (Lijima et al., 2007). It is undeniable that brewery employees play an important role in making sure that beer that is within acceptable standards is produced. Their involvement in the beer brewing process requires good personal hygiene, wearing appropriate gear, cleaning and sterilizing equipment, and the application of the clean-as-you-go principle. Therefore, regular training and monitoring must be prioritized by craft brewery managers (Kourtis and Arvanitoyannis, 2001). The latter authors emphasize the importance of the hygiene assessment status of handlers' hands and their aprons by using the sausage agar method. This method will be explained in detail in a next chapter as it was used in the current research.

The main purpose of the current research was to assess microbial management during craft beer production processes and to determine the implementation of hygiene practices by workers in the two establishments under study. It was envisaged that the outcomes could be used to ensure product quality and minimize associated risks. Hence, various recommendations, that are presented later, are offered to improve health and safety standards for craft beer establishments.

1.7 Problem Statement

It is a known fact that most breweries spend a substantial amount of time in ensuring a clean and safe beer production environment, especially when the business is within its early stages of operation (Olajire, 2020). Even though beer is a relatively safe beverage, uncontrolled microbial growth, such as *Saccharomyces cerevisiae var. diastaticus*, is commonly responsible for beer spoilage. A brewery's size impacts personal space, equipment, and the working environment during craft beer production, and these are important variables that could lead to increased levels of contamination on site. A significant and effective way of preventing spoilage of beer is by ensuring adherence to and the application of good hygiene practices through adequate cleaning and sanitation techniques. It also requires effective methods of control and monitoring (Manzano et al., 2011).

A positive attitude among employees is vital in ensuring that personal hygiene is observed and that the working environment is maintained at an acceptable standard of hygiene for safety. It was therefore argued that the impact of microorganisms and poor hygiene practices on craft beer brewing establishments should be assessed from a scholarly perspective to help such establishments to identify gaps and prevent possible threats to the business through recommendations of improved operational standards for product safety.

1.9 Policy Guidelines for the Management of Brewery Safety

Historically, there were very few food safety regulations in the beer brewing industry. The introduction of new laws by the Food Safety Modernization Act of 2010 of the United States has strengthened the operating standards in the brewery sector (Obolensky, 2012). Globally, craft brewery establishments are now obligated to abide by an updated Current Good Manufacturing Practices (CGMPs) guideline as a result of this new legislation within the United States (Pellettieri, 2015).

In the United States, the brewing industry functions in a highly complex regulatory environment, where the Food and Drug Administration and the Alcohol and Tobacco Tax and Trade Bureau are the main regulatory bodies that oversee the brewing sector (Mittelman, 2008). In South Africa, it is the National Liquor Act No. 59 of 2003 that governs and regulates the brewing sector (Hangula, 2024), while the National Liquor Act provides direction with regards to licences for the production and distribution of alcoholic beverages and their retail marketing (Banda, Matumba and Mondliwa, 2015). The general quality management system (QMS) used by most breweries is the Hazard Analysis and Critical Control Points (HACCP) guidelines (Jackson, 2006). This QMS is commonly used in South Africa by food and beverage establishments to effectively address their operational and production processes.

When the Good Manufacturing Practices (GMPs) are not followed, it can result in fines, fees for re-inspection, forced recalls, and even criminal prosecution. In the context of South Africa, a designated environmental health practitioner and food auditor are responsible for regular inspections, and they can expose shortfalls that can result in the aforementioned penalties. According to Baughman (2014), key focus areas that are essential for development include: operating facilities, sanitary areas, production equipment, and product flow, and include processes such as maintenance, receiving, warehousing, shipping, and pest control.

The Foodstuffs, Cosmetics and Disinfectants Act No. 54 of 1972 governs food safety and also encourages the implementation of effective pre-requisite programs within the food industry sector in South Africa (Ngwa, 2017). This Act also outlines the requirements for product labelling, which is an important aspect in the safety and marketing of alcoholic beverages.

1.10 Rationale for the Study

This research will enhance knowledge of microbiological control in craft beer breweries and will contribute to scholarly understanding of hygiene practices in such establishments. It will therefore add valuable microbiological information to strengthen academic outputs by the Faculty of Health Sciences and other related fields of study.

The findings may also be used as a tool for identifying gaps and building knowledge platforms while facilitating learning in the craft beer brewing industry, with particular emphasis on enhancing safety measures for both managers and workers. In this context, information about the study location may be significant in providing resourceful information for knowledge generation in other related areas and establishments. Other important considerations based on the outcomes of the study include awareness of the impact of microbiological and hygiene practices on craft beer production, which could benefit all stakeholders in this industry.

The results may also be used in academic institutions as a literature reference in comparative studies on craft beer production in KwaZulu-Natal and South Africa in general. The findings and recommendations may be used to inform students involved in craft beer research, thereby motivating wider research on the subject matter. The Msundunzi Municipality may also use these results as a benchmark to assist new craft beer establishments that might want to operate in the area.

In terms of the rationale, the following hypothesis was posed:

Hypothesis: Microbial contamination in craft breweries is a result of poor hygiene.

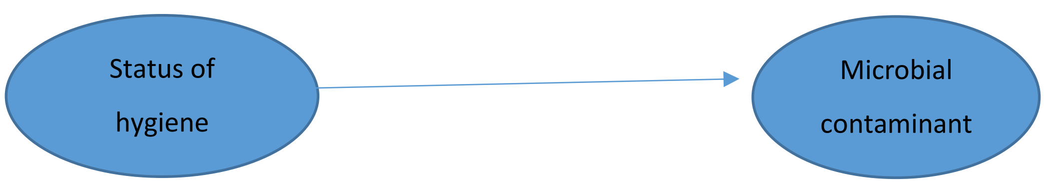


Figure 1.2: Hypothesis

This statement hypothesises that the status of hygiene practices amongst employees will cause/influence the growth of microbial contaminants in craft beer breweries. This implies that a relationship between hygiene and bacterial growth encountered in craft breweries exists.

1.11 Aims and Objectives of the Study

The aims of the study were to:

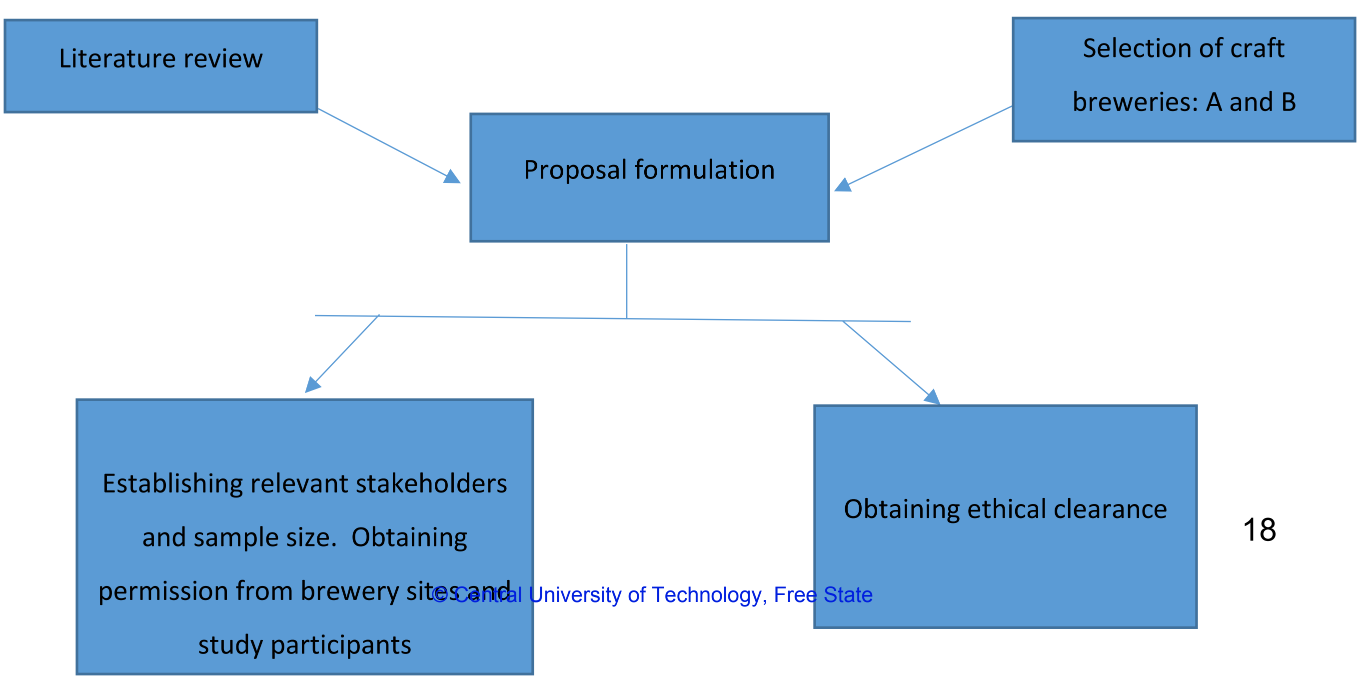
- Establish the status of hygiene control in the craft brewing establishments under study; and to
- Sequentially analyze the control of microbial contamination during the stages/steps of craft beer making during the brewing process.

The objectives were to:

- Investigate current hygiene and food safety practices amongst workers in the craft brewing establishments under study;
- Observe the compliance measures adopted by Brewery A and Brewery B according to South African food safety regulations; and
- Detect and evaluate any microbial contamination along the craft beer production line in the establishments under study.

1.12 Conceptual Framework and Execution of the Study

The conceptual framework of the study is presented diagrammatically in Figure 1.2 below. It outlines the study flow and the processes that were undertaken during this investigation.



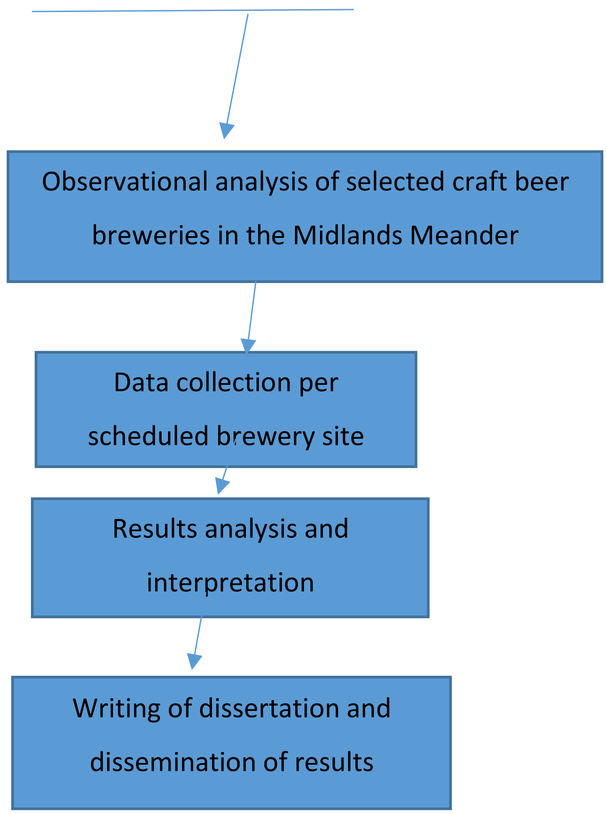


Figure 1.3: Conceptual framework of the study

1.13 Dissertation Structure

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Methodology

Chapter 4: Results

Chapter 5: Conclusion and Recommendations

1.14 Conclusion

Chapter 1 provided a synopsis of the craft beer market globally and locally and discussed various aspects regarding the production of craft beer, gaps in our understanding of the microbial contamination of craft beer, and opportunities to address and curb this threat to the industry. Existing trends and risk factors were highlighted, particularly in the operations of the craft beer brewery context. Evidence of a growing market due to changing consumer needs and profiles was presented. It was averred that South Africa is well positioned to experience an increasing demand for craft beer production. Hence, it was argued that adherence to safety measures is vital to ensure product quality and hygienic practices. The study’s aims and objectives were presented and a diagram of the conceptual framework of the study was provided.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Chapter 2 provides a discussion of literature sources that served as an important frame of reference for the study and that underscored its relevance. The literature sources that are citied in this dissertation provide an overview of existing methods of microbial detection, types of bacterial culture media associated with the craft beer industry, and the importance of implementing a Quality Management System (QMS) in a craft brewery. Other important aspects of the literature review include relevant legislation, capacity building through training, and the positioning of craft beer as a product of the future for generations to come.

2.2 Overview of and Developments in the Craft Beer Industry

Beer is one of the most well-known and popular alcoholic beverages in the world. It is made of water, malted grains (usually barley), hops, and yeast. However, because of its low hydrogen (pH) potential, the brewing process creates a favourable environment for microorganism growth (Robak and Balcerek, 2018). This means that a high bacterium count in yeasts has the potential for bacteria growth that can result in beer spoilage, especially when there is no pasteurization or sterilization-filtration during the brewing process (Duart et al., 2024). However, by constant microbial assessment through sampling for cleanliness and measures that ensure the hygienic status of the beer being brewed, a brewer is able to create a product with a long shelf life and with few or no complaints from customers. Such measures also ensure increased production levels and low rates of product rejection.

The current study investigated craft beer brewing on a relatively small scale as opposed to a traditional large alcohol production factory that produces beer commercially. As indicated by the growing craft beer market in South Africa, this industry is beneficial as it creates job opportunities for numerous locals and contributes to the economic sector (Pokrivcak et al., 2019). Even though a craft beer brewery is typically smaller in size than a larger commercial brewery, the products can still offer characteristics that are similar to those of traditional beers.

However, the brewing process is prone to the development of microorganisms, which is due to the rich nourishment nature of wort and the added factors of growth produced by the brewing yeast (Olaniran et al., 2017). There is a comparatively long production process that follows a sequence of steps, from the boiling of wort to the packaging of beer, with batch formation of beer for several weeks allowing unwanted microorganisms to start developing. Therefore, it is necessary to follow all steps correctly in order to have effective controls in place and to make sure that the quality of the brewery beverage is not compromised, even if produced in a small establishment. Hence, this study assessed microbial contamination in all stages of the craft beer making process. Although most breweries place emphasis on good hygiene practices that are mandatory for ensuring a brewing environment that is healthy and safe (Douglas, 2020), some contamination still occurs. In this context, there are possible loopholes in the system that need to be monitored to ensure that the product is of optimal quality. Research in Italy has shown that this is sometimes not the case, especially if certain standards are not adhered to, such as hygiene practices that are compromised (Capasso et al., 2017).

Based on this information, it was an important consideration in this study to select and investigated craft beer breweries to determine the prevalence and nature of safety protocols. Key areas of investigation were product quality and the hygiene standards in the brewery environment.
Beer is an alcoholic beverage that is commonly consumed in the food and beverage industry. It is consumed in both house dining and restaurant contexts as well as during outdoors social events, while it is highly popular in the retail sector in a commercialized form. Therefore, with such a wide market audience, hygiene practices are essential in

preventing any health-related risks that can be associated with beer. Good hygiene practices also ensure good quality beer, which is a very important business attribute (Holah, Lelieveld and Gabric, 2016). The importance of hygiene in vessels, machinery, and on all surfaces is crucial because poor maintenance crucially impacts the final quality of the product.

Van Houdt and Michiels (2010) urge brewery handlers to constantly maintain good hygiene practices during the entire production line. Globally, mass beer production and distribution usually occur in a sealed system, meaning that cleaning procedures occur without dismantling. However, even such systems are prone to bacterial growth on surfaces, which poses a threat to beer quality (Vaughan, O'Sullivan and Sinderen, 2005). The traditional methods of cultivation are still found to be effective in most brewing processes (Ciont et al., 2022), but alternative methods of production are constantly being developed and regulated within the clinical microbiology field and within the food industry, which faces the possibility of pathogens amongst their products. However, such applications are difficult to use directly in breweries (Ciont et al., 2022).

2.3 Effective Control of the Craft Beer Brewing Process

During the beer production process, the malting, mashing, and fermentation steps are followed which are part of a microbiological process (Cocolin et al., 2011). However, the fermentation process of beer is susceptible to spoilage. If favourable conditions persist, microorganisms may start to grow and off-flavours may spoil the final product (Priest and Stewart, 2020). Figure 2.1 below illustrates the six steps involved in the craft beer brewing process, namely milling, mashing/malting, lautering, boiling, fermenting, and filling. Each step will be explained in detail in the order of the process below:

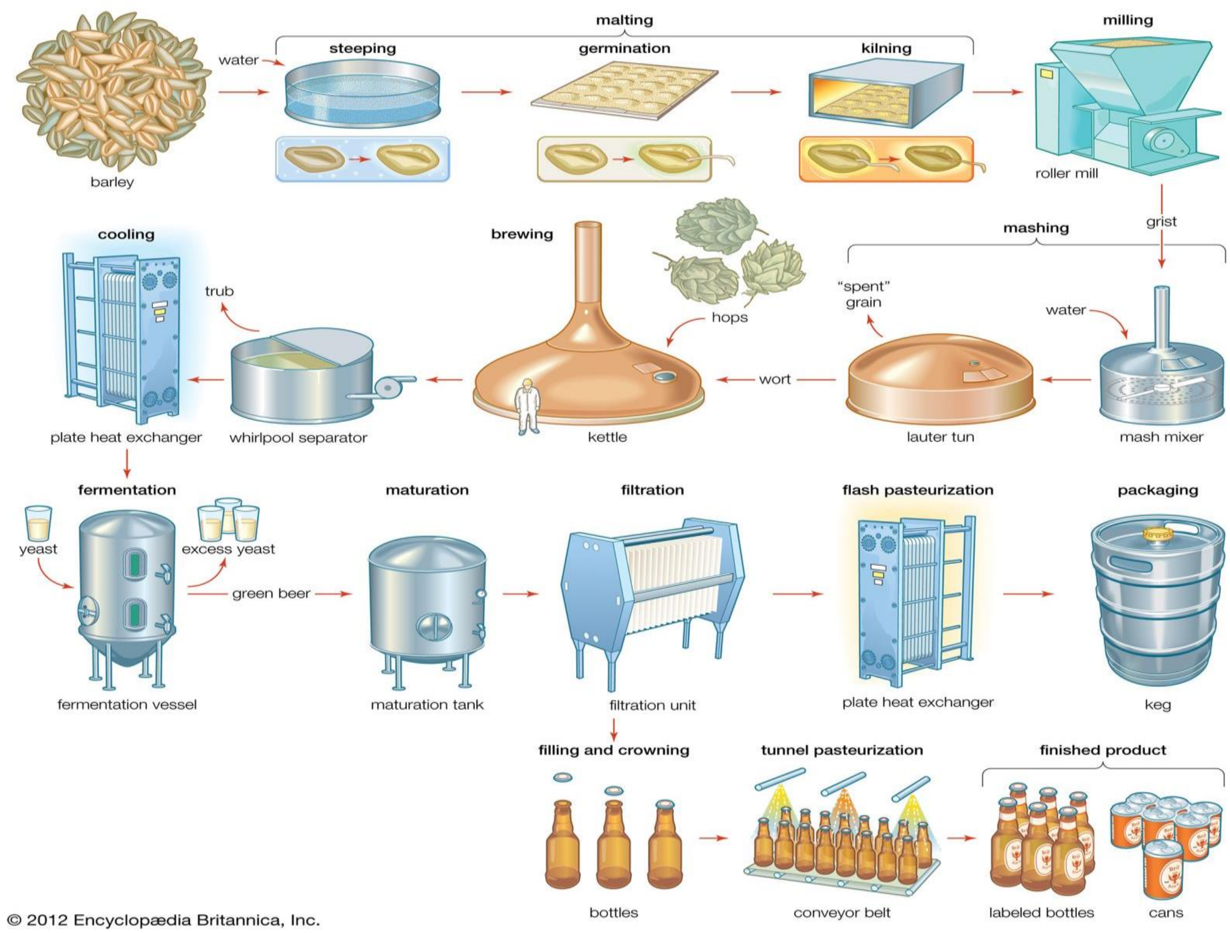


Figure 2.1 Processes involved in brewing
Source: Encyclopaedia Britannica, 2012

Step 1: Milling

Step one in the brewing procedure is milling, whereby whole malted grains are broken in order to be opened for processing. The husk or outer layer of the grain and the inner part are crushed and broken into pieces, allowing the liquor masher to access the entire grain.

This milling process is an important step in the procedure because if the grain is not milled properly, it can result in beer with off-flavour.

The aim is for the grain to be crushed enough in order to expose the starchy centre of the barley seed without destroying the grain hulls that cover them (Campbell, 2012).

Step 2: Malting/Mashing

The barley that is malted are grains that have begun the process of germination. Malting allows the formation of activating enzymes in the grain for the conversion of starches into sugar. This malted grain is combined with hot water to allow the formation of a mash, which is left at a temperature of about 65°C for up to an hour. During this process, the previously developed enzymes in the malting process starches are broken down into fermentable sugars (Banda et al., 2015).

If the mixture becomes too cold during the mashing stage, the velocity of the enzymes usually decreases and less conversion occurs. However, should the temperature increase too much, the enzymes usually become deactivated, and the process will not continue. Every temperature is optimum for a different enzyme, which could be an enzyme that breaks down proteins. By heating the mash, a bit more in each step, an unlikely enzyme is capable of executing the job in a sequence (Baiano,2020).

Step 3: The lautering process

This step involves the separation of the formed extracts during mashing from the spent grain to create wort. A mash that is sweet allows the used grains and liquid, which are called wort, to be moved to the kettle. This is accomplished in a lauter tun, which is an open, wide vessel with a temporal bottom, or in a mash filter, which is a plate-and-frame filter created for this specific separation process. Lautering is strictly a temperature-related process. Before the drainage of the wort from the grist, the mash temperature must be increased to about 75°C-77°C (Briggs, 2004). This allows for maximum extraction of sugars without sourcing any harsh tannins from the grains. It must be ensured that the used water must be within a set temperature range to retain more fermentable material. The high heat also assists with stopping some enzymatic activity (Ramos et al., 2015).

Step 4: Boiling of wort

The wort's sterility is ensured by boiling it, which helps to prevent contamination by unwanted microbes. During the boiling step the hops, which contributes to aroma and flavour compounds, are added to the beer to enhance its characteristic bitterness. The heat from the boiling process causes proteins in the wort to change to a semi-solid state while the Ph of the wort drops. This inhibits the later growth of certain bacteria (Wunderlich and Back, 2009). The vapours produced during the boil volatilizes off-flavours, which includes dimethyl sulphide precursors. This is important in ensuring an even and strong product. The boil lasts between 60 to 120 minutes depending on its intensity. The additional schedule of the hops and the volume of the wort usually involve evaporation, which is generally expected. The boiling stage takes about one hour and, after about 45 minutes, an additional portion of hops is added (Wunderlich and Back, 2009). There is a reason for not adding hops all at the same time, because its effect various between certain stages. The early addition of all the hops can result in too bitter beer, as well as the loss in aroma. However, to ensure that beer is of good quality, you need to ensure that hops is added at specific times for a specific type of beer (Farber and Barth, 2025).

Step 5: Fermentation

This is the next step after the wort boiling, which involves fermentation. The yeasts transform the sugars into alcohol during the fermentation process, whereby carbon dioxide is constituted resulting from a chemical transformation. Therefore, fermentation must not take place in a sealed vessel, because it will cause the pressure to constantly build up (Briggs, 2004). The fermentation process begins once yeast has been added into the boiled liquid. If the yeast has been added at a too high temperature, this can lead to yeast cells being destroyed, as it is highly temperature sensitive in nature. Hence, the liquid is always made to cool down to a temperature of about 20-30°C, depending on the type of yeast used (Peyer, 2017). Once the yeast has been added to the liquid, it must be left at a warm temperature, because when it is left in a fridge, the chances are the yeast growth will be very slow, which will prolong the fermentation process. When the temperature is around 20°C, yeast growth becomes faster and fermentation occurs quickly. Therefore, setting the required temperature is highly dependent on the beer selection and the yeast used during the fermentation process (Peyer, 2017).

Step 6: Packaging

Packing plays an essential role in product safety and quality. Furthermore, packaging will attract customers and can position a brand in the market. Breweries have to consider their target market and regulations to effectively design suitable packaging and labelling of their product. From a production point of view, there are various processes that beer has to go through in the packaging line, such as filtration and pasteurization before it reaches the bottling/kegging/canning stage (Eaton, 2017). Packaging is an important step that also ensures good shelf life and transportation ease. It is therefore important to ensure that, when the product reaches this stage, it is of a suitable standard to be packaged for the market and consumption.

2.4 Potential Beer Spoilage Organisms

Coliforms are bacteria commonly used as indicators of environmental contamination, while faucal coliforms are hygienic indicators. They are the most dangerous bacteria that derive from animal and human waste (Paruch and Maehlum, 2012). Beer is commonly served with food in pubs and restaurants, and ensuring hygienic practices is important for controlling biofilm formation on all related equipment, including in pipelines, tanks, and on joints (Storgårds et al.,2006). An effective hygiene protocol should therefore ensure that documentation exists on how equipment must be constructed to allow for all surfaces that are in contact with beer to be easily cleaned. In general, all the surfaces that come into

contact with food and beverages must be disinfected, all equipment must be cleaned, and pipelines must be cleaned and drained automatically (Schmidt and Piotter, 2020).
A study in Finland discovered that, despite hygiene practices in a brewery establishment, undesirable organisms were still found in the beer being tested (Storgards and Priha, 2009).

2.5 Utilization of Appropriate Bacterial Culture Media

The technique of culturing bacteria on a medium in a laboratory is known as 'bacterial culture'. Different bacterial species have diverse culture parameters, with oxygen being the most essential component (Bonnet et al., 2020). Bacterial cells are cultivated in either an aerobic or anaerobic culture, depending on whether the bacteria need oxygen. For the bacteria to develop, they require the right nutrients, which are supplied by culture media (Mészáros, 2022).

An even greater surface area for growth is provided in a laboratory by filling Petri dishes with prepared agar and solid media. However, caution must be exercised to prevent over-drying of the solid media, as this may minimize bacterial growth and/or cause cell death. A solid culture medium is beneficial, provided there is a need to form a solid/pure culture of bacteria from the material which includes numerous species of bacteria or strains. The use of a certain type of medium depends on what one is culturing or testing (Atmanto,Paramita and Handayani, 2022).

Additionally, only certain bacterial species or strains can grow in these highly selective media. The process includes the addition of inhibitors into the culture medium, which inhibit growth of the bacteria besides the target bacterium. Examples of inhibitors are certain chemicals, colourants, antibiotics, antiseptics, and sodium salts (Bonnet et al., 2020).
When handling bacterial cultures, the handler should consistently apply good aseptic practices in addition to using sufficient bacterial culture media to prevent contamination.

This means that, to protect the bacterial cultures from aerosols, the handler should work in a laminar flow hood or biosafety cabinet wearing clean gloves (Mukherjee et al., 2023).

Utilization of correct culture media is fundamentally important to ensure that pure cultures are obtained to allow growth, to control counts of microbial cells, and to cultivate and select microorganisms (Hayek et al., 2019).

2.5.1 The sausage agar method

The sausage agar method is a basic and faultless way of counting the number of microbes on surfaces or equipment, such as conveyors, tables, hooks, knives, and any other types of equipment sampled. The trace elements that are present in the agar medium are necessary for microbiological growth to ensure effective sampling from surfaces (Garg et al., 2010).

Over the past 60 years, microbiologists have been trying to detect and measure microorganisms on surfaces, but it was only in the 1930s that designing and assessing the prime methods for sampling surfaces were successful (Chimileski and Kolter, 2017). Many variables affect the choice of a certain technique, such as the kind and chemical makeup of a surface and the anticipated amounts and kinds of microbial contaminants. While some studies usually focus on accurately quantifying the number of germs on surfaces, others tend to provide an index of sanitation (Chimileski and Kolter, 2017).

In terms of composition, the agar sausage consists of a plastic sausage-like casing which is filled with agar medium. During its application, the sausage is usually cut off and the agar column is brought into contact with the area to be tested when testing a surface or food. A sterile knife is used to cut a slice that is approximately 0.5 cm thick. The slice is then placed in a Petri dish with its exposed surface on top. One Petri dish is typically filled with four slices, which are then incubated at 37^{o}C for 12 hours. One slice should be used as a sterility control in every second dish, and it should not have come into touch with the specimens being examined (Louw, 1967; Moore and Griffith, 2002).

Griffith (2002) demonstrated that the distribution of bacteria on surfaces, whether they were present singly or in colonies, could be reflected using the agar sausage technique. The success of this technique is due to the colonies being broken down during sampling. Swab rinse procedures were also found to yield a single cell count. According to Louw (1967), the agar sausage technique is specifically utilized in commercial settings, while Freitag (2023) avers that it serves to offer an index of sanitation in industry settings. The use of the agar sausage method, as reported by Ten Cate in Europe and Louw (1967), is to regulate the cleanliness in food and brewery establishments. As it has been shown to be quite useful in the bacteriological sampling of food and equipment surfaces (Ranken, 2012), this method has the added benefits of being inexpensive and requiring few resources. Moreover, it is easy to demonstrate and can also be utilised by employees after training in food factories and in breweries (Ranken, 2012).

2.5.2 Lin's Wild Yeast Medium (LWYM)

Certain 'wild' or non-brewing strains of *Saccharomyces cerevisiae var. diastaticus*, often shortened to *S. diastaticus*, have the potential to decarboxylase the phenolic acids in the wort to their corresponding phenols, which can result in unwanted off-flavours in beer. It is essential to separate these wild Saccharomyces yeasts from brewery fermentations that produce beers with phenolic off-flavours (Gernat, Brouwer and Ottens, 2020). Different media have been commonly and widely used in breweries in recent years to detect wild yeasts. These media allow for the quantitative estimation of contaminating wild yeasts, such as *S. diastaticus*, and their isolation for additional characterization. Nevertheless, no single medium is perfect for detecting every type of wild yeast (Hill, 2025).

For the identification of wild yeast, Walters and Thisclton, (1975) developed a method using Lin's wild yeast medium, which was later improved by Morris and Eddy (Gobbi et al., 2013). This medium encourages the growth of *Saccharomyces cerevisiae var. diastaticus*, which is one of the wild yeast species that inhibits the growth of other yeast cultures or bacteria. The Lin's wild yeast medium was therefore specifically developed for this purpose (Gobbi et al.,2013).

2.6 Hygiene Management in Craft Beer Production

The key criteria for quality beer are fulfilling customer expectations, achieving consistency, and the elimination of unwanted surprises (Pelletieri,2015). Customers reportedly require characteristics such as flavour, aroma, colour, alcohol content, haze, foam, and content of gas, to name a few (Carvalhoet al., 2018). These specifications stay mostly the same for beers packaged in bottles, and sometimes in cans. However, a large quantity of dispensing parameters, including gas management, product temperature, and inadequate hygiene protocols, are to blame for beer quality compromise. Some of these factors that can affect how a brand is presented include how well it is being dispensed and the level of product loss, which is related to an incorrect mix, product pick-up, high or low pressure, and temperature that can either be too high or too low (Mallet, Stuart and Quain, 2017). Most closed systems used in beer distribution and production use cleaning-in-place (CIP) methods, meaning they don't need to be disassembled. The duration of cleaning in these systems is usually long and such systems may be affected by the time, depending on the process of bacterial adherence and aggregation at surfaces (Devolli et al., 2016). Cleaning-in-place (CIP) is the method used worldwide to make sure that the hygiene and cleanliness of a plant are not compromised. This process involves the cleaning of machines and the selection of an appropriate cleaning fluid to achieve a hygienic plant/cleaning process (Goode, 2012).

Breweries must use sanitary design and CIP systems to prevent the presence of potentially contaminating microbes, to reduce wild yeasts, to prevent wort and beer cross contamination, and to diminish equipment and pipework fouling (Davies et al., 2015). CIP methods are applied in processing lines that are closed and are used in the beer brewing process. Nevertheless, the implementation of CIP is often restricted by the collection of microorganisms on the surfaces of equipment. Hence, it is argued that the removal of dirt and germs requires mechanical cleaning (Davies et al., 2015). Although there are times during actual operations when the process has little mechanical activity, the turbulence flowing through the pipes and spray nozzles within the round-cylinder tanks may cause a mechanical force. This is due to the surface tension and low chemical penetration as cleaning agents struggle to remove microorganisms that have adhered to pits and crevices (Habschied and Mastanjevic, 2022).

Equipment and pipe fouling decreases heat transfer and fosters a habitat (environment) that is favourable for the development of microorganisms. Guarding against cross-contamination is particularly important in contract brewing because it can affect beer quality through compromising product flavour or cause the cross-contamination of yeast strains (Davies et al., 2015). When there's a possibility that surfaces and other equipment used in combination with the tank could contain traceable bacteria, then all the processes require hygiene practices because, without it, manufacturing cannot proceed. Using nutrient-dense raw materials for extended periods during processing can contaminate tank surfaces (Al-Sharify et al., 2025). If this risk is not addressed, it can have a catastrophic effect on product quality and availability as microbial proliferation will result and large batches of product may have to be discarded.

It has been shown that certain hydrodynamic properties control the cleaning process in closed systems (Li et al., 2019). In both production and cleaning, fluid fluxes play a crucial part. Computational fluid dynamics (CFD) is a technique that improves the hygiene of the components of equipment and their incorporation onto the process of production. Salo, Friis and Wirtanen (2005) state that keeping tanks clean is crucial in order to avoid contamination. Hygienic design principles are essential to minimize and control the contamination of brewery equipment, including tanks, pipelines, couplings, and other pertinent accessories.

Therefore, proper construction, process automation, process layout, and the correct choice of tools, materials, and accessories are key considerations in design. As part of the hygienic design, any surfaces that come into contact with the beverage should be simple to clean. All areas that come into contact with beer should be smooth, pipelines and equipment should drain easily, and pits, cracks, and pointed edges must be avoided. For every brewery, large or small, cleaning and disinfection are critical, and chemical cleansers have been regarded as more effective than disinfectants in removing germs adhering to surfaces (Habschied and Mastanjević, 2022).

Breweries usually utilise pressure cleaning using a low foam system or a thin-film cleaning system in order to clean exposed surfaces such as bottling conveyor chains, fillers, and bottle inspectors. To keep things clean, disinfectants that are effective in cold climates are often used (Storgårds and Priha, 2009), while hot solutions and strong chemicals should not be used. Foam cleaning and a disinfectant spray should be used together with basic cleaning that involves disassembling parts that are hard to visually assess. Furthermore, to stop the organisms that cause spoiling from spreading, care must be taken because pressure washing produces aerosols (Storgårds and Priha, 2009). The implementation of a good hygiene management system in the brewery sector plays an important role in ensuring product quality and environmental safety. Brewery handlers form a critical aspect of this process as they have to be hands-on in the cleaning process. Managers also have to put in place good training systems for hygiene management, while they need to guide and assist staff in achieving good hygiene standards at all times, according to legislation.

2.7 Capacity Building through Training Interventions for Brewery Handlers

Capacity building is vital to ensure that staff members understand the organisational culture and processes that safeguard product quality. Food safety training and educational interventions usually cover a major aspect of ensuring product quality and product safety for consumers. The different approaches followed by various food and beverage industries indicate that growth and improvement are vital, particularly pertaining to the implementation of strategic approaches that will ensure positive outcomes and effectiveness (ESIONE and Okeke, 2019).

Although craft beer is a product that is unique to the brewing sector, it falls in the food industry as it is a consumable and requires standard food safety adherence. An important aspect of ensuring good hygiene practices is that employees have access to training manuals and other relevant information for compliance with food safety regulations and regular in-house and external training. The learning material should be constantly available on-site to ensure easy access, and proper understanding among all employees is vital for referencing on the job. Training as an intervention measure should be well structured to capacitate every employee in the organisation (Kuhr et al., 2017).

Methods of training commonly include verbal lectures, demonstrations, virtual sessions, and the usage of posters to make requirements visible and accessible to everyone. Most craft breweries often engage in the participation of developmental programmes that enhance employees' knowledge and add value to the business (McGrath and O'Toole, 2013). All these initiatives can assist in effectively running the establishment and in complying with inspections and audits.

Brewery handlers are responsible for the correct application of acquired knowledge through various forms of training. Moreover, through good hygiene practices, effectiveness should be visible in any brewery. The application and practice of specified guidelines that inform the establishment must be regularly monitored, otherwise training will not be effective. Therefore, brewery management teams should align training interventions on hygiene with company policies to ensure that brewery handlers comply with an effective control and monitoring system (Pellettieri, 2015).

2.8 The HACCP System in Craft Beer Establishments

Every brewery establishment has to manage the possible contamination of the brewery by eradicating spoilage microbes that come from diverse sources. The main contaminants of beer emerge from raw materials and proliferation in vessels. Secondary contaminants are introduced into the beer during stages such as bottling, canning, and kegging (Villacreces, Blanco and Caballero, 2022). Roughly half of recorded microbiological issues have been ascribed to secondary contaminants (Obi, 2017). As a result of exposure to the habitat (environment) during the filling stage, bottling and canning lines in breweries are usually considered open production equipment. These have the potential to become contaminated from outside source and environmental surroundings (Priest and Stewart, 2020).

The HACCP system is widely used in beer production establishments and other operations as part of a quality management system. This system involves microbial control, prevention of bacterial contamination, and the application of hi-tech packaging equipment (Singh and Choudhary, 2018). According to Singh (2018), the implementation of HACCP in craft brewing can ensure effective control measures during the various processing steps to ensure safety and good beer quality. It is also governed by the South Africa's national standards SANS 10330:2007 which ensures food safety by providing requirements for implementing a Hazard Analysis and Critical Control Point (HACCP) system (Standards South Africa, 2007). HACCP is a safety tool that ensures:

- Upgrading of products' quality and operational efficacy; and
- Attention to customers' requirements and effective hygiene.

However, in addition to complying with the Foodstuffs Cosmetic and Disinfectants Act to ensure food and beverage safety for consumer, a well-implemented HACCP system reflects a well-established hygiene design (World Health Organisation, 2023).
This could be useful in monitoring and maximising beer analysis quality parameters during the production process. Despite quality assurance procedures, it is vital to make sure that the process of cleaning is efficient. Visual inspection, swab samples, and microbial analysis of the next batch are key during the CIP process (Bai et al., 2007).

HACCP is considered an important management system and a scientific technique in craft beer breweries as it contributes to ensuring a safe beer product. de Llano, Rodríguez-Saavedra and Moreno-Arribas (2025) highlights that when HACCP is applied in the brewery industry, it focuses on critical control points, the monitoring of objects, and sound control standards.

The flow chart for the production of various alcoholic drinks was studied by Singh (2018) in India, who conducted an extensive analysis of the application of HACCP to discover any weaknesses in the line of production. This also included the implementation of critical points in compliance with ISO 9000. The study revealed that a well-established HACCP system in the selected breweries resulted in an end product that was of high hygienic quality (Singh and Choudhary, 2018).

2.9 Safety Disposal of Spoiled Craft Beer in Breweries

A study was conducted in British craft beer breweries to obtain details of the brewery process and operation, with particular emphasis on the disposal of by-products (Kerby and Vriesekoop, 2017). The investigators discovered that craft brewers in urban areas used different disposal methods compared to those in rural areas. The brewers in urban areas tended to dispose of higher waste through sewage systems and landfill-sites, including optioning for the use of external companies, such as anaerobic digester plants and bio-recycling (Kerby and Vriesekoop, 2017). This study also posits that most rural brewers of craft beer have a working relationship with farmers who get rid of their by-products by using them as nutrients for their crops.

Even though craft beer brewers normally have a working relationship with users of by-product, they still don't have an option for every waste product they need to dispose of, whereas larger industrial breweries tend to have such options (Kerby and Vriesekoop, 2017). This suggests that there is an existing gap for small-scale craft breweries that do not have the capacity to ensure safe and sustainable waste management processes.

The brewery industry uses energy and raw materials for manufacturing and the distribution of waste products. Energy usage in the value chain is relatively high and this has implications for the environment. The manufacturing industry in South Africa does consider its energy sources to minimise the costs and emission of carbon due its high contribution to national CO_2 emissions (Kan, Mativenga, and Marnewick, 2020). It is essential to understand the impacts of waste products on the environment and to put in place measures to reduce these effects without reducing final product quality. In craft beer brewing, waste disposal steps are performed hands-on, unlike in larger breweries that use automated equipment. Hence, standard operating procedures (SOPs) and waste energy management systems must be implemented carefully in order to achieve sound waste disposal measures in the craft beer industry (Agyingi, 2020).

Numerous by-products are generated in the brewing process that involve resources such as grain and hops. While much research has been done to escalate sustainability both environmentally and economically within the operations of craft beer brewing, little is known about the use of increasing waste volumes of brewery by-products as a valuable product stream emanating from this industry (Kerby and Vriesekoop, 2017). Craft breweries mostly make use of sewage lines for liquid waste disposal and landfill sites for solid waste disposal. These are, however, unsustainable and potentially costly. Most craft beer brewers will have tailored disposal solutions that suit their budgets and the geographic constraints of their waste streams, but these are currently largely dependent on government programs/systems for safe waste disposal. Albert (2021) argues that the craft beer industry must evaluate its manufacturing procedures and implement innovative techniques that lower energy usage and waste creation in order to lessen excessive waste generation.

2.10 Craft Beer Positioning in the Market

Bolton and Tarasi (2017) outline key areas that need to be considered when positioning craft beer in the market, namely the selection of significant choices to allow learning within the industry, the building of value to support the firm and its customers, and "directing origin of value". These authors also emphasise the importance of "resource investments across functions, channels, organisational units, [to] globally advance the product and customer document case". These areas are vital when positioning the brand in the market and establishing a good market base. Marketing plays a significant role in business advancement, and craft beer is a niche product offering that needs consideration of the dynamics of its niche-ness and its safety for consumption.

The market for craft beer is growing rapidly, and driving this industry is consumers' increasing appreciation for distinctive and artisanal beers. Many opportunities for growth and market penetration can be explored, despite existing restrictions related to product expansion. Furthermore, distribution and regulatory issues may hinder market growth. For craft beer brewers, overcoming these challenges in the face of intense competition and environmental concerns creates a dynamic and complex environment (Lahnalampi, 2016).

Well-implemented brewing companies compete fiercely in the craft beer business. Craft breweries find it strenuous to obtain a significant market share which is caused by immense marketing budgets, large distribution networks, and economies of scale possessed by the industry titans (Pozner et al., 2021). Craft breweries can find their ability to expand to be limited by competition, and there is a need to come up with new ways to set their products apart. By using e-commerce platforms and international trade agreements, craft breweries can enlarge into new areas and expand the diversity of them customer base. Craft brewers may now introduce their distinctive products to a wider range of consumers thanks to easier access to a worldwide market.

Craft beer is experiencing massive growth as a result of collaboration between brewpubs and brewers. These collaborations present brewers with a platform to experiment, produce one-of-a-kind and limited-edition brews, and attract customers searching for distinctive and pleasurable beer experiences (Pozner et al., 2021). More precisely, brewpubs are uniquely placed to highlight innovative craft beer and motivate direct customer interaction, which will speed the market's growth (Romano, Ciani and Capece, 2025).

2.11 Labelling Regulations for Product Safety

South African beer, which is governed by the Foodstuffs, Cosmetics and Disinfectants Act No. 54 of 1972, under regulation R146 the labelling of foodstuffs that are sold for public consumption. Along with incidental topics, this Act regulates the import, manufacturing, and sale of food items, cosmetics, and disinfectants and it also directs the requirements for product labelling and product safety (Štulíková et al., 2020). The functions of beer packaging are to protect the product from degradation, sustain quality, preserve hygienic content, and provide consumers with ingredient and nutritional information (Ramos et al.,2015). Labelling is a vital platform for information dissemination from the producer to the consumer, and consumers have the right to be aware of and to access such information. Labelling is also there as a comprehensive and legal strategy to notify customers about the health dangers that may arise from alcohol intake. It also provides consumers with relevant information about the ingredients, shelf life, and manufacturer's information for traceability. Product details are indicated on a label, and these details are usually printed on the packaging, which is a piece of material attached to a container or object which could be made of fabric, metal, polymer, or paper, to name a few (Van Doosselaere, 2024).

Another option is that a label is printed directly onto the product or container. The label normally gives instructions and any other relevant safety precautions in addition to details about the product and its intended uses and informs consumers about the product's features (Van Doosselaere, 2024). Other information relevant to consumption includes nutritional labelling, which provides data on energy content that can contribute towards an individual's nutritional and health status (Van Doosselaere, 2024).

Any beverage with more than 1.2% alcohol by volume should be clearly labelled with the alcoholic strength so that it is easily discernible by consumers. It is important that alcohol information labels are accurate and provide reliable information at all times. It is broadly admitted that alcohol labels must communicate that excessive drinking or inappropriate behaviour are not advised or encouraged, although alcohol consumption is significant in many cultures and is fundamentally meant to be enjoyed.New packaging trends in beer beverages mostly focus on modified materials of packaging to enable a link with environmental conservation (Borah and Dutta, 2019).

Common materials that were traditionally used in beer packaging were glass, metals, cardboard, and plastic. The correct selection of materials for packaging plays a major role in sustaining quality and sustaining freshness between distribution and storage (Morgan and Lane, 2022). Therefore, to ensure product safety, it is important that beer products have appropriate labelling information such as product name, country of origin, alcohol content, address of the manufacturer, storage information, expiry date, nutritional information value, and health messages. Such information is vital to ensure traceability (Thøgersen, 2023).

2.12 Conclusion

The beverage industry is growing and there is mounting pressure for safety standards to be on a par with changing consumer demands. Therefore, issues around environmental sustainability and sourcing local products have become highly important because they have direct implications for markets and product quality and acceptability. Consumers are becoming more aware of their rights, privileges, and the role of social responsibility that companies the need to project product offerings. Craft breweries are important local sources of beer products that are already competing with larger market-leading brands; hence, the playing field is not so level for such small establishments.

Brewery hygiene is an important aspect in minimising the risk of contamination and ensuring good quality of end product. Microbiological control is a regulative system that is necessary to prevent and eliminate contaminating microorganisms. It is important to detect such microorganisms early through on-going hygiene control and to maximise the procedures of cleaning to improve overall hygiene. To achieve this goal, microbiological analyses using standard selective media are suitable for the examination and detection of contaminating microorganisms.

A successful hygiene assessment of surfaces during the brewing process can yield beneficial results to eradicate the impact of microbial contamination that may have detrimental environmental, health, and economic consequences. At the same time, good hygiene practices and the implementation of an effective HAACP system within breweries play an important role in microbial growth reduction within a beer brewing environment. The literature highlights that there is room for improvement in the brewery industry when it comes to hygiene management and the implementation of effective monitoring measures to ensure the minimization of bacterial growth. Brewery handlers also have a major part to play in making sure that hygiene practices are followed rigorously on a daily basis.

This chapter discussed debates in relevant literature and presented various findings on the craft brewery establishment. Essential factors that impact this industry were highlighted, such as methods, processes, systems, product quality, and market dynamics. All of these factors can influence hygiene practices through microbiological monitoring of craft beer production. The next chapter will explore the methods that were used to obtain the data sets that are analysed and discussed in Chapter 4.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter will delineate the methodology that was employed to assess hygiene practices in craft beer production. The methodology included sampling, data collection, and the data analysis processes that were used to address the study's objectives. The methodology selected for the study was considered suitable for determining the various aspects that could influence hygienic practices adopted in these breweries. When selecting research methods, the following criteria were considered to ensure that the research objectives were met:

- Two craft brewery establishments were identified as the targeted research sites.
- Breweries of a particular size and operating systems were selected.
- The time frame of the project and the logistics required to collect the samples were considered.
- Available resources, including testing kits and laboratory accessibility, were determined beforehand.

3.2 Ethical Clearance

An ethical application process was submitted using online registration to access the Research Information Management System (RIMS) which was supported by the Health Sciences Ethics Committee (HSREC) of the Central University of Technology, Bloemfontein in collaboration with the University of Free State (UFS). Ethical approval was granted by UFS-HSD2020/0406 to conduct the study (Annexure A). All protocols were followed according to the Human Research Council guidelines regarding the treatment of human participants.

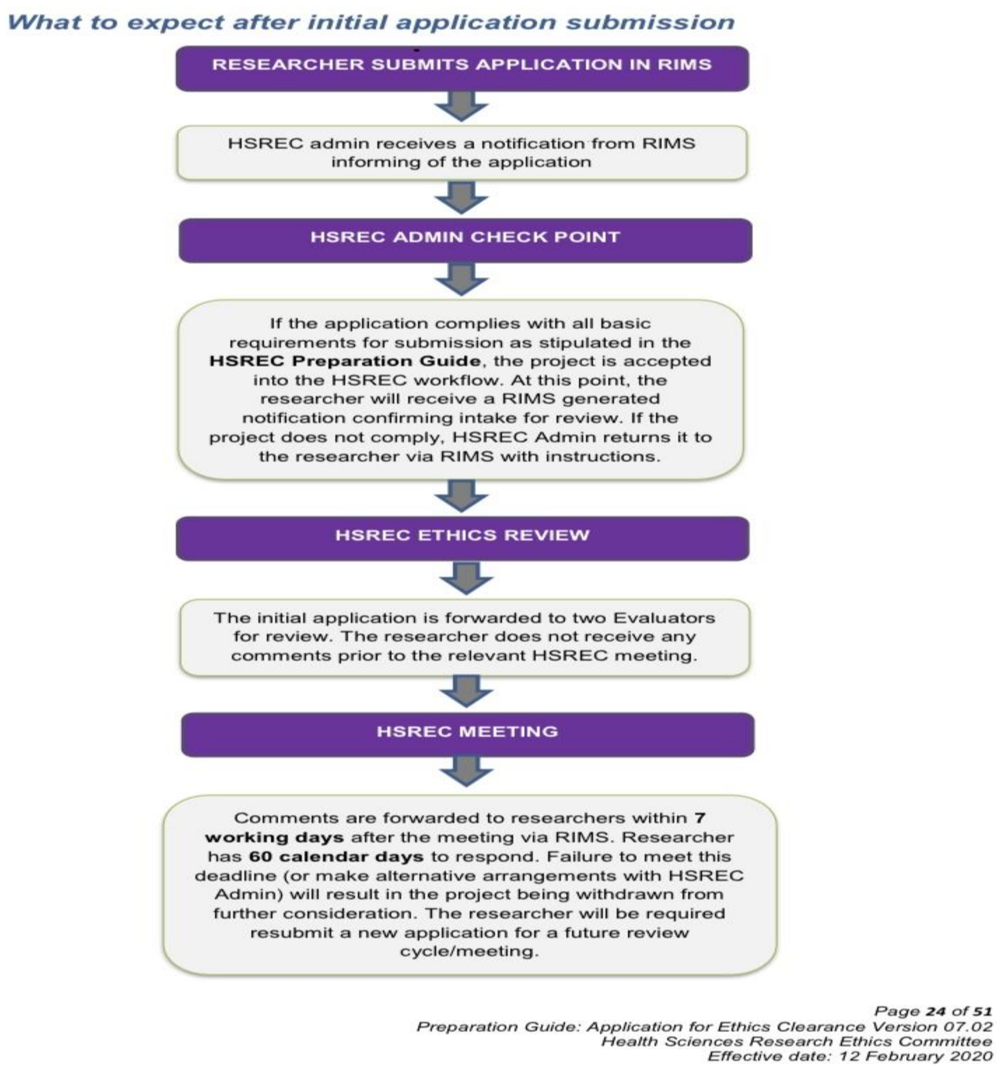


Figure 3.1: Stages of the ethical clearance process

Source: Health Sciences Research Ethics Committee, 2020

Permission was also granted by the operational management teams of selected Brewery A and Brewery B to conduct inspections and interviews and to take swabs (Annexure B). The study jurisdiction fell under the supervision of the Msunduzi Municipality located in KwaZulu-Natal Province. The Msunduzi Environmental Health Services granted consent for the analyses to be conducted in a certified laboratory. All inspections and observations followed appropriate guidelines for assessing food establishments. All the voluntary employees who participated in the study willingly signed the consent form which was a component of the self-administered survey. Information regarding the study objectives was provided in an information letter together with a consent letter that was given to each participant.

3.3 Empirical Study Design

The study design followed the following six steps:

Stage 1: Environmental analysis of the brewery sites and problem identification

Site visits were conducted for inspection purposes at Brewery A and Brewery B, where an audit checklist was used as a guideline to check environmental compliance. The findings were recorded for further analyses and conclusions were drawn based on observations made for each establishment using the checklist.

Stage 2: Literature review

Articles relevant to the study were sourced and are referenced in this dissertation to ensure accurate reporting and understanding of trends currently in the craft beer market. Furthermore, this was necessary to find a balance between previous and the current research. Different articles from past and recent studies were perused to compile a literature review, as presented in Chapter 2.

Stage 3: Planning the study design and processes

A study proposal was submitted to the relevant academic institution as a precursor to conducting research in the Health Sciences field. After approval had been granted, the researcher engaged with her supervisors to seek guidance regarding various research specifics. The study design process involved identifying key features that needed to be addressed and a hypothesis was formulated, followed by the study objectives.

Stage 4: Stakeholder consultation and engagement

Stakeholders, namely the craft breweries' operational management teams, had to be consulted to obtain permission to conduct the research in the two selected craft beer breweries. Consultations were also initiated with relevant UMsunduzi Municipality personnel and laboratory staff to ensure acceptable and trustworthy data analyses.

Stage 5: Study rollout, monitoring and management of data

Questionnaires were rolled out during the data collection phase to the participating brewery employees and engaged with the participants individually. Data were captured and managed on an Excel spreadsheet which only the researcher had access to. This data was securely stored for the study period as required by the university's policy for storage of data.

Stage 6: Reporting on the study results

The results emanating from the analyses are reported in tables and graphs and explained in the discussion section of this dissertation. Conclusions are drawn concerning their meaning and implications.

The breweries are situated in the Natal Midlands which is a popular tourism area. The circle on the map in Figure 3.2 shows where the study was undertaken. This area is administered by the Msunduzi Local Municipality which has a Category B municipality ranking. It is situated in the uMgungundlovu District in KwaZulu Natal. uMgungundlovu is a municipal district of Pietermaritzburg, which is the capital city of the KwaZulu Natal province, and located about 80 km from Durban, the country's busiest harbour. It is also linked to the country's busiest industrial hub, Gauteng, by the N3 that runs through the district (www.bing.com, 2022).

Figure 3.2: Map of the location of the study area in the Midlands Meander (ww.bing.com, 2022).

3.4 Study Approach

This was a comparative study that utilised scientific data collection and analysis methods. The investigation focused on two selected craft breweries and drew comparisons between the two based on quantitative and qualitative data. These breweries are within the same geographical area and are referred to as Brewery A and Brewery B. Using both quantitative and qualitative data, the study is characterised as a mixed-methods investigation. Mixed-methods research collects, analyses, and triangulates data by 'mixing' the quantitative and qualitative findings in a single study in order to elicit in-depth understanding of the research problem (Klassen et al., 2012). The two establishments were visited, swabs were collected and analysed, questionnaires were administered, and the findings were compared by the researcher who is a trained environmental health practitioner.

3.5 Sampling Strategy

The study involved purposive sampling of the two brewery sites based on their close distance and known operations. The brewery sites are 8 km apart and in the same geographical area. The craft breweries were part of the municipal data base, an appointment was secured to meet with the craft breweries managers physically in order to discuss permission to conduct the study.

This sampling type that was employed, which is also known as judgement sampling, meant that the researcher utilised their expertise to pick the most useful sample for the purposes of the research (Campbell et al., 2020). Hence, the researcher visited both establishments, conducted observations, administered questionnaires to employee volunteers, and comprehensively judged the operations from a mixed-methods study approach.

The qualitative research component involved the technique of an observational audit checklist that was used to gather information on structural compliance/requirements for the brewery establishments.

The quantitative approach also formed a bigger component of the study where, the technique of a self-administered questionnaire was used, which allowed the researcher to gain in-depth knowledge of the specific phenomena she investigated, instead of making statistical inferences in this instance where the population was small and precise (Sibona and Walczak, 2012). The purposively selected sample was therefore effective as intended by the rationale for its inclusion.

As the research was propelled by the mixed-methods approach, quantitative data was also recorded after the collection of swabs and beer samples for microbial data analysis. This was purposive considering that only the two selected craft brewery sites were compared regarding their characteristics and operations.

The quantitative method thus involved numerical data collection and analysis aimed at finding patterns and averages within the population; hence, two sets of laboratory analysis data were obtained (Sibona and Walczak, 2012).

The selection criteria for the two brewery sites were the following:

- The brewery had to be legally operating in the area with a license.
- The brewery should be listed under the uMsunduzi Environmental Health Inspection Unit.
- The brewery had to be at least two years in operation.
- The brewery should have staff operating the production line.
- The brewery should have sufficient equipment to ensure effective production of the beer.

Exclusion criteria included any brewery in the area that was not yet officially recognized, breweries producing beer on a commercial scale, breweries outside the Msunduzi Municipality's jurisdiction and database, and breweries that operated only seasonally.

Site visits were an important methodology utilised in terms of collecting data.

3.5.1 Description of the breweries investigated

Brewery A:

Brewery A is privately owned and located in the Nottingham area which is 8 kilometres from Brewery B. This site has a HACCP system in place used as their food safety

monitoring tool and complies with the Food Regulations R638 of June 22, 2018 (Department of Health, 2018). Brewery A employed five people and had been in existence for 23 years at the time of visit. This brewery produces on average two hundred litres of lager beer per week and has one product range. Brewery A conducts ongoing training on sanitation and hygiene on a monthly basis and random in-house training on a weekly basis to ensure the effectiveness of hygiene practices.

Brewery A has well-developed systems implemented for hygiene monitoring/management such as HACCP with a small population size of employees (n= 5) due to most of their processes being automated.

Brewery B:

Brewery B is located in the Midlands Meander overlooking the farmlands of Nottingham. The brewery has approximately 10 full-time employees and has been in existence for 9 years. In terms of processes, this brewery still follows an old traditional style of brewing for their production line. They rely on manual labour for managing the production processes and their beer production volume varies depending on the productivity of the strength of the production line staff members. This is restrictive as there is limited use of technology for production.

This brewery produces an average quantity of 50 litres of craft beer per week and the product range is mainly lager craft beer. The brewery has a strong market base as it caters for local distribution and public events such as festivals. This brewery relies on its developed policies for ensuring food safety and has the HACCP system in place, but it was only partially functioning at the time of visit.

3.6 Measuring Instruments

The study used various measuring instruments to effectively address the objective of collecting a variety of data sets. The following instruments were used for data collection:

3.6.1 Self-administered questionnaire

The self-administered questionnaire was used to gather in-depth information on the hygiene practices employed in the two breweries. These included the washing of hands, sanitation, and wearing of personal protective clothing. The information also included waste disposal practices during the brewing process. The questionnaire was presented and discussed in English but translated in isiZulu for all the employees to understand.

It was distributed on rotation intervals of two employees at a time in the staff canteens and the employees answered on the same day. The survey period took an hour and the employees of each brewery answered to the best of their abilities. The questionnaire had been designed by the researcher with reference to similar investigations by previous studies (Shuvo, 2018). An excel spreadsheet was used to capture the data which were analysed by calculating percentages for each presented frequency, summing up the total number of respondents per criteria, divided by population size, and multiplied by 100 to obtain a percentage (%).

3.6.2 Observation checklist

Observing the structural establishment at each of the two selected breweries formed part of this study. The data were captured based on an audit checklist sourced from Food Regulations 638 of 22 June, 2018 (Department of Health, 2018), which was one of the tools used to gather information based on set requirements for a brewery establishment. This tool covered the status of construction, the maintenance of floor hygiene, the condition of walls, ceilings, lighting, and ablution facilities, and the drainage of waste in the breweries. The audit checklist used as qualitative method also included investigating the type of disinfectant used, hygiene monitoring programs in place, employee training in hygiene practices, frequency of sanitation training conducted, and self-reporting questions. The data were collected by doing a walk-through inspection and ticking according to each criterion. Additional notes/comments were also recorded of each brewery's hygiene status for descriptive purposes (Department of Health, 2018). The data were analysed by means of a descriptive comparative table to compare the two breweries.

3.6.3 Microbial data index

Microbial sampling was conducted which involved the use of sausage agar method in order to swab various surfaces and equipment's within the breweries, which included the vessel (mash mixer), kegging tank, packaging area, aprons, and both hands of the staff. Working equipment were further examined to evaluate the hygiene status of the swabbed surfaces and equipment's.

Table 3.1 summarises the areas swabbed and the reference guidelines for an acceptable swabbing area.

Table 3.1 Swab calculation standards for a craft beer production line

Swab Collection Points	Method	Benchmark Guidance Value	Status
Hazards Area in Craft Beer Production ▪ Surfaces throughout the production line ▪ Production equipment ▪ Protective clothing of employees ▪ Employees hands	Sausage agar method	▪ $0 \leq$ CFU/100cm$^2 \leq 8$	Very good
		▪ $12 \leq$ CFU/100cm$^2 \leq 36$	Good
		▪ $0 \leq$ CFU/100cm$^2 \leq 116$	Satisfactory

Source: (Viro, 2019; Department of Health, 2018)

3.7 Procedures for Microbial Data Collection

3.7.1 Sampling of areas and equipment

After permission had been granted by the site managers, key areas for taking swaps were identified which included the vessel (mash mixer), kegging tank, packaging area, aprons, and employees' hands. The researcher arrived during peak time in the afternoon to collect samples. The collection of microbial data involved the taking of swabs from the surfaces to assess the level of microbial contamination.

The researcher used a sampling tool kit and also prepared other relevant material needed to collect the swabs. A mixture was made by measuring 500 ml distilled water in a 200 ml beaker (refer to figure 3.4 and 3.5). Then, 5 g of bacteriological agar No. 2 and 20 g of violet red bile agar were added. The mixture was stirred and heated until completely dissolved. Subsequently, it was poured into sterile 50 ml artificial casing syringes and stored in a fridge to solidify for 30 minutes or until ready for sampling.

3.7.2 Sampling protocol for employee and surface swabs

Before proceeding with the sampling, the researcher donned suitable personal protective clothing: gloves, hairnet, apron, and safety shoes as per the guidelines of the brewery sites. The employees were made comfortable by the researcher and she briefed them on the procedure and the purpose for collecting swabs from their hands and aprons and from the equipment.

The sliced surface of the sausage agar was smoothly compressed against the surfaces of the selected kegging and bottling tanks, aprons, and hands to check for microbiological contamination (FAO, 2019). This may be compared to a 'stamp' process. After the surfaces had been in purposeful contact with the agar sausage, thick slices of the contact areas transformed to the agar were cut off in slices of 0.5 cm using a sterile knife. The slices were transferred to sterile Petri dishes. A sterile paring knife was used before taking a new sample, and 3 slices of 'stamps' were collected from the surfaces of the kegs, bottling tanks, aprons, and hands. Each Petri dish held 3 slices and was properly labelled with a date and identified on a data sheet before it was placed in a cooler box and incubated at room temperature for 12 hours. This quality assurance process for labelling was conducted as per FAO (2019) guidelines.

3.7.3 Agar sausage gel media

The agar sausage method was used because it is a simple and precise procedure to determine microorganism/coliform counts on the surfaces of equipment, human hands (left & right hand), and clothing. The procedure can be used to collect samples from all kinds of equipment, e.g., conveyors, tables, tanks, hands, aprons, and knives, to mention a few (Horwitz,1974). However, the sausage agar is not ideal for sensitive evaluation due to its high cell absorption. Additionally, it is also associated with challenges concerning standardizing the sampling method, while its reproducibility is often inadequate (Barnes, 2008). Fortunately, these drawbacks did not impact the samples taken in the current study.

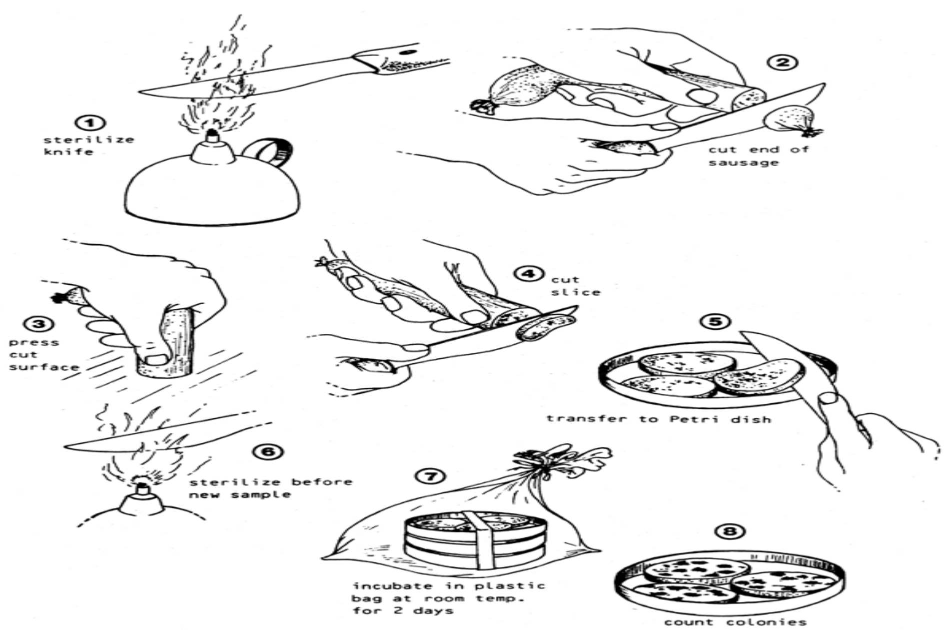


Figure 3.3: Application of the sausage agar method

Source: Barnes, 2008

3.7.3 Sampling protocol for beer

Aseptic sampling techniques were used for craft beer sample collection. The specific type of craft beer that was sampled was lager beer.[2] An aseptic sampling technique involves the collection of samples in a sterile environment to prevent contamination between collections. Aseptic samples are normally used to verify other processes to assist various observations between two collections, and for the elimination of product contamination (López, Roche and and RodrÃguez, 2020).

The researcher collected a minimum of 5 ml craft beer samples from a single production line of lager beer from each brewery. Duplicates of each production line of the same sample were collected. For the two breweries, a total of four craft beer samples per brewery were collected over a period of two months between Week 1 and Week 3 of

October 2021 and November 2021. The purpose of the collection of duplicate samples from the same production line was a quality assurance measure to ensure that the researcher had extra reserved craft beer samples in case of spillage during transportation.

The samples were stored in a cooler-box and delivered to the laboratory for analysis to test for *Saccharomyces cerevisiae var diastaticus* using Lin's Wild Yeast Medium (LWYM). This medium was prepared using the following ingredients: LWYM dehydrated powder, mixed with a crystal violet solution. A suspended 4.4 grams of LWYM was inserted in a 500 ml flask and 1.0 ml of crystal violet solution was added and stirred. The solution was heated to boiling point to dissolve the medium and the flask was swirled frequently to avoid caking. The mixture/solution was put into an autoclave at a temperature of about 121˚C for 15 minutes to ensure sterilization of the medium. This

[2] A lager is a type of beer characterized by its bottom-fermenting yeast and cool fermentation process, resulting in a crisp, clean taste. Unlike ales, which use top-fermenting yeast at warmer temperatures, lagers are brewed at lower temperatures, and often undergo a longer "lagering" or storage period for flavour development (Google, accessed 10 July 2025).

was transferred to a flask in a water-bath at about 45˚C, and cooled. Once cool, 15 ml of the medium was transferred to sterile Petri dishes and were left to solidify (refer to figure 3.6 and 3.7).

The poured solidified plates were kept at a temperature of 4˚C for the duration of 24 to 48 hours before use, but it was ensured that it was used within 5 days of preparation because the medium would inhibit the growth of wild yeast.

The Lin's wild yeast medium that was used which contains sugars, vitamins, trace elements, and amino acid building blocks necessary to promote the selective growth of *Saccharomyces cerevisiae var. diastaticus.*

Figure 3.4: Equipment used to measure 500 ml of the medium

Figure 3.5: Distilled water with density tablets in a magnetic stirrer

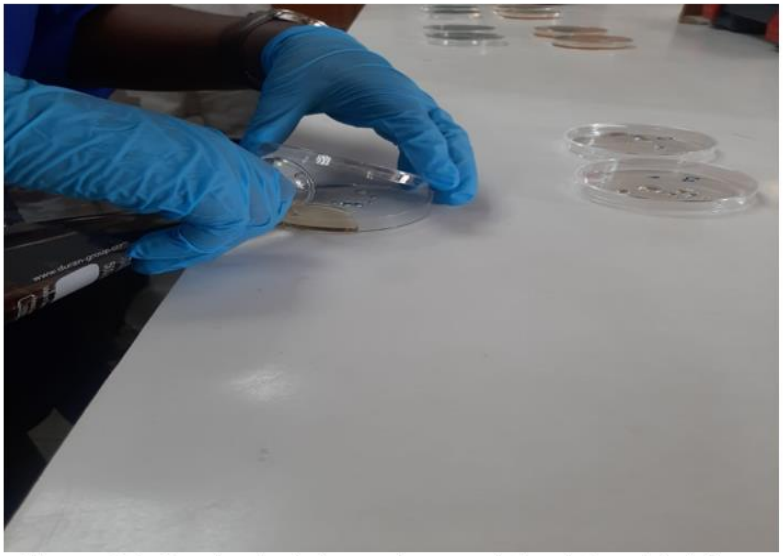


Figure 3.6: Pouring technique of agar solution into petri-dishes

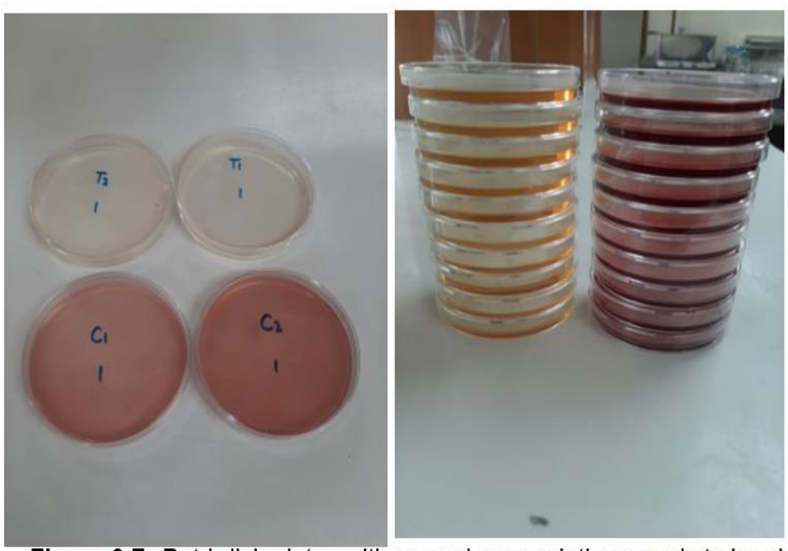


Figure 3.7: Petri-dish plates with poured agar solutions ready to be placed in an incubator for microbial growth

3.8 Statistical Data

3.8.1 Capturing and coding data

The data were captured and coded and inserted on an Excel (R) spread-sheet by the investigator. Analysis of the questionnaire data were done using the Statistical Package for Social Sciences (SPSS) for Windows Version 17.0 software program. All data from the observation checklist and the self-administered questionnaire were recorded on an Excel spreadsheet after collection. The spreadsheet was used as a standard template, where results from Brewery A were separated from results of Brewery B to comparatively look at the two establishments.

Data from the observation checklist and questionnaire are presented in tables and graphs. Microbial data for both the brewery sites were recorded by the researcher on a data recording tool during sampling, and further stored on an Excel spreadsheet which was the standard template. The data sets obtained from microbial data were analysed by application of mathematical formulas to obtain readings for the data. Data were presented in graphs derived from the exponential graph and bar graphs and then plotted to represent the relationship between hygiene and bacterial growth.

Statistical analyses were performed to highlight patterns and trends within the research study area. For this comparative study, reliability was one of the tools to test the consistency and stability of the results of the self-reported questionnaire administered to employees at craft Brewery A and Brewery B. This helped to determine consistency across a set of items/criteria designed to measure hygiene and safety practices in the two craft breweries. The questionnaire reliability was measured making use of Cronbach's alpha, which yielded the coefficient of about 0.886 across the six items/criteria, where a high Cronbach's alpha value would indicate a strong internal consistency and well-correlated items/criteria. Therefore, a Cronbach's alpha value of above 0.8 was deemed good, indicating that respondents answered the questions well and consistently. Therefore, it was confirmed that with an obtained Cronbach's alpha value of about 0.886

items within a questionnaire were mostly reliable, interrelated and measured as a unified construct, which also strengthened the validity of the findings and supported the use of the questionnaire for the assessment of hygiene and safety practices in the two craft brewing establishments.

3.8.2 Statistical data analyses

Section analysis was used to search through specific components of the study questionnaire by examining individual items and combined responses to better understand patterns of hygiene practices between the two selected craft breweries, which revealed insight into which practices were adhered to consistently and which required improvement. This also allowed for in-depth recommendations for the craft breweries in terms of their hygiene standards.

Further statistical tests and analyses were conducted to address the study's objectives, which included descriptive statistics of CFU levels using swabs and beer samples by determining mean, median, standard deviation, and minimum and maximum values to summarise microbial distribution. A trend analysis test was part of this study to display line graphs for the visual purpose of CFU levels over time and showing trends for the craft breweries in the results of both swabbing and beer samples.

A paired t-test was conducted to assess the patterns of microbial growth between time points within each brewery, and the results of one-way ANOVA tests were incorporated to assess the distinctions in CFU numerical data across all time points in Brewery A and Brewery B. For comparisons between the two breweries, an independent t-test was conducted on CFU levels in Brewery A and Brewery B at each sampling point, and an ANOVA test was conducted for the combined analysis tested for significant differences in microbial growth between Brewery A and Brewery B. A chi-square trial test was done to evaluate the relationship between the two brewery establishments and to categorize the statuses of hygiene based on the CFU threshold.

The questionnaires were self-administered and collected after 30 minutes to prevent the participants from discussing the answers. Scratches or markings on the questionnaire were not allowed to ensure that the data were not tampered with. During the stages of microbial sampling in the laboratory, the aseptic sampling technique was followed to prevent contamination by unwanted microorganisms. The samples collected from the craft breweries were stored in a cooler-box during transportation to maintain the temperature and integrity of the samples.

Sampling was done by the researcher who has a background in laboratory work and the results obtained were compared to established reference ranges specific to the tests conducted. Data from the samples were collected and stored in a computer for the duration of the study and protected by a password. The observation checklist used by the researcher was sourced from relevant legislation to ensure that relevant research outputs were observed and addressed accordingly, and to make sure of the reliability and the validity of the observational checklist, which was a standardised inspection tool that outlined the appropriate craft brewery establishment requirements to be measured.

3.9 Conclusion

This chapter delineated the research methodology and processes involved in addressing the study objectives. The instruments used were carefully selected to ensure that all the necessary variables were analysed. This research aimed to establish the hygiene status and control procedures of two craft beer brewing establishments and to analyse an effective control of microbial contamination in the stages/steps of brewing. Chapter 4 will present the data and the in-depth analyses of the results and the interpretations of findings by the investigator.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the comparative results that emerged from the data that had been obtained from two craft beer breweries using various data generation and analysis tools. The findings revealed varying results, highlighting the need for quality and safe craft beer products emanating from consistent monitoring and sound operational and maintenance procedures. The results are reported in tables, graphs, and in-text discussions that provide evidence of the overall hygienic status of the establishments as well as the suitability of their respective operational and hygiene practices.

This study aimed to explore the hygiene and safety practices within the two craft beer breweries by focusing specifically on individual behaviours related to personal protective measures, cleanliness, and sanitation during brewing processes. With the increasing popularity of craft brewing, ensuring that safety and hygiene protocols are consistently followed is crucial in maintaining quality and safety standards. This research also utilised data from a self-reported questionnaire to determine the frequency of staff members' specific practices of hygiene, including washing of hands, jewellery removal, and the wearing of personal protective clothing. By examining these practices in the two breweries, the study identified good and poor adherence patterns and highlights areas for improvement. Although the scope of the study was relatively limited and the findings may not be generalised, they may still inform a broader level of comprehension of safety standards within the craft brewing industry, and may also be utilized to support initiatives aimed at promoting safe and hygienic brewing environments.

The literature argues pertinently that microbial contamination within brewery environments poses significant risks to both product quality and consumer health (Ciont et al., 2022). Therefore, understanding the prevalence and trends of microbial contamination levels across different brewery surfaces and beer samples can inform quality control strategies and sanitisation protocols. This part of the study examined the microbial contamination levels detected in swab and beer samples taken at the two breweries (Brewery A and Brewery B) over several time points. Microbial levels across these environments were compared, and the results are presented and discussed. The aim was to evaluate contamination trends over time, determine if significant differences in microbial loads existed between the two breweries, and to assess variations within each brewery at specific intervals. This study also aimed to assess the structural establishment status of the two craft breweries to emphasize the important role adhering to hygiene protocols and demands within the craft beer brewery environment, and to address certain criteria such as training, structural status, and inspection frequency within the two craft brewery establishments. Data were also elicited that formed part of the research conclusions drawn from recorded observations using an inspection tool.

4.2 Summary of Hygiene Observations and Analyses

The results in Figure 4.1 reflect the combined analysis of the two breweries to illustrate a holistic picture of the personal hygiene practices prevalent in these two breweries. The trend analysis of hygiene and safety practices between the craft beer breweries revealed varying levels of adherence across different factors, indicating areas of strength and areas for improvement.

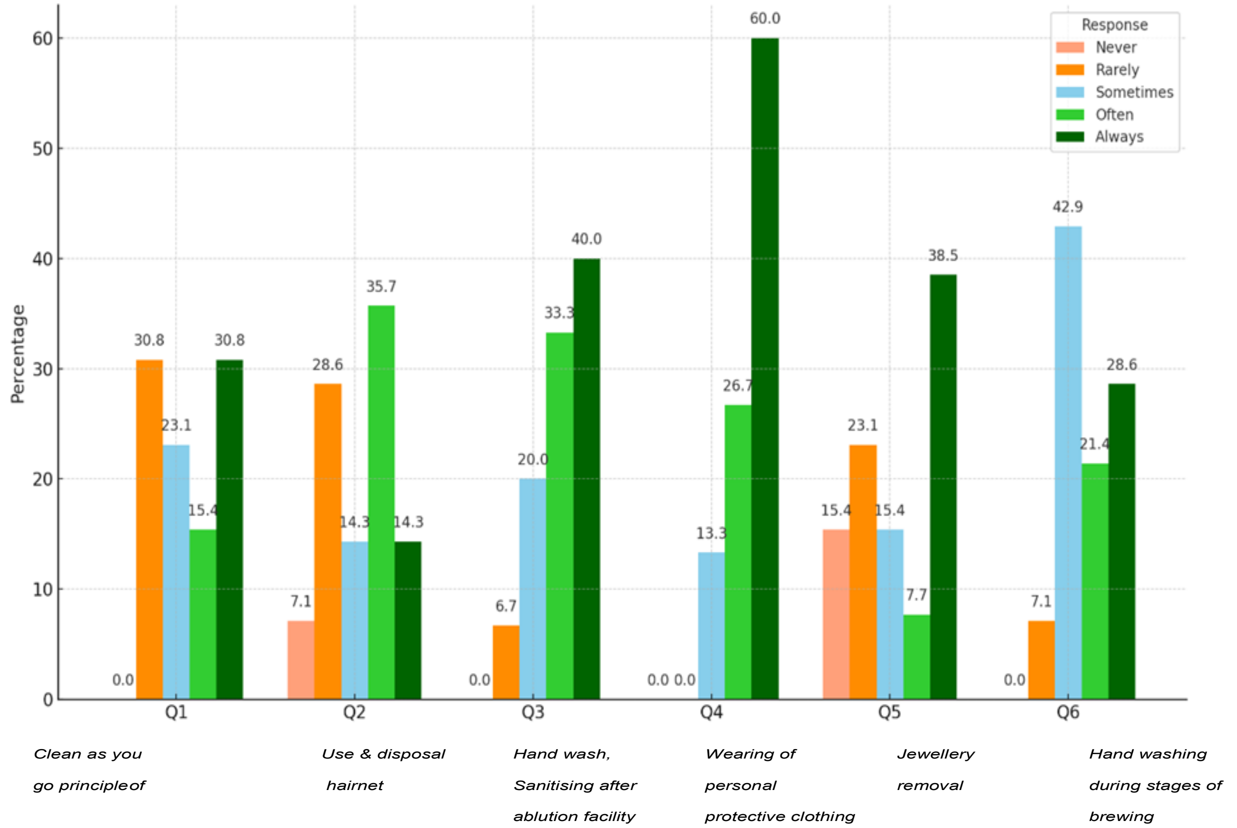


Figure 4.1: Percentages of combined data for both breweries on self-reported questions

4.2.1 Combined results of the two breweries

High adherence in personal protective clothing: The data showed strong adherence to wearing personal protective clothing, with 60.0% of respondents indicating they "Always" followed this practice. This high level of consistency suggests that the brewers acknowledged the importance of protective clothing in ensuring both personal and product safety.

Mixed adherence to hand washing practices: The responses for hand washing and sanitising after using ablution facilities showed that 40.0% of the participants "Always" followed this practice, while an additional 33.3% did so "Often." Hand washing during brewing stages had a slightly lower adherence, with 28.6% always following this practice. This indicates a positive trend toward regular hand hygiene, but also suggests the imperative to encourage more consistent adherence.

Inconsistency in the "clean-as-you-go" practice: Adherence to the "clean-as-you-go" principle was somewhat varied, with only 30.8% “Always” following it and a similar percentage indicating they "Rarely" did. This inconsistency might reflect either a lack of emphasis on this practice or challenges in implementing it regularly.

Varied use of hair nets and gloves: The use and disposal of hair nets and gloves presented mixed results, with 35.7% of the respondents "Often" following this practice, while 28.6% did so "Rarely." This practice appears less consistently followed than others, indicating an area where improved adherence could enhance overall safety.

Moderate adherence to jewellery removal: The practice of jewellery removal showed moderate adherence, with 38.5% indicating they "Always" removed jewellery, while a notable 15.4% "Never" did. This variation suggests that jewellery removal may not be uniformly emphasised in hygiene protocols issued by the respective breweries.

The comparative results in Figure 4.2A and Figure 4.2B reflect notable differences between Brewery A and Brewery B regarding hygiene practices. Providing an insight into adherence trends and highlights areas of potential improvement.

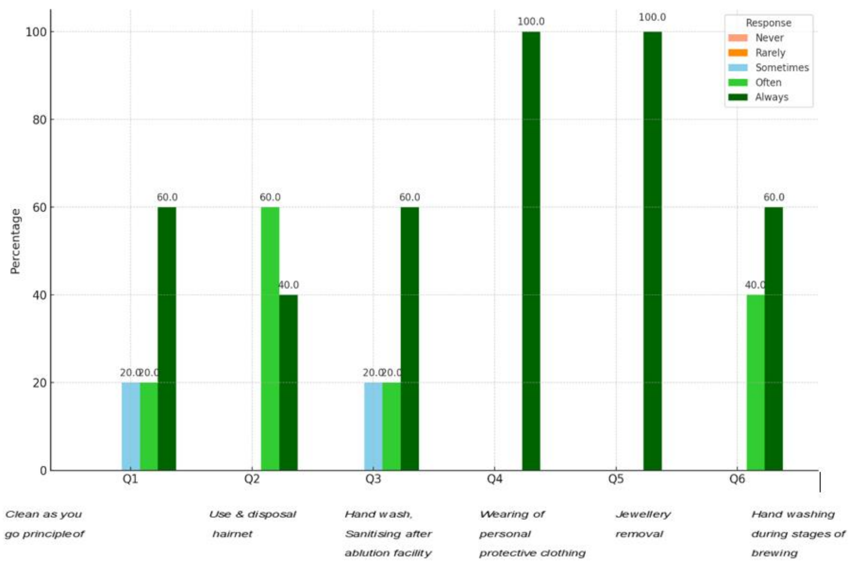


Figure 4.2A: Percentage of responses for self-reported questions Brewery A

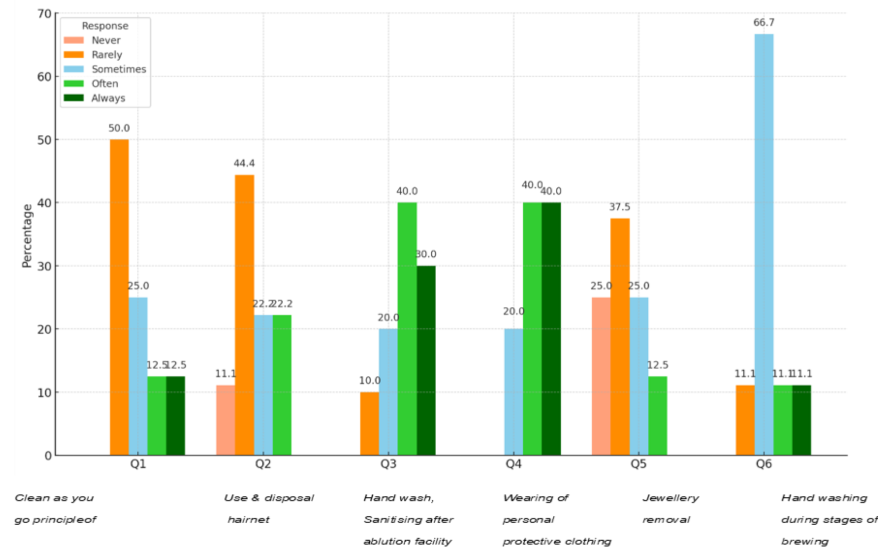


Figure 4.2B: Percentage of responses for self-reported questions Brewery B

4.2.2 Comparative results between the two breweries

Adherence to the clean-as-you-go principle: Brewery A had a high level of adherence, with 60.0% of the respondents stating they "Always" followed the clean-as-you-go principle. In contrast, Brewery B had a more varied response, with only 12.5% "Always" adhering to this practice and 50.0% "Rarely" doing so.

Use and disposal of hair nets and gloves: Brewery A again demonstrated relatively high adherence, with 40.0% "Always" using and disposing of hair nets and gloves, whereas Brewery B showed a wider distribution as 44.4% "Rarely" adhered to this practice and only 22.2% followed it "Often".

Hand washing/sanitising after using ablution facilities: Brewery A showed high adherence with 60.0% "Always" washing or sanitizing hands, compared to 30.0% in Brewery B that also displayed a mix of "Often" (40.0%) and "Sometimes" (20.0%).

Wearing of personal protective clothing: Brewery A showed complete adherence, with 100% of respondents "Always" wearing personal protective clothing. Conversely, in Brewery B only 40.0% "Always" followed this practice, while the remaining responses were split between "Sometimes" (20.0%) and "Often" (40.0%).

Removal of jewellery during brewing operations: Brewery A had high adherence with 100% of the respondents stating "Always" removing jewellery. Brewery B, however, was less consistent, with only 12.5% "Often" adhering to this practice and 25.0% never doing so.

Hand washing during brewing operations: Adherence to hand washing during the brewing stages showed that in Brewery A 60.0% "Always" followed this practice, while in Brewery B 66.7% adhered "Sometimes" but only 11.1% "Always" do so.

Table 4.1 presents comparative data of the hygiene and safety practices between Brewery A and Brewery B. These data provide insight into adherence trends. Areas for improvement emerged unequivocally, particularly in Brewery B. The data, summarised using proportional tests, revealed statistically significant differences in adherence patterns across the two breweries.

Table 4.1: Personal hygiene practices in Brewery A and Brewery B

				Practices of the clean-as-you-go principle	*Use and disposal of hair nets and gloves*	*Hand washing/ sanitising after using ablution facilities*	*Wearing of personal protective clothing*	*Removal of jewellery when brewing*	*Hand washing during the stages of brewing*
Brewery-A	A	Never	Count	0	0	0	0	0	0
			Row-N %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Rarely	Count	0	0	0	0	0	0
			Row-N %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Sometimes	Count	1	0	1	0	0	0
			Row-N %	20.0%	0.0%	20.0%	0.0%	0.0%	0.0%
		Often	Count	1	3	1	0	0	2
			Row-N %	20.0%	60.0%	20.0%	0.0%	0.0%	40.0%
		Always	Count	3	2	3	5	5	3
			Row-N %	60.0%	40.0%	60.0%	100.0%	100.0%	60.0%
Brewery-B	B	Never	Count	0	1	0	0	2	0
			Row-N %	0.0%	11.1%	0.0%	0.0%	25.0%	0.0%
		Rarely	Count	4	4	1	0	3	1
			Row-N %	50.0%	44.4%	10.0%	0.0%	37.5%	11.1%
		Sometimes	Count	2	2	2	2	2	6
			Row-N %	25.0%	22.2%	20.0%	20.0%	25.0%	66.7%
		Often	Count	1	2	4	4	1	1
			Row-N %	12.5%	22.2%	40.0%	40.0%	12.5%	11.1%
		Always	Count	1	0	3	4	0	1
			Row-N %	12.5%	0.0%	30.0%	40.0%	0.0%	11.1%
		Proportional Test		**0.232**	**0.079**	**0.850**	**0.117**	**0.003**	**0.028**

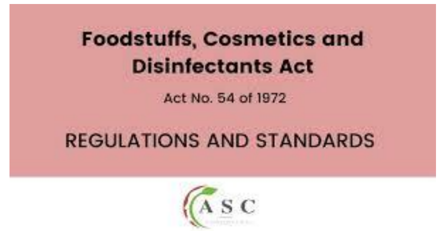
The proportional test results for the removal of jewellery during brewing operations (p = 0.003) revealed a statistically significant difference, underscoring that Brewery A had a much stronger adherence to this safety practice compared to Brewery B. These outcomes outline the significance of emphasizing jewellery removal as a critical measure of safety within Brewery B. Moreover, there was a noticeable and significant difference (p= 0.028) between the breweries for hand washing, with Brewery A showing greater consistency in hand washing during brewing operations. These findings suggest that Brewery B could benefit from additional focus on these specific practices to align with safety standards adherence in Brewery A.

4.2 Observations of Potential Exposure to Risks: Operational Practices

Table 4.2: Workplace hygiene practices in the two craft beer breweries

Workplace practices	Comparative observations between Brewery A and Brewery B			
	Brewery A	**Brewery B**	**Food Safety Standards/Legislation**	**Existing practices**
Training, information and hygiene systems	This brewery had well-developed systems in place which included a well-established HACCP system within the brewery. The training system was well implemented and structured to accommodate all the employees within the brewery where there were information posters available on hygiene and sanitation, and ongoing training records on a monthly basis were available. These covered proper hand washing techniques, sanitization, use of personal protective equipment, and proper disposal of	Brewery B was still developing their systems and relied on government awareness in terms of training, which included public imbizo and advocacy sessions provided by the government. They had over these training sessions, if provided, but conducted in-house training on hygiene management on a quarterly basis. This training focused on basic hygiene awareness in the canteen. There was no proper monitoring as their records were not up to date.	The hygiene systems within beer brewing establishments of any kind are covered by specific standards such as ISO 22000 which outlines the food safety management systems that promote food safety, quality and efficiency by ensuring adherence to HACCP system requirements. These pre-requisite methods and requirements are outlined to ensure food safety through emphasis on audits and training as important in the food industry.	A craft brewery must have well implemented hygiene systems in place with monitoring tools and training opportunities for all staff members. Brewery A showed adherence to hygiene standards as a fully functioning HACCP system was in place. It had well-structured, effective training programs. Brewery B still adhered to old, out-dated traditions and training while with the required hygiene practices were neglected.

	waste. The employees had access to an online training program implemented for their brewery. Brewery A had a supervisor who monitored and facilitated training programs and ensured that information was always circulated on time at all times.			
Regular inspection of food premises by sanitary-officers (for adequacy of size, supply of water, ablution facilities, and lighting)	In this brewery the inspection frequency by a municipal inspector was moderate. Brewery A had a monitoring tool in place which covered water supply, waste management, sanitation, and lighting and they applies this tool monthly as part of their in-house inspection protocol. This inspection ensured that the brewery establishment was in good condition and well-maintained at all times.	Brewery B had a high frequency of inspection visits by a municipal inspector due to their ongoing non-compliance status and structural defects of cracked floors, damaged ablution facilities, old paint, and dirty sinks. All required improvement. The identified structural defects indicated poor attention to vital brewery components that this research exposed.	Inspections are conducted by an Environmental Health Practitioner who is fully registered with a legal oversight body, namely the Health Professions Council of South Africa. This body ensures registration and compliance of the profession. Inspections are done according to the Foodstuffs, Cosmetics and Disinfectants Act: Regulation 638 to ensure on-going monitoring and compliance which highlights that such facilities must have adequate lighting, be well ventilated, have a good supply of clean water, and have ablution facilities. HPCSA Health Professions Council of South Africa	Each establishment is expected to comply with a set of requirements that are monitored by an inspector. Brewery A complied with the requirements set out in relevant regulations, whereas Brewery B showed non-compliance with these regulations.
Craft beer storage at	Brewery A had a storage area/room which was neatly	Brewery B had a small storage area/room which was also used as staff	The storage of craft beer is regulated under the Foodstuffs, Cosmetics and Disinfectants Act: Regulation 638,	All storage areas must be clean and neatly packed at all times.

correct temperatures	packaged and met the requirements of a well-structured store room, where a good storage room is neatly packed and has clear pathways with easy access to stored products. The refrigerators were fully functional with a backup generator in case of load-shedding, allowing the beer temperature to be kept constant.	changing rooms. It was untidy because various goods were stored here. This brewery did not have any backup in the event of load shedding and their beer storage/fermentation temperature was not constant.	which outlines that beverages such as beer are to be stored at room temperature in a storage room which must be free of any obstacles and be kept clean and neat at all times. 	Brewery A complied and adhering to clean storage requirements, whereas Brewery B had a small, untidy storage area used for multiple purposes and constant human presence.
Good environmental hygiene	Brewery A adhered to good hygiene practices and ensured at all times that their work environment was neat and well maintained through the application of good cleaning and sanitation procedures. They also ensured that pest control and decontamination were done by a competent external service provide to ensure proper decontamination on site.	In Brewery B, some of the members of staff adhered to good hygiene practices while most were negligent/ignorant of these requirements. The work environment was untidy and reflected tardiness/a lack of training.	The requirements set out by the above Act within regulation R638 mandate a hygienic environment free of pests. It must be sanitised regularly the clean-as-you-go principle must be adhered to. 	Environmental hygiene in the workplace is a legal imperative. Craft beer brewery sites must be kept clean, safe and sustainable. Brewery A complied by maintaining an environment that was in good state of hygiene, whereas Brewery B neglected good hygiene and had an environment that was in a bad state of cleanliness.

4.4 Microbial Analyses of Swab and Craft Beer Samples

4.4.1 Comparative and trend analyses

Figure 4.3 reveals that an unhygienic trend was consistently high in Brewery B that had higher CFU values in swab samples than Brewery A across all time points. The microbial levels in Brewery A remained relatively stable over time with only slight fluctuations, indicating consistent sanitisation practices. In contrast, Brewery B displayed a more variable trend, with significant increases and decreases in microbial levels between certain time points. The peak at Time Point 3 for Brewery B suggested a possible lapse in contamination control or an incident leading to elevated microbial counts (refer to table 4.3).

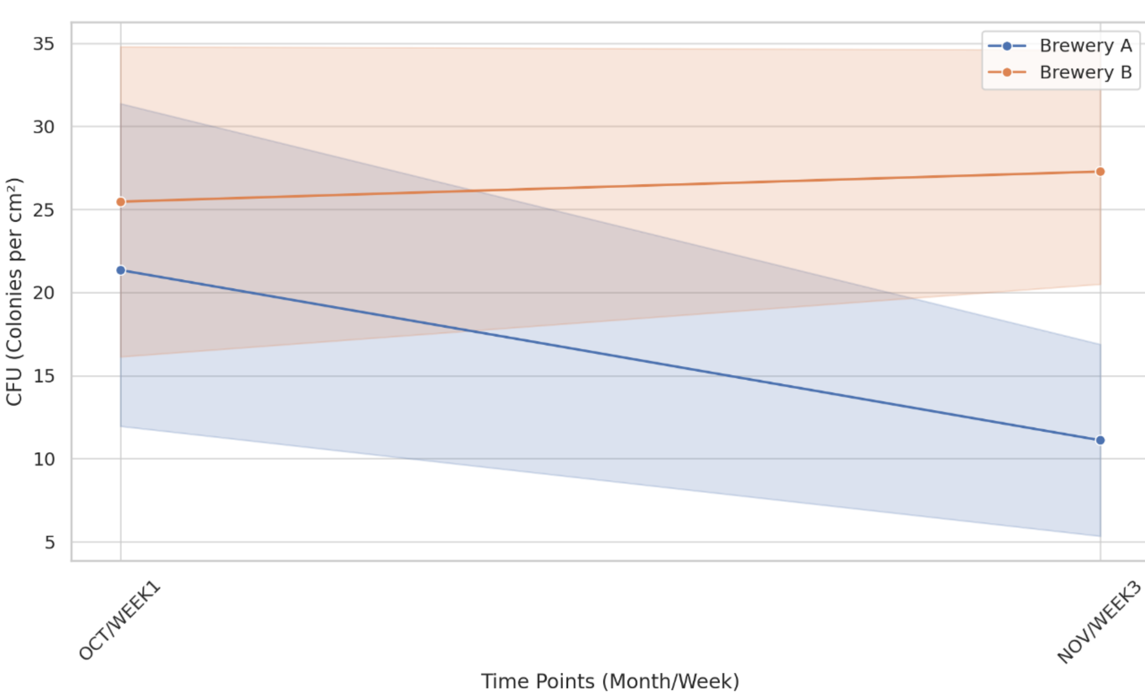


Figure 4.3: CFU Levels over time for swab samples

Figure 4.4 shows a similar trend in beer samples, with Brewery B exhibiting higher microbial levels than Brewery A across time points. Brewery A maintained relatively low and stable CFU counts, indicative of effective contamination management in the production process. Brewery B, however, showed an increasing trend in CFU levels toward the latter time points, suggesting a potential progressive contamination issue or insufficient sterilisation measures during these periods (refer to table 4.3).

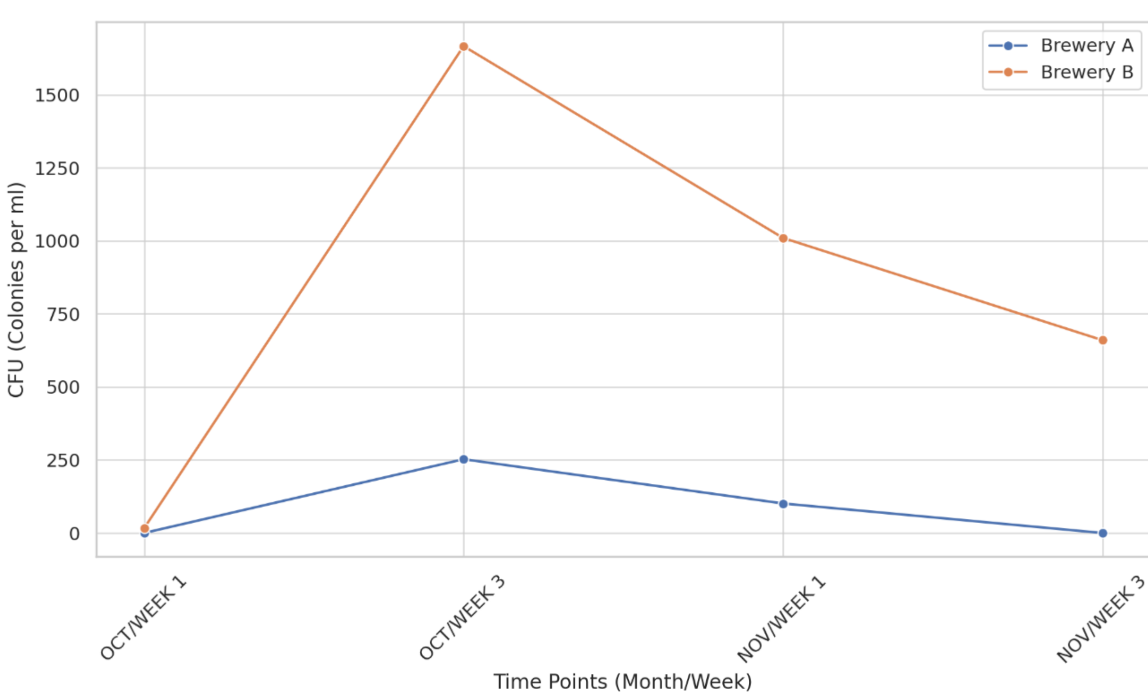


Figure 4.4: CFU Levels over time for beer samples

4.4.2 Paired t-tests within-brewery comparisons

The paired t-tests for CFU levels between consecutive time points in each brewery yielded the following findings (refer to table 4.4):

- **Brewery A**: No significant difference in swab CFU values was detected across the four time points (p>0.05), suggesting stable microbial control.
- **Brewery B**: Significant fluctuations in microbial levels were detected in swab samples across time points (p<0.05), particularly between Time Points 2 and 3, indicating potential variability in contamination control.

- For beer samples, Brewery B displayed significant CFU variations across time points ($p<0.05$), while Brewery A's beer samples remained stable over time.

4.4.3 Between-brewery comparisons

The independent t-tests conducted on each time point revealed significant differences in CFU levels between the two breweries ($p<0.05$) in both swab and beer samples (refer to table 4.5). Brewery B had consistently higher CFU values than Brewery A. A combined analysis using

ANOVA confirmed significant overall differences in CFU levels between the breweries ($F=5.31$ and $p<0.01$).

4.4.4 Chi-Square test of hygiene status

The chi-square test demonstrated an important association between premises and hygiene status (χ2=26.32\chi^2 = 26.32χ2=26.32, *p*=0.001), indicating that Brewery A and Brewery B differed significantly in their statuses in terms of the satisfactory, good, and unsatisfactory categories.

Table 4.3: Descriptive statistics of CFU levels in swab and beer samples

Brewery	Mean CFU	Median CFU	Std Deviation	Min CFU	Max CFU	95% CI Lower	95% CI Upper
A - Swab	16.22	15	11.7	2.6	38.4	16.01	16.43
B - Swab	26.37	27	12.3	8.5	41	26.14	26.6
A - Beer	8.5	8	4.5	3.2	18.4	8.32	8.68
B - Beer	33	31.5	9.1	17.3	48.2	32.72	33.28

Table 4.4: **Within-brewery paired comparisons of CFU levels across time points**

Brewery	Time-Point 1 vs 2	Time-Point 2 vs 3	Time-Point 3 vs 4
A - Swab	> 0.05	> 0.05	> 0.05
B - Swab	< 0.05	< 0.05	< 0.05
A - Beer	> 0.05	> 0.05	> 0.05
B - Beer	< 0.05	< 0.05	< 0.05

Table 4.5: **Between-brewery CFU comparisons for each time point and combined analysis**

Time Point	Mean Difference (CFU)	t-Statistic	p-Value
1	10.15	2.13	< 0.05
2	11.23	2.67	< 0.05
3	8.9	2.05	< 0.05
4	9.42	2.34	< 0.05
Combined	9.85	2.51	< 0.05

4.4.5 Discussion of results

This study facilitated a comparative overview of the hygiene and safety practices employed by the two craft beer breweries under study. The study specifically examined brewery staff members' respective adherence practices to essential behaviours, namely the wearing of personal protective clothing, hand hygiene, and adherence to sanitation measures. The investigation also included an overview of microbial contamination within the craft breweries by obtaining data of various sampled surfaces and the beer, and by observing the craft beer breweries' diverse structural integrity appearances. The results highlighted both strengths and opportunities for improvement, with significant differences in adherence observed between the two breweries. There were clear differences between Brewery A and Brewery B in terms of hygiene, safety compliance, and microbial prevalence in the craft beer production and management processes.

4.5 Attaining the Objectives of the Study

4.5.1 Study Objective 1: Monitoring practices of hygiene and food safety

With reference to Figure 4.2A, Brewery A demonstrated a higher level of adherence across most hygiene and safety practices than Brewery B, particularly regarding wearing personal protective clothing and consistently removing jewellery during brewing operations. These results could be related to the automated operations that had been put in place by Brewery A which restricted human involvement. (Also see Table 4.2, which indicates that training and visits influenced the management of the brewery). Therefore, ensuring ongoing training and inspections seemed to encourage staff members' adherence to food safety regulations, which could be attributed to high accountability. A study in India by Parekh, Agrawal and Bagale (2017) found that a craft beer brewery with automated brewing systems aimed to accomplish an intact process of hygiene control with the assistance of electronic microcontrollers that observed and adjusted all variables within the brewing stages based on the brew recipe. This obviated the need for ongoing observations by humans, which also contributed to limited direct human contact with the beer being brewed.

Conversely, Figure 4.2B indicates that Brewery B exhibited lower adherence in areas such as jewellery removal and regular hand washing during brewing stages, indicating areas for improvement. The difference between these observations can be attributed to poor hygiene practices in Brewery B, that were largely related to employees' negligence and negative attitude towards personal hygiene, lack of ongoing training, and limited resources. A similar study in Italy conducted by Manzano et al., (2011) revealed that the most effective way to minimise microbial contamination in a craft beer brewery environment is by controlling contamination with the application of adequate cleaning, sanitation, and good personal hygiene practices. It was observed in the current study that environmental health practitioners had recorded challenges due to the increasing cost of protective wear coupled with budget constraints in food establishments, and this could have been a factor that impacted Brewery B, suggesting the need for more in-depth exploration across a broader scope in the craft beer brewing industry.

The discoveries of this research highlight the importance of reinforcing hygiene protocols within the craft brewing sector, particularly for practices with variable adherence such as the "clean-as-you-go" principle and hand hygiene during brewing operations. Obi (2017) outlines the importance of adherence to hygiene guidelines within a craft beer brewery establishment and places strong emphasis on continuously monitoring systems to ensure effectiveness. This imperative is also highlighted by Baiano (2020).

Future interventions could focus on standardising these practices across breweries to enhance safety and maintain quality. In summary, the study underscores the need for continued emphasis on hygiene practices in the craft beer brewing industry, with targeted improvements that support a safer, more consistent brewing environment across all establishments.

4.5.2 Study Objective 2: Observation of compliance standards for breweries

Again, Brewery A had advanced hygiene systems in place such as good training, information programs, good beer storage, and good environmental hygiene. Brewery A also adhered to a well-implemented HACCP system that was fully functional, and this ensured compliance with standards within this craft beer brewing establishment. The literature strongly urges such compliance. For instance, Singh and Choudhary (2018) states that the implementation of HACCP in craft brewing can ensure effective control measures during the various processing steps to enhance beer safety and ensure good quality. Furthermore, it was evident that Brewery A was invested in ensuring compliance to relevant food safety regulations and standards and to inspection requirements as carried out by municipal Environmental Health practitioners. The structure of the latter establishment was well-maintained, which was another positive factor that demonstrated its commitment to and compliance with food regulations and standards.

Craft beer Brewery B consistently showed low adherence to hygiene systems, such as lack of training and information systems resulting in non-compliance with food safety standards. This poor performance could be attributed to financial constraints impacting structural development and the lack of participation in information training sessions provided by the local municipality. However, external training is not the only option, as

McGrath and O'Toole (2013) argue that various cost-effective methods of training can be effective, such as verbal training on site, demonstrations, virtual training, as well as the display of posters on walls to make key information visible and accessible to everyone. All these initiatives, including paying attention to investing in sound infrastructure, can assist a struggling craft beer brewery to effectively run the establishment and to comply with inspections and audits.

Newbold et al., (2003) confirm that food and beverage establishments can achieve high compliance rates, as 70% of the establishments in their study had high compliance rates. This included the provision of proper storage facilities. The current study's overall assessment showed that Objective 2 was achieved, as it was found that Brewery A was consistently more compliant compared to Brewery B. However, the potential to rectify gaps in the implementation of internal monitoring practices to achieve a constant standard of good hygiene exists. This will require Brewery B to focus on training and information interventions and consistent supervision of employees to ensure adherence to mandated safety standards.

4.5.3 Study Objective 3: Microbial detection on craft beer production

This objective was achieved, as the study outcomes showed a significant difference in the microbial contamination levels between Brewery A and Brewery B. Brewery B exhibited higher contamination levels in both the swab and beer samples. These results suggest differences in microbial management practices and environmental factors between the two breweries. Within-brewery comparisons further revealed more stable contamination levels in Brewery A over time, in contrast to the fluctuations observed in Brewery B. The chi-square results support the interpretation that Brewery B had a higher unsatisfactory hygiene status than Brewery A, as demonstrated by its higher CFU counts.

Although the levels differed, the fluctuations in microbial contamination within both craft breweries over time could be attributed to a lack of information regarding consistent sampling techniques for monitoring. As indicated earlier, craft beer Brewery B was highly compromised due to financial constraint and its dependence on municipal monitoring and sampling to ensure adherence to safety protocols. A study conducted by Bamforth (2009) on sampling within the craft beer environment showed that consistent testing for the sterility and improved awareness of hygiene status will lead to improved overall management by brewery handlers and the minimisation of contamination. Moreover, such practices ensure effective microbial control within a craft beer brewery establishment, particularly if the development of surface-attached bacteria on beer dispensing equipment is regularly monitored because most beer contaminants reside on unclean brewing equipment and surfaces. The latter findings were supported by the current study.

Furthermore, Holah, Lelieveld and Gabric (2016) argues that good hygiene practices play a critical role in the production of good quality beer of all types, which is a critical business attribute. The current study demonstrated that employees in Brewery A showed better adherence to hygiene practices compared to those in Brewery B. The literature urges the importance of knowledge and hygienic vessels, machinery, and all surfaces in beer brewing processes. If this environment is not hygienic and well maintained, microbial contaminants will thrive and crucially impact the quality of the final brewed product, which was demonstrated by the current study. Staff at Brewery B potentially compromised the quality of the craft beer produced due to negligence in hygiene practices that exacerbated microbial growth in this establishment.

Despite quality assurance procedures, it is vital to make sure that a cleaning procedure is structured, while emphasis should be placed on visual inspections and the regular analysis of swab samples. Moreover, microbial analysis of the next batch of beer should be conducted during the CIP process, as executed by the current research study that applied these practices to accomplish the research objectives. The detection of beer spoilage organisms, particularly in locally-produced craft beers, should be a constant concern among the operational managers and staff of such establishments. An internal hygiene monitoring protocol that mandates certain practices should be in place and visibly displayed for all workers to see in the craft brewing establishment. This protocol should be derived from all pertinent regulations to ensure consistent compliance with food and beverage safety regulations.

4.6 Conclusion

The measuring instruments that this study employed facilitated a comprehensive evaluation of the two craft beer establishments' conditions and operations, the staff members' hygiene practices, and the overall production processes to produce craft beer. The comparative nature of this study unpackaged similarities and variations between the two craft beer breweries. The evaluation of the data revealed substantial differences between the two, particularly concerning microbial contamination levels across time points, with Brewery B demonstrating higher microbial loads in both swab and beer samples compared to Brewery A. These findings underscore the importance of rigorous sanitation protocols in such breweries, particularly in areas showing high contamination. The trend analysis and statistical comparisons provided valuable insights into the temporal stability of contamination levels, suggesting that Brewery A maintained more consistent control over microbial contamination than Brewery B. The results emanating from this study may be utilised to inform brewery-specific interventions aimed at improving hygiene and reducing contamination in both production environments and end products.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In the previous chapter, the outcomes of this research were outlined and discussed in order to determine if the research objectives had been achieved. Feasible and systematic demonstrations through the presentation and discussion of credible data illuminated how the differences manifested in these breweries. This last chapter summarises the overall findings of this research study and maps out the conclusion. Pertinent recommendations are offered that can be tailored to improve operations, such as introducing clean production protocols and continued craft beer brewery case studies. Areas for future research studies in this field are also highlighted.

The beer brewing industry has confronted various challenges in controlling contamination as microorganisms tend to cause beer spoilage that affects the quality of the end product. It was affirmed by referring to the literature that the brewery environment is known to be susceptible to microbes. Due to spoilage microbes that are able to infiltrate the brewing process at any time from the beginning till the end, the final product's microbial stability can be compromised at an early point along the brewing stage. To keep wort and beer from spoiling, microorganisms that may have infected the raw materials such as hops, malt, and water, should be removed throughout the brewing process. Bacteria, including acetic and lactic acid bacteria, *Enterobacteriacea, Pectinatus, Megasphaera, Zymomonas,* and wild yeasts are microbes that can cause deterioration in beer.

Good quality assurance procedures and systems, such as the HACCP guidelines and Regulation R908 of 2003 under the Foodstuff, Cosmetics and disinfectant Act (Act No.54 of 1972), are essential for making sure that the of level cleanliness along the brewing process is high, specifically in cases where there is no sterilised filtration of the craft beer or bottle pasteurisation. Although the cleanliness of breweries has progressed significantly in recent years, secondary contaminations are also responsible for a growing percentage of microbiologically contaminated beers. By assuring that surfaces along the beer brewing process is monitored and sampled for microbiological contamination, the end product's safety will be ensured. In addition, the implementation of and adherence to proper hygiene systems and protocols will ensure that brewers are capable of producing craft beer that has a prolonged shelf life with minimal complaints from customers, increased rates of production, and minimal product rejection. The facilitation of ongoing and focused training and awareness programs that focus on hygiene practices among brewery handlers is also highlighted, because controlling contamination with proper cleaning and sanitation is the most efficient approach to stop beer from spoiling. Even though this study did not measure the effects of microbial load on the beer quality, their impact on the beer and customers' level of satisfaction are likely to be negative. It is therefore of paramount importance that Brewery B ensures that it prioritises the efficiency of its management systems to avoid product loss and brand degradation.

5.2 Study Challenges and Limitations

The most important challenges the study encountered were the following:

- Gaining access to and obtaining the permission of the craft beer breweries' managers/owners to conduct the study was a challenge that involved formal written requests and a long waiting period. These privately-owned businesses are highly sensitive to requests that might expose their operations. The researcher was fortunate that the delayed process finally ended when written permission was granted.
- The research was conducted during the COVID-19 period in 2020 and 2021, which impacted the data collection time frame as access to the brewery sites was restricted. Data collection was also delayed as lockdown restrictions were often adjusted.

The following limitations impacted the study:

- The study focused on craft beer breweries, which is a narrowly explored topic within the wider domain of beer brewing research. There were literature gaps on this topic, especially in South African regions. Most earlier studies focused on the commercial beer production market, which limited information and compelled the researcher to rely mainly on research findings of studies in Europe and North America, indicating a need for future research in the South African context.

- The study findings were also limited by the relatively small scope of the investigation. Only two craft beer breweries in a growing industry were targeted, but the methodological scope was significantly deep to ensure credible and trustworthy findings that may be considered by similar establishments and future researchers as a springboard for investigations of a wider scope.

5.3 Main Findings of the Study

The objectives of this research were to determine if there were any differences in hygiene practices by workers between Brewery A and Brewery B. The results elicited by the self-reported questionnaire are reported in Figure 4.2A and Figure 4.2B. The observed trend showed different operational patterns between the two breweries. For instance, Brewery A showed more adherence to cleaning and the wearing of personal protective clothing requirements than Brewery B. Moreover, Brewery A showed significantly higher levels of washing and sanitation after use of ablution facilities than Brewery B, whose levels were low to medium for these variables. Comparative data also reflected consistency in the removal of jewellery and adhering to hygiene requirements by staff members of Brewery A, while Brewery B showed less consistency and greater negligence in adhering to stipulated regulations and standards. A correlation was observed between the hygiene practices by the brewery workers and the hygiene status of the craft respective breweries.

The study revealed that significant improvement was required for Brewery B to comply with existing food (beverage) and hygiene standards. Based on the findings, concerted efforts should be made by this establishment to implement a good hygiene system such as HACCP, whose impact was absent in this brewery. It was also shown that Brewery A complied significantly better with structural requirements for food establishments, as good storage and a hygienic environment were evident compared to craft beer Brewery B, which had no developing system and fewer municipal inspection visits. Moreover, training programs at the latter establishment were not well structured, with a poor storage area. The distinct differences between the selected craft breweries and areas for improvement are presented in Table 4.2.

The assessment of microbial contamination showed that Brewery B yielded a higher level of microbial growth than Brewery A. Moreover, Brewery A constantly maintained low levels of microbial growth while microbial growth on surfaces in Brewery B were somewhat erratic. There was an indication that lack of hygiene was a prevalent problem in Brewery B because the presence of microbial growth was detected over time, with a noticeable spike at a certain time point.

Furthermore, the results of swab samples of various surfaces to detect microbial contamination showed that, overall, Brewery B yielded greater microbial growth levels than Brewery A over time, as presented in Figure 4.3. Brewery A showed a decrease in the growth of micro-organisms at a certain time point.

5.4 Conclusion

In light of the various interconnected factors explored throughout this study, it was concluded that the measuring instruments used provided a comprehensive assessment of the conditions at the two establishments. Clear differences emerged, with particular emphasis of the behaviour and attitude of the staff, the production processes, and the levels of microbial contamination in the establishments. Concern was raised regarding hygiene management in both craft brewery establishments, but particularly Brewery B, which was attributed to limited resources as the traditional brewing methods were still used at the latter establishment. This was deemed a hazard to food and beverage safety standards that require more updated execution and applications. This study showed that a craft brewery is dependent on its employees to facilitate the brewing process, and successful craft beer brewing operations undeniably require an end product that was produced with more focus on quality that quantity. More particularly, if hygiene is compromised it has the potential to jeopardize product safety and facilitates a favourable environment for microorganisms to thrive. Hygiene practices must be consistently reinforced and brewery handlers must be well trained in the most updated and scientifically correct procedures to ensure that a good product enters the market.

It was also revealed that one of the craft breweries neglected structural requirements, which compromised compliance with standards and regulations. If craft brewery operational managers (and by implication owners) ignore policy and guidelines, they put the entire operation and the reputation of the enterprise at risk. In essence, the study urges the consistent training of brewery handlers, sound hygiene management using HACCP, swabbing and testing for microbiological contamination at every stage of the beer brewing process.

The latter observation is pertinent as the variation in microbial counts on the surfaces of the equipment could have occurred due to a polluted environment, including water, air, pests, brewery handlers, and customer closeness within the spaces of production. Definite differences between these two craft breweries were noted, such as the layout of equipment, the quality of the equipment, the floor plan, brewing procedures, recipes, suppliers' ingredients, training methods of employees, and cleaning rules. The lack of hygiene and staff tardiness suggest that stricter practices and hygiene measures should be implemented, particularly in Brewery B.

It was also concluded that a well-established craft beer brewery with well-implemented systems may tend to focus the product's quality rather than quantity, as was alluded to earlier. This means that when hygiene practices are adhered to and taken seriously by the operational managers and brewery handlers, the brewery environment becomes less favourable for microorganisms to thrive, which is a positive impact. Therefore, ongoing monitoring of adherence to hygiene requirements ensures good maintenance and a good product that is safe and trustworthy. Again, this requires training and consistent monitoring to sustain a high level of knowledge and hygiene. Hence, when hygiene and sanitation are prioritised in a craft brewery, effective control of contamination becomes an imperative and easy to manage by all handlers.

It is therefore essential that craft beer brewers establish and follow a protocol for cleaning and sanitation. This should include capping tank valves when not in use, production surface monitoring for signs of wear, access restriction of areas with maximum risk of contamination, and rigorously following manufacturing processes that are good for microbreweries. Conducting regular retraining of employee is also necessary to ensure persistent adherence to the stipulated protocol.

5.5 Recommendations

5.5.1 Recommendations for the brewery establishments

The study recommends that brewers of craft beer ensure that prevention procedures for microorganism growth are well implemented and continuously monitored internally and by external audits. Secondary opinions through inspections are necessary to observe the national policy framework set for food operating establishments. Specific attention should focus on the procurement of quality equipment of good design, while the highest hygiene standards should be maintained. Cleaning and disinfection should be conducted meticulously, regularly, and effectively to ensure continuous microbial monitoring and eradication.

Secondly, craft beer breweries' operational managers/owners must invest in staff development programmes to enrich and update knowledge and hygiene practices and to ensure well-structured establishments. It is also important that craft beer brewers and traders work together to maximise consumers' enjoyment of the product. Both should also be aware of the importance of optimum storage parameters in the microbrewery domain to ensure craft beer of the highest standard.

5.5.2 Recommendations for the local municipality

This study affirms that the monitoring of the craft beer industry is a municipality's mandate in the food and beverage domain. Moreover, ensuring craft beer breweries' compliance with established regulations in line with the national regulatory framework, and enforcing these regulations, are part of a municipality's mandate to ensure that the micro food and beverage industry in its area of responsibility does not compromise the community's and tourists' health. The frequency of inspections of craft beer breweries should be revisited and increased if necessary to achieve change and compliance in the areas of hygiene and structural development. The education and support provided by municipal officials also play a crucial role in capacity building among craft beer brewery employees. Hence, municipal officials must embrace their oversight mandate to offer safe products for consumers and a conducive working environment for employees. It is thus recommended that regular visits of craft beer breweries are conducted and that regulations are enforced at the peril of establishments that do not comply.

5.5.3 Recommendations for policymakers

Policymakers in this field of study should involve the public during the drafting process where relevant topics are addressed. They should also devise a strategic plan to ensure public health awareness and that clear and understandable messages are conveyed to the citizenry. It is also recommended that the Craft Beer Association South Africa (CBASA) hosts workshops for small craft beer brewers to inform them of best practices and procedures for brewing high-quality craft beer without the use of costly quality control equipment. The study urges a need for the improvement of the environmental health practitioners' ratio in South Africa, as there is a shortfall in the Environmental Health Practitioner (EHPS) ratio where statistically it is shown that in South Africa there is approximately 4116 registered EHPs instead of the 6,203 required for the ideal recommended ratio of 1:10 000 by WHO's. This is a significant gap between the ideal ratio and the current reality, which impacts monitoring of and compliance by food and beverage establishments. An urgent focus on recruiting EHPs to increase the frequency of monitoring and evaluation should be prioritised by the government to ensure compliance within the sector.

5.5.4 Recommendations for future researchers

It is recommended that similar studies be conducted in other provinces of South Africa to enrich the literature on the craft beer brewery sector. Future research should be tailored to incorporate other variables, such as the implications of product shelf life and consumers' perceptions of product quality and desirability.

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Central University of Technology, Free State

ANNEXURES

ANNEXURE A: Ethical Clearance Approval Letter

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

18-Jun-2021

Dear **Ms Vuyiswa Nonhlakanipho Zulu**

Ethics Clearance: **Influence of hygiene practices through microbiological monitoring of craft beer production process in the Pietermaritzburg midlands meander breweries.**
Principal Investigator: **Ms Vuyiswa Nonhlakanipho Zulu**
Department: **Environmental Health Sciences - CUT**
Submission Page

APPLICATION APPROVED

Please ensure that you read the whole document

With reference to your application for ethical clearance with the Faculty of Health Sciences, I am pleased to inform you on behalf of the Health Sciences Research Ethics Committee that you have been granted ethical clearance for your project.

Your ethical clearance number, to be used in all correspondence is:**UFS-HSD2020/0406/2906**

The ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

Permission to be obtained and submitted from the two breweries:
1.Nottingham Road Brewery
2. Happy Days Brewery

We request that any changes that may take place during the course of your research project be submitted to the HSREC for approval to ensure we are kept up to date with your progress and any ethical implications that may arise. This includes any serious adverse events and/or termination of the study.

A progress report should be submitted within one year of approval, and annually for long term studies. A final report should be submitted at the completion of the study.

The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; International Council for Harmonisation (ICH) Harmonised Guideline, Integrated Addendum to ICH E6(R1), Guideline for Good Clinical Practice (GCP) E6(R2), 2016, SAHPRA Guidelines as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours Sincerely

Prof. A. Sherriff

Central University of Technology, Free State

ANNEXURE B: Informed Consent Letter

Statement of Agreement to Participate in the Research Study:

- I hereby verify that I was notified by the researcher, ______________________ (name of the researcher), with regards to the nature, conduct, advantages and disadvantages of the study - Research Ethics Clearance Number: ___________,
- I have received, comprehended the written information above (Participant Letter of Information) pertaining to the study.
- In line with the requirements of research, I confirm that the collected data during this research may be processed in a computerised system by the researcher.
- At any stage I may, without prejudice, holdback my consent and participation in the study.
- I've received enough opportunity to ask questions and (of my own free will) declare myself ready to participate in the study.
- I understand that significant new outcomes developed in due course of this research which may link to my participation can be made available to me on request.

_____________________ ___________ _______ _________________

Participant Full Name **Date** **Signature**

I, ______________________________ (name of researcher) herewith verify that the above participant was fully informed with regards to the nature, advantages and disadvantages of the above study.

_____________________ ___________ _________________

Researcher Full Name **Date** **Signature**

Central University of Technology, Free State

ANNEXURE C: Breweries Permission Letters

brewery at netherwood.

Dr SM le Grange
For Attention: Mrs M Marais
Block D, Room 104
Francois Retief Building

PO Box 339 (G40)
Nelson Mandela Drive
Faculty of Health Sciences
University of the Freestate
Bloemfontein
9300

Dear Dr SM le Grange

PROJECT TITLE: INFLUENCE OF HYGIENE PRACTICES THROUGH MICROBIOLOGICAL MONITORING OF CRAFT BEER PRODUCTION PROCESS IN THE PIETERMARITZBURG MIDLANDS MEANDER BREWERIES.

I Roscoe (Brewery manager), hereby grant Ms. Nonhlakanipho Vuyiswa Zulu permission to conduct the above-mentioned research project at Happy Days Brewery.

Yours faithfully

Brewer and Owner
Happy Days Brewery

[09/06/2021]

Brewer and Owner
Happy Days Brewery
Office: 033 266 7132 roscoe@netherwood.co.za

Permission Brewery A Letter

THE NOTTINGHAM ROAD BREWING COMPANY
PURE BEER BREWED AT RAWDONS
CRAFTING BEER SINCE 1996

Dr SM le Grange
For Attention: Mrs M Marais
Block D, Room 104
Francois Retief Building

PO Box 339 (G40)
Nelson Mandela Drive
Faculty of Health Sciences
University of the Freestate
Bloemfontein
9300

Dear Dr SM le Grange

PROJECT TITLE: INFLUENCE OF HYGIENE PRACTICES THROUGH MICROBIOLOGICAL MONITORING OF CRAFT BEER PRODUCTION PROCESS IN THE PIETERMARITZBURG MIDLANDS MEANDER BREWERIES.

I John Morrow (Brewery manager), hereby grant Ms. Nonhlakanipho Vuyiswa Zulu permission to conduct the above-mentioned research project at Nottigham Road Brewery.

Kind regards
John Morrow
Brewery Manager

[15/06/2021]

Nottingham Road Brewery, Rawdons Hotel, R103 (Old Main Road) Nottingham Road, 3280.
Tel: 033 266 6728 E-mail: brewery@rawdons.co.za

Permission Brewery B Letter

ANNEXURE D: Observational Inspection Checklist for Brewery Establishment

Regulations Governing General Hygiene Requirements for Food Premises and the Transport of Food Published in Government Notice No. 638 of June 22 2018

The following checklist will be used to assess adherence to the regulations

REQUIREMENTS	**YES**	**NO**
Interior wall surfaces to be constructed of smooth, impervious material and tiled or with a light painted colour, washable paint that is impervious.		
Floors to be built with hard, material impervious and brought and smoothly finished.		
Dust proofed ceiling is required, a smoothly and light paint colour should be used which should also be washable.		
Lighting and ventilation to be provided in accordance with the provisions of the National Building Regulations.		
Sink that is double bowled with good supply of hot water and running cold water for equipment's wash. Soap supply and other agents of cleaning materials should be provided.		
Double bowl sink with a supply of piped running hot and cold water for cleaning and food/beverages preparation.		
Effective means of insect/rodent control should be provided.		
Clean toilet facilities are maintained on the premises		
Suitable refuse receptacles are provided.		
All tables, equipment and furniture to be disinfected (70% alcohol-based disinfectant), cleaned and maintained.		
No live animals or birds were evident on the premises		
Employees are trained and maintain hygiene practices and such records are kept.		

Protective clothing (aprons, hairnets) is made available and utilised by all staff.		
Beer is stored in a refrigerator at 50 ºC to 55 ºC to prevent loss of flavour.		
Beer is stored in a cool, dark area away from high moisture.		

OBSERVATIONS CHECKLIST: BREWERY A and BREWERY B

OBSERVATION ON EMPLOYEES	ADDITIONAL COMMENTS

Central University of Technology, Free State

ANNEXURE E: Self-Reported Questions

1. Do you wash your hands before handling craft beer?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

2. Do you also wash your hands during brewing process?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

3. Do you use a hairnet when brewing?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

4. Do you remove any jewellery when brewing?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

5. Do you regularly wash your hands during the stages of brewing?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

6. Do you wear personal protective clothing when brewing?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

7. Do you wash/sanitise your hands after using an ablution facility?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

8. Do you dispose each hairnet after use?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

9. Do you practise the ‘clean as you go’ principle when brewing craft beer?
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always