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# Industrial Potentials of *Saccharomyces cerevisiae*

**[1]Elijah Nya and [2]Owoidihe Etukudo**
[1]Dept of Biotechnology & Genetics, Akwa Ibom State University, PMB 1167, Uyo, Nigeria
[2]Dept of Genetics & Biotechnology, University of Calabar, Calabar, Nigeria
E-mail of the corresponding author**:**

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**ABSTRACT**: *Saccharomyces cerevisiae has attracted much technological concern in recent times, owing to their extensive used in food manufacturing, fermented beverages like wine or beer and in promoting the development of industrial biobased products. Saccharomyces cerevisiae also known as yeast are eukaryotic organisms found in a wide ecological niches such as soil, water, air, plants, fruits and plant saps. Saccharomyces cerevisiae strains is the most common yeast known in history for their fermentative ability and are today biotechnologically compliance for industrial production of many products such as ethanol, yoghurt, Cheese, bread, wine and other alcoholic beverages. From their natural habitat, they have been successfully isolated and evaluated for their metabolic and fermentative activities. Investigations by many authors have shown that yeasts can be isolated from palm sap or juices, passion fruit, water melon and pineapple where they colonized as their natural habitats. The isolates from these habitats have also been evaluated and found to have attributes essential for industrial and commercial purposes. The attributes investigated include ethanol production, yoghurt, Cheese, leavening ability for bread making and other dairy products. Besides the aforementioned, yeast are used in the global food processing and manufacturing. They are said to impart improvement in food quality, taste, texture, flavour and nutritive values. In this chapter, I elucidate the potentials of Saccharomyces cerevisiae strains with reference to their industrial and commercial uses. Their classification, cultivation and selection are also discussed.*
**KEYWORDS**: *saccharomyces cerevisiae*, yeast cultivation, fermentation, characterization, commercial uses.

## INTRODUCTION

*Saccharomyces cerevisiae*, the most popular yeast are eukaryotic organisms and indeed a unicellular fungus that are found in a wide diversity of ecological niches as their natural habitat such as water, wastewater, soil, air, plant and fruits. From these natural habitats, they demonstrate their physiological, biochemical, metabolical and fermentative (enzymatic) activities (Walker and Stewart, 2016). Furthermore, nutritionally yeasts are not demanding. They grows well commonly in a medium supported with sugary foods, amino acids, vitamins, minerals and alcoholic beverages including local wine such as palm wine (Okafor, 1975), fermented fruit juices such as Burukutu (Ayemor and Matthew, 1972). Other examples of fermented beverage with natural source of support for the growth of Yeast and mould are traditional ciders produced from spontaneous fermentation of juice (Sergi, 2020), Sweet oranges juice *Citrus sinensis* (Raybaudi-Massilia *et al.*, 2009; Al-Jedah and Robinson, 2002), Coconut wine *Cocos nucifera*, fermented sugar-cane juice *Saccharum officinarum* L., (Noroul Asyikeen *et al.,* 2013) and fermented rice (Noroul Asyikeen *et al.*, 2013; Kurtzman and Fell, 1998). This is in contrast to other high profiling microorganisms such as lactic acid bacteria, *Aspergillus oryzae*, and *Pseudomonas sp*. (Sergi, 2020).

The practice of isolating and evaluating microbial strains featured prominently in the field of biotechnology, especially when in search of microbes with pharmaceutical potentials, industrial or commercial attributes. For this purpose, many ecological niches are usually scavenged for one microbe or the other using biotechnological techniques. Principally, the search for *Saccharomyces cerevisiae* strains of importance with reference to industrial potentials is not exempted. In general, various micro organisms have been appropriately isolated, cultivated and evaluated in this way for industrial production of biofuel, enzymes, antibiotics and various organic acids (Amendola and Rees. 2002). However, among the *Saccharomyces* yeast that is responsible for ethanol, $CO_2$ and other secondary metabolites production from grape must and sugars carbon source are *Saccharomyces cerevisiae* strains while non–*Saccharomyces* yeasts contributions cannot be ignored as they play a substantial role in the early stages of fermentation, produce other metabolites relevant for flavour and quality, enhance the appeal and value of wine. Consequently, two classes of *Saccharomyces* yeasts are known viz: *the non-Saccharomyces* yeast and the *Saccharomyces cerevisiae.*

i. The *non-Saccharomyces* yeast are subset of unicellular fungi with high metabolic rate used in numerous fermentation processes but considered as contaminants since their enhanced metabolic rates ends in synthesis of undesirable final products (Sergi, 2020; Ciani and Maccarelli, 1997). They were originally seen as responsible for microbial spoilage in wine production, due to their isolation from spoiled wines or winery environment (Van Kerken, 1963). In fermentation processes, they are the majority in the initial phase, to the point where their growth become inhibited due to increased concentration of ethanol, added $SO_2$ and with attendant exhaustion of dissolved oxygen (Grangeteau *et al.*, 2016). However, the initial assertion stipulating that all *non-Saccharomyces* yeasts died soon after the initial phase of fermentation due to the rising level of ethanol concentration and added $SO_2$ has not been uphold by recent researches (Querol, *et. al.*, 1990). The use of modern biotechnology tools in fermentation processes leading to improved reduction in ethanol concentration and $SO_2$ had been advanced as the reason for this claim. Besides, be it as it may, at this point, *Saccharomyces* *cerevisiae*, the most ethanol resistant yeasts began to thrive and predominate in the fermentation process and complete the fermentation for synthesis of the final product.

Among the most studied *non-Saccharomyces* yeasts that attract special importance for researches include species of *Hanseniaspora* (Kloeckera), Candida, *Rhodotorula*, *Issatchenkia, Pichia, Debaryomyces, Zygosac- charomyces, Torulaspora, Schizosaccharomyces, Metschnikowia, Cryptococcus, Lanchacea*, *Brettanomyces and Kluyveromyces*, among others are found at low levels in fresh must (Bisson and Kunkee, 1991). Furthermore, it is asserted that most *non-Saccharomyces* yeasts showed poor performance technologically in relative to *Saccharomyces cerevisiae* such as low fermentative power and poor production of ethanol. Notwithstanding, *non-Saccharomyces* yeasts possess some characteristics that is lacking in *Saccharomyces cerevisiae.* For instance, *non-Saccharomyces* are good in the production of high levels of aromatic compounds such as esters, higher alcohols and fatty acids (Cordero-Bueso *et al*., 2013). Furthermore, some authors have also reported that the fermentative activity of some *non- Saccharomyces* yeasts are carried out in the presence of oxygen leading to an increase in cell biomass with corresponding decrease in ethanol yield. Thus presenting a phenomenon which can be exploited to achieve reduction in the ethanol content of wines by using co-cultured fermentation techniques with *Saccharomyces cerevisiae* (Ciani *et al.,* 2016). However, fermentations with mixed cultures or co-culture of *non-Saccharomyces cultures and Saccharomyces cerevisiae* have been reported to produce fermented beverages with organoleptic quality or high sensory profiles (Canonico *et al.,* 2016) .

Customarily, the use of *non-Saccharomyces* in the wine expansion has not been common due to previous investigations which showed that several non-*Saccharomyces* species produce high levels of undesirable compounds that affect wine quality such as acetic acid, ethyl acetate, acetoin and acetaldehyde (Comitini *et al.,* 2011). Regrettably, this non inclusion of non-*Saccharomyces* yeasts in the fermentation process may have been the reason for the loss of complexity and poor distinctive characteristics of fermentative products (wines). Thus, it is pertinent to say here that there is every possibility that non-*Saccharomyces* yeasts are not always associated with the production of off-flavoured compounds or odors, but they have an important influence on wine flavour depending on the species involved in the fermentation process. Furthermore, these non-*Saccharomyces* yeasts possesses fastidious metabolic features such as increase in wine colour stability, capacity to produce low volatile acidity, enzymes and other metabolites related to primary and secondary aroma that affect the organoleptic characteristics of wine (Ciani *et al.,* 2010).

ii. ***Saccharomyces cerevisiae***: *Saccharomyces* simply means sugar fungus because it utilizes sugar for growth. It is a unicellular fungus commonly called brewer's yeast, or baker's yeast, naturally found in sugary fruits and plant saps including Palm-wine, Raffia palm-wine, fermented drink from *Sorghum bicolor* (Burukutu), ripped fruits (Amri *et al,* 1982) as also shown in table 2, indicating the natural habitats of *Saccharomyces cerevisiae,* where it can be isolated for industrial use. However, it has been reported that fruits, vegetables, fruit juices and other agricultural products are among important micro-habitats for this yeast species (Kurtzman and Fell, 1998). Fortunately, yeasts have become veritable tool in biotechnology. Specifically, it is also a popular model in industrial biotechnology since it is a well-studied and characterized microorganism in terms of genetics, metabolism, physiology and serves as genetic toolbox for metabolic engineering (Cao *et al.*, 2020). In the wild, yeast has the capacity to ferments and oxidized fermentable carbon sources and as such can ferment sugars to produce alcohol mainly ethanol and carbon dioxide under anaerobic condition. Secondly, it can grow rapidly on sugar or glucose sources to produce high yield biomass under aerobic condition. *Saccharomyces cerevisiae* is the yeast usually used for baking of breads, used in fermentation of beers, wines, production of fuel and alcohol (Ayanru, 1989), as enunciated in table 1:indicating the different industrial application of yeast biomass.

Morphologically, *Saccharomyces cerevisiae* is of different shape; it can be round, oval or ellipsoidal in shape depending on its cultivation, environment and the growth phase. *Saccharomyces cerevisiae* is the most studied fungi and in recent times the most utilized in the fermentation of carbon sources, such as wines and beers due to its desirable fermentative capacity, fast growth and easy environmental adjustment. For instance, they tolerate high concentrations of $SO_2$ on which most *non-Saccharomyces* yeasts do not survive (Sergi, 2020), they are characterized by their enhanced ability to ferment a high spectrum of carbon sources among which are sugars, glucose, fructose, sucrose, maltose etc. Furthermore, they tolerate acidic environments with *pH* values around 3.5 or even less (Sergi, 2020). Although in most biotechnology processes, it is evident to find in nature some species or representatives of *Saccharomyces cerevisiae* that do not necessarily possessed these characteristics For example, let's take a look at the main types of *Saccharomyces cerevisiae* and other non-*Saccharomyces* used in the industrial production of selected alcoholic beverages or drinks as shown in parts in table 1 below:

**Table 1. The Different applications of yeast biomass in industrial production**

| Products applications | **yeast biomass** involved |
|---|---|
| Beer (Lager beer.<br>Ale and limbic beer) | *Saccharomyces pastorianus*<br>*Brettanomyces bruxellensis*<br>*Saccharomyces cerevisiae* |
| Wine | *Saccharomyces cerevisiae*,<br>*Saccharomyces bayanus*<br>(pure cultures) and naturally-occurring yeasts |
| Whisky | *Saccharomyces cerevisiae*: Scotish whisky currently used selected distilling strains of *S. cerevisiae* in three main formats, cream yeast, pressed (cake) and dried yeast. |

| | |
|---|---|
| Malt whisky | Distilleries traditionally use pressed yeast, but larger grain distillers have now adopted cream yeast. |
| Rum (sugarcane spirit obtained by the distillation of cooked fermented sugar cane juice and molasses). | *Saccharomyces cerevisiae* and *Schizosaccharomyces pombe* |
| Brandies, Gin, Vodka, etc. | *Saccharomyces cerevisiae* (the base wine is produced by pure starter cultures of *Saccharomyces cerevisiae* |
| Cheese whey-derived beverages | *Kluyveromyces marxianus*. (Lactose-fermenting yeast to produce ethanol destined for gin) |
| Cachaca (typical Brazilian spirit produced from the distillation of fermented sugarcane juice). | *Saccharomyces cerevisiae* (Cardoso *et al.*, 2004). |
| Bioactive compounds encapsulation , | *Saccharomyces cerevisiae* biomass. Encapsulation of volatile molecules as flavors to guarantee permanence during the industrial process Salari *et al.* 2013; Normand *et al.*, 2005) |
| Drug delivery system | Yeast microcapsule used in the delivery of charged nanoparticles: quantum dots gallium nanoparticles, and various fluorescent nanoparticles (Sabu *et.al.*,2019). |
| Wound dressing sheets | Yeast β-glucan for development of dressing sheets for wound healing (Kofuji *et. al.*,2010). |
| Textile and paper industry | Potential use of f yeast biomass or ungal pulp in the production (Cerimi *et. al*.,2019) |
| Polyols: Glycerol | Produced during normal yeast metabolism, or when yeasts are under with osmotic stress. Glycerol may impart desirable viscosity to fermented beverages especially wine (Walker,2014). |
| Sulphur compounds, e.g. Hydrogen sulphide Dimethyl sulphide, Sulphur dioxide | Beverage flavour and aroma compounds eg. In beer Higher conc. impart off flavour |

Besides the aforementioned natural habitats of *Saccharomyces cerevisiae* in table 2 below, other investigations by many authors have shown that yeasts can be isolated from fermented *Sorghum bicolor*, passion fruit, water melon and pineapple juice, soils, and fermented raw cocoa pulps, where they colonized as their natural habitats. The isolates from these habitats have also been evaluated and found to have attributes essential for industrial and commercial purposes. The attributes investigated include ethanol production, yoghurt and Cheese production, leavening ability for bread making and other dairy products.

**Table 2: Natural habitats of *Saccharomyces cerevisiae,* where it can be isolated for industrial use**.

| Natural habitats | types of Yeast Involved |
|---|---|
| Oil palm *Elaeis spp* sap or juices<br>*Raphia* palm Sap or juices. | *Saccharomyces cerevisiae* (Okafor, 1972. Okafor, 1975) |
| Grape fruits, grape juice,<br>berries fruit surface, cocoa juice | *Saccharomyces cerevisiae* (Duart et al., 2010;<br>Thais *et. al.*, 2006). |
| Plant, bark and leaf of Oak trees | *Saccharomyces cerevisiae* Wang *et. al.*, 2012, Sampaio and Goncalves, 2008. |
| Soils | *Saccharomyces cerevisia.* Knight and Goddard, 2016. |
| Insect- flies, social Wasps and Bees | *Saccharomyces cerevisiae* Chandler *et. al.*, 2012; Stefanini *et. al.*, 2012; Goddard *et. al.*, 2010 |
| Human –made environ e.g. Wineries | *Saccharomyces cerevisiae* (Ciani *et. al.*, 2004) |
| Pineapple, Papaya, Soursop, Sweet corn,<br>mango, Fermented rice. | *Saccharomyces cerevisiae* (Kurtzman and Fell, 1998;<br>Noroul Asyikeen *et. al.*, 2013). |

At this juncture, let us consider the different industrial Production in which *Saccharomyces* yeast are employed together with the global food processing and manufacturing sectors.

Many civilizations have used *Saccharomyces cerevisiae* for many years in industrial production of fermented foods and beverages, including cheese, yoghurt, bread, beer, and wine. Principally, with the advent of science and technology, this unicellular organism had become the hub of industrial research and applications (Zymanczyk-Duda *et. al.*, 2017). The contributions of Louis Pasteur in 1857 on yeast fermentation and metabolism cannot be overemphasized. His work had laid a great momentum to understanding of yeast fermentation process. Coupled with the emergence of biotechnology as a science of the new millennium, yeast cells are extracted from their natural habitats, evaluated or characterized and screen for potential industrial attributes and the successful ones are selected for used as factories in view of their ability to convert fermentable carbon source into valuable products that can be used for commercial purposes, mostly as food additives and flavouring agent (Celeste Cottet *et. al.,* 2020). Today, the demand for yeast biomass for industrial production has increased immensely, not only for food and beverages but also for a wide range of other industrial products as articulated below:

**The production of alcoholic beverages.**

The fermentative and oxidative capacity of *Saccharomyces yeasts* has been exploited by many industries and suitable strains selected and used in the products development as appropriate. It is common knowledge that the yeast species that is used in the production of alcoholic beverages worldwide is *Saccharomyces cerevisiae.*

The discovery of the use of *Saccharomyces cerevisiae* in the production of alcoholic beverages from fermentable carbon sources has led to the growth of fermentable food industry (Walker and Stewart, 2016). However, the importance of yeast in industrial production can never be wish away in a hurry. Besides it uses as fermenter, it play a role not only in optimizing production yield but also in maintaining the organoleptic or sensory quality of the products (Walker and Stewart, 2016). However, pure cultures of selected strains of *Saccharomyces cerevisiae* are usually used in large-scale bioreactor for brewing, winemaking and distilled spirit production This is in contrast to small-scale fermentation where indigenous microflora, including wild non-*Saccharomyces cerevisiae* present in the carbon sources and in the production vessels may be relied upon. For example, in the industrial production of some types of alcoholic beverage, non-*Saccharomyces cerevisiae* are instinctively prevalent either as biostarter cultures, or borne out of spontaneous fermentations. In the other hand, in winemaking the *Saccharomyces cerevisiae* strain are used as biostarter culture during fermentation, may be overrun by the indigenous micro flora associated with the fermentable carbon source (in this case such as grapes musts).

**Beer Production:** The use of yeast for the production of beer, span for thousands of years. At the beginning, it started as every other products of classical biotechnology, first by intuition and later by systematic and scientific studies, informed with the emergence of modern biotechnology. These eukaryotic unicellular organisms have become the center of attention of several investigations for new applications (Zyma ´nczyk-Duda *et. al.,* 2017). The first infinitesimal observation of the yeast cell was reported by Antoine van Leeuwenhoek in 1680. Subsequently, after many years, the contributions of Louis Pasteur in 1857 became the key to understanding the fermentation process. Furthermore, Türker, (2014) reported that the first pure cultures known as starter cultures, were obtained by Hansen and Müller-Thurgau to produce beer.

Beer is the most consumed alcoholic beverage worldwide (Sergi, 2020). It is customarily made from four major types of ingredients viz: i. malted cereals (barley or other cereals), ii. Water, iii. Hops and iv. yeast, each contributing to the final taste and aroma of the product - beer.

However, during fermentation process, yeast biomass /cells convert the fermentable carbon source - (barley or other) and their derivatives (sugars and other metabolites) into ethanol and $CO_2$. At the same time, hundreds of secondary metabolites that influence the aroma and taste of beer are produced. Dzialo *et. al.,* (2017) reported that it is the variation in these metabolites produced by different yeast strains that causes yeast to influence beer flavor. In industrial Beer production, fermentation process involve heterogeneous microflora - a mixture of different yeast species that contribute to the final product, thus giving the beer a high degree of aroma and taste. Principally, most breweries have their own stock of selected yeasts for their specific beers. As it is well-known, two types of yeast are used in brewing: *S. cerevisiae* and *S. pastorianus*. *S. cerevisiae* is used as top-fermenters to produce **ales** while *S. pastorianus* is a bottom-fermenters used in lager brewing processes (Libkind *et. al.,* 2011). Nowadays, the demand for yeast biomass is on the increased, favouring the production not only of beer but of other beverages and wide range of products.

**Wine production:** Wine production requires specificity in microbial strains used. This is because microbial strains are largely responsible for the complexity and sensory quality of fermented wine.In wine fermentation, strains with desirable specific characteristics are needed, for instance, high ethanol producers reaching the values of 11–13% v/v are sort for (Sergi, 2020). The fermentation of wine is known to be a complex process with various ecological and biochemical processes involving yeast strains (Fleet, 2003). Okafor, (1975) had reported palm wine to be a natural carbon source of *Saccharomyces cerevisiae*. This sweet fermented beverage obtained as the sap of oil palm tree *Elaeis spp*. and the sap of Raphia palm *Huckerri spp,* is known to contain a heavy suspension of live yeasts and other bacteria (Okafor, 1975). The fermentation of carbon source for the production of beverage is said to depend on the performance of yeast to convert the sugars into alcohol and esters. Besides, the different species of yeast that develop during fermentation process, they also determine the characteristic of the flavour and aroma of the final product (Fleet, 2003). Furthermore, since different carbon sources e.g. fruits have different compositions, it is needful that efficient yeast strains adapted to different environments, of sugar composition and acetic acid concentration be sourced for. Fortunately this description qualifies *Saccharomyces cerevisiae* as the main yeast strains that are commonly reported to be responsible for alcoholic fermentation (Duart *et al.,* 2010).

The use of non-Saccharomyces yeast strains as starter cultures for wine production has become increasingly popular, particularly due to their positive effect on wine composition, color, aroma and flavor. For instance, Varela *et al.,* (2021), describes the characterization of the volatile aroma composition and the sensory profile of Shiraz and Cabernet Sauvignon wines produced with novel active dry yeast preparations of *Metschnikowia pulcherrima* compared to that of reference strains (Varela *et al.,* 2021). Briefly, winemaking treatments included non-inoculated fermentation, two reference strains of *Saccharomyces cerevisiae* fermentations and sequential fermentations inoculated with either *M. pulcherrima AWRI1149* or *M. pulcherrima AWRI3050* or *S. cerevisiae*. Microbial population dynamics during fermentation was determined with the use of Amplicon-based internal transcribed spacer phylotyping. Secondly, wines were analyzed for volatile composition and subjected to sensory analysis. The results showed that *M. pulcherrima* strains survived and dominated in the fermentation and produced distinctive wine volatile profiles. These differences in volatiles resulted in significant differences for several sensory attributes. Furthermore, wines made with active dry yeast preparations of *M. pulcherrima AWRI1149 and M. pulcherrima AWRI3050* were also characterized by increased intensity of desirable sensory attributes and by low scores for negative descriptors. Their work provides winemakers with additional yeast preparations that can shape sensory profile and wine style (Varela *et al.*, 2021).

Of the place of nonconventional yeast in wine industry *Oenococcus oeni* is the main lactic acid bacterium of interest to enology because it conducts malolactic fermentation in the great majority of spontaneous fermentations. It has been shown that after their inoculation in wine, various strains does not only perform fermentation quickly and completely but also create differences in the organoleptic sensory level between wines produced (Pascal et al., 2021). However, their phenotypic analyses confirm that different strains differ in their capacity to metabolize sugars, citric acid, and many other compounds, which have an impact on quality of wine products. Lactic acid bacteria are present in all grape musts, in almost all wines during the winemaking process, and sometimes in wines after several years of bottle aging (Pascal et al., 2021). Depending on the wine's characteristics and on the stage of the winemaking process. The species and strains encountered are variable and more or less abundant. They metabolize numerous substrates and carbon sources Lactic acid bacteria therefore play an important role in the transformation of grape must into wine (Pascal *et al.*, 2021). Their impact on wine quality however, depends on the species and strains present; on the substrates they subsist for transformation, and the stage at which transformations took place. The lactic acid bacteria isolated from grape must and wine belong to the *Lactobacillaceae* family with the *Lacto-bacillus* and *Pediococcus genera*, and *Leuconostocaceae* with *Leuconostoc* and *Oenococcus* (Pascal *et al.*, 2021). Four parameters very distinctly determine the growth rate of lactic acid bacteria in wine: viz. pH, temperature, alcohol content, and $SO_2$ concentration as elucidated earlier.

Acetic Acid Bacteria are also another nonconventional yeasts use in wine industry. Indeed, known to be present on ripe grapes. The populations vary greatly, in number and species, and are well adapted to growth in sugar-rich and alcohol-rich environments (Barata *et al.*, 2012). The bacteria in this family are separated into two genera: *Acetobacter and Gluconobacter*. The species G. oxydans, *Acetobacter aceti* and *Acetobacter pasteurianus* are the ones that are most frequently found in the course of winemaking (Barata *et al.*, 2012).. The three species succeed each other during winemaking.

Although possible in all genera, the characteristic metabolism of *Acetobacter* is the oxidation of ethanol into acetic acid with high products yield. Finished wines contain around 0.3–0.5 g of volatile acidity (expressed as $H_2SO4$) per liter, resulting from yeasts and lactic acid bacteria metabolisms.

Above this concentration, acetic acid from acetic acid bacteria accumulates; leading to the problem called vinegar taint. In view of this, the accumulation always be avoided not only because of its negative effect on wine quality but also because of the legal limits on the concentration of volatile acidity permitted in wine by regulatory authority. The increase of volatile acidity also depends on the wine storage period and method. In large-capacity tanks, the increase in volatile acidity is lower than in other tanks like barrels. To avoid spoilage from acetic acid bacteria, the winemaker takes winery hygiene as important, in order to eliminate potential contamination sources from microorganisms. It is obvious that the population decreases slowly during bottle aging and the total exclusion of oxygenation leads to the elimination of these contaminant bacteria (Barata *et al.*, 2012).

**Traditional local beverages from Nigeria**

**i. Palm wine and Raphia palm wine:** Fermented carbon sources like saps/juices from Oil palm and Raphia palm trees are both popular beverages in Nigeria and other West African countries. These too are well known natural habitats to heterogeneous microflora including *Saccharomyces cerevisiae* yeasts (Ayemor and Mattthew, 1972). Ayogu, 1999). In Nigeria, especially the Southern part of the country, palm wine and Raphia wine also referred to as the fermented sap from oil palm tree *Elaeis guineensis* and Raphia palm *Raphia hookeri* respectively are popular wines/beverages. The physiology and microbiology of these two had been well studied and reviews of its literatures are available in public domain (Ayemor and Matthew, 1972). *Saccharomyces cerevisiae* is a constituent of palm wine and many researchers in Nigeria have explored both biological and economic aspect of the *Saccharomyces* yeast found in palm wines. For instance, Ayanru, (1989), reported from his work, the observed morphological and physiological *Saccharomyces* variants or strains that could affect the organoleptic quality of palm wine. Other workers have described variants /strains that are potentially useful as leavening agents, brewing agents for wine, beer, and production of biofuel or bioethanol, as the case may be (Bassir, 1982; Bell *et al.*, 2001).

Oil Palm and Raphia palm wines are milky alcoholic beverage produced from the inflorescence of the palm trees. It is the most consumed and widely cherished natural traditional alcoholic beverages especially in West Africa particularly, Nigeria. This milky juice is extracted from the oil palm (Elaeis guineensis), and Raphia palm (Raphia hookeri). It is certified to contain over 13% sucrose at tapping period or extraction time. It is collected usually with the use of small jerican or calabash which is hung at the mouth of the tapping incision made on the palm tree. Soon after sometimes, fermentation set in and yeast spores, especially those of *Saccharomyces cerevisiae* infect the juice and soon start the fermentative process of the fermentable sugar. At this point, Palm wine can be consumed as an alcoholic beverage. In the other hand, the fermentation process could be allowed to cure fully or completely and afterward distilled into *gin* or *kaikai*. Furthermore, the fermented juice could also be used for the isolation of *Saccharomyces cerevisiae* for subsequent used as leavening agent (brewer's yeast, or baker's yeast) for bread making (Cogliati M, 2013). The use of palm wine as a leavening agent for raising flour dough is said to be attributed to the presence of *Saccharomyces cerevisiae*, a yeast strains contained in the palm juice/sap. This also informed the name - baker"s yeast as it is called in the bakery industry (Olabisi, 2017).

The nature of palm wine are so unique that it has attracted public concern and generated national research interest to investigate its industrial application and economic importance. Likewise, the proficiency of yeast isolates from palm wine is so diverse that Fawole and Oso, (1998) opined that it can be suitable for fruit wine production and thus suggested that acceptable wine could be produced from other fruits using palm wine yeasts.

**ii. Burukutu: Fermented beverage from *Sorghum bicolor* and Millet *Pennisetum glaucum.***

Burukutu is a fashionable alcoholic beverage of vinegar-liked flavour prepared from *Sorghum bicolor* grains and Millet *Pennisetum glaucum* (Kolawole *et al.,* 2007). It is widely consumed as one of the alcoholic wines in rural areas of Northern Nigeria, Ghana, Togo, Kenya, Ethiopia, Burundi and off-course, among the poverty stricken populace. It popularity among the people might be attributable to it being cheap and affordable as compared to the commercial brewed beer. It has been reported by Bennett *et al.,* (1998), that the percentage alcoholic content of Burukutu beverage ranges from 3 – 6% and with nutritive contents of vitamins, iron, magnesium, manganese, phosphorus, calcium, 26.7 starch and 5.9 g of protein per liter (Egemba and Etuk, 2007). The production of burukutu involves five basic stages, which include: i. Steeping, ii. Malting, iii. Mashing, iv. Fermentation and v. Maturation. The products from step i to iii are allow to undergo fermentation facilitated by *Saccharomyces cerevisiae* sugar fungi, followed by maturation for or within the duration of 48 hours for the emergence of the final product.

**1. Production of Flavouring compound**

Chemical identification of aroma and flavouring compounds in wine derived from the fermentative and metabolic activity of *Saccharomyces* yeasts has been widely reported in the literatures in the recent times (Lambrechts and Pretorius, 2000). Various fermentation products, including ethyl and acetate esters, higher alcohols, fatty acids, lactones, and sulfur compounds have been reported as important flavouring compounds especially for the sensory perception of different wine types (Carrau et al., 2008). While this review provides important information on the sensory profiles of *Saccharomyces* yeast volatile compounds, more targeted research is required on the sensory impact of these compounds especially when combined in a complex food matrix such as wine and beer and how they contribute to flavour quality (Pires, 2014). These compounds can be seen in parts in table 3 below:

**Table 3: Flavour/Aroma compounds produced by yeasts relevance in industrial production**

| **Flavour compounds** | **Descriptor(s)** | **References** |
|---|---|---|
| Isoamyl acetate | Banana, pear | Takeoka *et al.*, 1989 |
| Ethyl acetate | Fruity, solvent | Takeoka *et al.*, 1989 |
| Ethyl hexanoate | Apple, fruit | Takeoka *et al.*, 1989 |
| Ethyl octanoate | Fruity, fatty | Rychlik *et al.*, 1998 |
| Ethyl decanoate | Pleasant | Guth, 1997 |
| 2-Methyl-1-propanol | Solvent-like | Rychlik *et al.*, 1998 |
| 2-Methyl-1-butanol | Malted | Rychlik *et al.*, 1998 |
| 3-Methyl-1-butanol | Whiskey, malt, burned | Rychlik *et al.*, 1998 |
| β-Phenylethyl alcohol | Floral, honey | Guth, 1997 |
| 1-Propanol | Fresh, alcohol | Ferreira *et al.*, 2000 |
| Isobutyric acid | Cheesy/rancid | Guth, 1997 |
| Isovaleric acid | Sweat, acid, rancid | Ferreira *et al.*, 2000 |
| Butanoic acid | Rancid, cheese, sweat | Takeoka *et al.*, 1989 |
| Hexanoic acid | Cheese, rancid, fatty | Guth, 1997 |
| Octanoic acid | Rancid, harsh, cheese, fatty acid | Guth, 1997 |
| Decanoic acid | Fatty, unpleasant | Guth, 1997 |
| γ-Butyrolactone | Pleasant, creamy, caramel | Clean, 1996) |
| Ethyl 4-hydroxybutanoate | Caramel | Akita *et al.*, 1988 |
| β-Phenylethyl acetate | Pleasant, floral | Guth, 1997 |
| 3-Methylthio-1-propanol | Boiled potato, rubber | Guth, 1997 |

Information obtained from: Carrau *et al.,* (2018), from public domain.

Furthermore, besides the aforementioned compounds in table 3 above, another important flavoring compound produced by yeast is ester ethyl caproate (Yoshikawa, 1999). Ethanol and caproic acid is ester ethyl caproate precursor since its synthesis and accumulation in yeast cells depend on the presence of ethanol and caproic acid, in tandem with the control of alcohol acyl transferase and esterase enzymes (Verstrepen *et. al.*, 2003). Other flavouring compounds are also observed to be found in other beverages, in most cases, isoamyl acetate is the main contributor to the fruity and sweet aroma in most industrial products (Yoshikawa, 1999);

Therefore, a strategy used in isolating strains with a higher compendium of flavouring compounds is to obtain cerulenin-resistant mutants of *Saccharomyces* strains. This is a potent antifungal, inhibitor of fatty acid synthase in various organisms especially in *Saccharomyces* yeasts. In a study conducted by Maristela de Arau´jo *et al.*, (2005). *Saccharomyces cerevisiae* were isolated from fermentation vats of a *cachaca* distillery and the strains characterized according to their abilities to ferment, flocculate and produce flavouring compounds. The utilization of selected strains with such abilities to produce these compounds benefited the Brazilian *cachaca* industry by increasing the levels of the desired flavouring compounds in the beverages besides contributing to the lowering costs of production among others.

## 2. Bakery Yeasts: as a leavening agent in Bread production

*Saccharomyces cerevisiae* a.k.a Baker's yeasts play an important role as a leavening agent in bread making. The leavening of flour dough for baking of bread and other bakery products is essentially through fermentation of the dough by *Saccharomyces cerevisiae*. It does not only induce and increase the volume of dough through gas incorporation but also helps creating the desired flavor and texture (Fleury *et al.,* 2002).

The fermentation of the dough by the yeasts is the most critical phase in the bread manufacturing process. The quality of the bread is determined by the fermentative yield of yeast cells achieved during fermentation process. However, the fermentation rate is conditioned by the additives or ingredients used in the preparation of the dough, such as sugar and salt. It is a common practice among Commercial bread producers to produce various types of dough such as lean, spongy, sweet soft or hard dough. The discovery of the use of *Saccharomyces* yeast to leaven bread some years ago has contributed to the growth of bakery industry in Nigeria and the world over. However, with the successful isolation of a special strain of this yeast from its wild habitats viz, *Saccharomyces cerevisiae* from Palm wine or Raphia palm sap/juice comes in revolutionary changes in the bakery industry. Fermented palm wine is well known to harbor heterogeneous microflora that always include yeasts Thus *Saccharomyces cerevisiae* is seen as component of palm wine (Ayemor and Matthew, 1972). The use of palm wine in Nigeria and indeed in other part of the world as a leavening agent for bread making is attributable to the presence of *Saccharomyces cerevisiae* contained in the palm sap (Okafor, 1972). *Saccharomyces cerevisiae*, in its role as leavening agent, converts the fermentable sugars present in the flour dough into carbon dioxide resulting in the expansion of the dough or raising the dough as the carbon dioxide forms bubbles. When the dough is baked, the bubbles present and remain, give the baked product a soft spongy texture (Olabisi, 2017).

## 3. Chocolate production from Cocoa Fermentation

It is a well known fact that Chocolate is produced with the use of Cocoa beans or seeds as a major raw material. Chocolate production is a complex process involving numerous chemical reactions. The most significant processes, involving most of the reactions crucial to the development of chocolate flavour and aromas are raw cocoa pulp fermentation, drying and roasting of cocoa bean, chocolate conching and tempering. However, during fermentation of cocoa beans growth of *Saccharomyces* yeasts and bacteria took place, formation of important precursors occurs, which are essential prelude for further chemical reactions in the processing pathways of chocolate production. Roasting is one of the most important processes due to the occurrence of Maillard's reactions, during which aroma compounds are formed. Conching is mixing and heating treatment that is done to produce liquid chocolate, evaporate volatile acids, remove excess moisture, and develop a desirable color and proper viscosity (Aprotosoaie, 2015; Afoakwa, et al., 2008; Beckett, 2008).

The characteristic nature of raw cocoa beans described as having a reddish-purple colour and bitter with astringent taste is attributable to the presence of high phenolic compounds and a polyphenols notably, anthocyanins, The fermentation of the beans leads to the enzymatic breakdown of proteins and carbohydrates inside the bean, thus leading to the development of organoleptic flavour. This is indeed, aided by microbial fermentation of the cocoa pulp surrounding the beans during post harvest processing. Yeasts especially *Saccharomyces* and other spontaneous microbes ferment the juicy pulp surrounding the cocoa beans by different methods, including an anaerobic and an aerobic phases. During the anaerobic phase, the sugars of the pulp (sucrose, glucose, fructose) are fermented by the yeasts to yield carbon dioxide, ethanol, and low amounts of energy (Papalexandratou, and Nielsen, 2016; Ho *et. al.,* 2014). The aerobic stage is dominated by lactic and acetic-acid-producing bacteria (Ho *et.al;* 2018). This process enables or contributes to the final bitter and astringent taste of the end product.

Furthermore, microbial starter cultures have been reported to be extensively used to enhance the efficiency of industrial fermentations. However, the fermentation involved in the production of chocolate is still facilitated by a spontaneous process that relies on the natural microbiota of non-*Saccharomyces* yeasts and *Saccharomyces cerevisiae* populations. As a consequent, cocoa pulp fermentations involved a wide range of microorganisms, with lactic acid bacteria *LAB*, acetic acid bacteria *AAB*, and *Saccharomyces* yeasts being the main players (Lopez and Dimick, 1995; Schwan and Wheals, 2004). However, recent studies suggest that these microbes might have little or no influence on cocoa flavor and quality, since cocoa fermentations lacking non-*Saccharomyces* yeasts gave acceptable chocolates aroma with no differences in sensory rankings (Ho *et al.,* 2015). Nevertheless, spontaneous microbiota like AAB, are known to affect cocoa flavour by producing acetic acid, which diffuses into the cocoa beans. This diffusion contributes to the disruption of cocoa bean cells and as a results, various endogenous enzymes involved in the production of flavour precursors, like reducing sugars, amino acids, and peptides, are released (Hansen *et al.,* 1998). In addition, the potential of two strains of two non-Saccharomyces species- *Pichia kluyveri and Cyberlindnera fabianii,* that produce very large amounts of fruity esters to modulate chocolate aroma have been investigated and Meersman *et al.,* (2016) reported the results that showed sensory analysis by expert panelists confirming significant differences in the aromas of chocolates produced with different starter cultures. Together, the results showed that the selection of different yeast cultures opens up other novel avenues for modulating chocolate flavour.

The potentials of using *Saccharomyces* yeast cells as starter cultures for cocoa fermentation and flavour attributed to them have been reported by many authors in the literatures (Ho *et al.,* 2014; Meersman *et al.,* 2015; Batista *et al.,* 2015). Aside from the aforementioned role of yeast cells as biostarter in cocoa pulp fermentations, *Saccharomyces* yeast cells produce numerous secondary metabolites, such as flavour-active compounds including aldehydes, carbonyl compounds, esters, fatty acids, higher alcohols, organic acids, phenols, and sulfur-containing compounds (Lambrechts and Pretorius, 2000) and fruity volatiles compounds, such as esters. All these are especially important, because they impart the fruity character of many fermented beverages (Delvaux. 2003) and are suggested to principally contribute to cocoa flavour (Crafack *et al.*, 2014). However, the production of these fruity aroma compounds varies greatly between yeast species and strains (Steensels and Verstrepen 2014; Steensels et al., 2014).

## 4. Ethanol production

*Saccharomyce cerevisiae* (Fermentative yeasts) readily ferment glucose, fructose, mannose, galactose, sucrose, maltose into ethanol and carbon dioxide. It uses sugars as its carbon sources during anaerobic respiration. *Saccharomyce* cerevisiae is sometimes regarded as ethanologenic yeast that can readily ferment glucose substrates as carbon source and converts it into ethanol and carbon dioxide. The sequence of enzyme pathway here involves glycolysis i.e. the conversion of glucose to pyruvic acid and can be summarized as:

$$\text{Glucose} + 2\text{ADP} + 2\text{Pi} + 2\text{NAD}+ \rightarrow 2\text{Pyruvate} + 2\text{ATP} + 2\text{NADH}+ + 2\text{H}+$$

Along this pathway, yeast cells or biomass are supplied with energy in the form of *NADH+* for growth. Furthermore, in glycolysis, glucose is initially phosphorylated using *ATP* to produce fructose 1, 6-biphosphate which is then split by aldolase to form two triose phosphate compounds. Further phosphorylation forms two triose diphosphates from which four H atoms are accepted by two molecules of *NAD+*. In the latter stages of glycolysis, four molecules of ATP are formed and this resulted in the formation of two molecules of pyruvic acids, with 2 molecules as net ATP produced. Thus, this remain the only source of energy obtained by *Saccharomyces cerevisiae* during fermentative metabolism. Yeast cells undergoing alcoholic fermentation of sugars under anaerobic condition involved *NAD+* regeneration. This regeneration of *NAD+* is necessary to maintain the redox balance in furtherance to glycolysis processes (Graeme and Graham, 2016).
In the first step, pyruvate is decarboxylated by pyruvate decarboxylase before a final reduction, catalyzed by alcohol dehydrogenase *ADH* to ethanol:

$$2\text{Pyruvate} + 2\text{NADH} + 2\text{H}+ \rightarrow 2\text{NAD}+ + 2\text{Ethanol} + 2\text{CO}_2$$

The intermediate compound that is formed in this reaction is *acetaldehyde* which acts as the electron acceptor and is generated following pyruvate decarboxylation (Graeme and Graham, 2016).However, *Saccharomyces cerevisiae* stands out as the most employed yeast for ethanol production at industrial level despites the fact that ethanol can be produced by many spontaneous microflora and other non-*Saccharomyces* yeasts. Inarguably, bioethanol production by *Saccharomyces* yeasts is by far the largest biofuel and ethanolic products in industrial biotechnology sector. Bioethanols are renewable energy that has attracted most scientific research and industrial patronage in recent times. Bioethanol, biofuels, biodiesel and biogas are the dominant renewable energy among others that have been investigated widely (Dai et al., 2007), Fortunately, the fermentative potentials of *Saccharomyce* yeasts can be used to offset the negative environmental consequences of fossil fuels and its attendant social impacts. *Saccharomyce* yeasts are known to ferments wide range of substrates such as molasses, starch based substrate, sweet sorghum cane extract and other lignocellulose wastes containing sugars and polymerized them into cellulose and hemicellulose, which are liberated by hydrolysis and subsequently converted to biofuel (Dai et al., 2007), Interestingly, *Saccharomyce* yeasts can be used to transform lignocellulose wastes including agricultural and forestry residues into bioethanol, biofuels, thus the industrial potential of *Saccharomyce* yeasts is much more significant. With this the emphasis in the world now is on bio-economy as against oil and gas economy of yester years.

## 5. *Saccharomyces Cerevisiae* Cells as Film Material

*Saccharomyce cerevisiae* is industrially the most widely exploited yeast species in the world. With its inherent biodegradable potentials and being ubiquitous in nature, *Saccharomyces cerevisiae* cells are used to produce biobased films forming materials e.g. biopolymers has been a raw material for our teaming industries. Furthermore, *Saccharomyces cerevisiae* biomass contains polysaccharides and proteins and these could be isolated for advantage (Delgado *et. al.,* 2016). Nowadays, these biopolymers isolated from the biomass are gathering more industrial and scientific momentums in the industrial and scientific communities respectively, for research and development of biodegradable materials for food industry.

Yeast biomass had been described by authors as natural low-cost food ingredient for human nutrition (Celeste *et. al.,* 2020). In recent years, significant interest has emerged for its other applications. For instance, it is used as probiotics for both human and animal dietary supplements and for the development of biodegradable materials for food packaging. Their other uses include:

i. Brewer's spent yeast biomass has a potential value for its bioactive compounds
ii. Yeast biomass is an important source of biopolymers for preparation of biodegradable films.

These advances were achieved in response to the new trend and consumer demands for natural products that create less environmental contamination (Delgado *et. al.,* 2016). For instance, Delgado *et al.,* (2016), prepared casted films based on integral yeast biomass. In their work, the authors demonstrated that yeast biomass (10% dry mass wt) from which the film was formed was dispersed under high-pressure homogenization. However, in order to obtain the yeast components which was used to develop the film, it was necessary to break the cell using cell disruption method and release the cytoplasmic content. In this way, the cell proteins and polysaccharides were free to interact and form the film network. Normally, under high-pressure homogenization, the yeast cells are broken to release the intracellular materials to the surrounding environment. Furthermore, in their study, different heat pressure treatments were applied. Pressures higher than 60 Megapascal *MPa* were more effective, and those higher than 125 *MPa* was the most effective (Delgado *et. al.,* 2016). The first homogenization was used to disrupted the cell, before the heat treatment was applied to denaturalize enzymes and proteins present and the second homogenization was applied to eliminate possible aggregates that was formed during the heat treatments. Then the solvent i.e. water in this case, was removed from the film matrix (Peltzer *et. al.,* 2018). Similar results were obtained by Guerrero et al. (2010), in films made from soy protein isolates, using heat treatment above 180 ◦C for substantial degradation of biomass materials (Guerrero *et al.,* 2010).

In another investigations with yeast films, glycerol was used as a plasticizer i.e. glycerol in this case was added to the already treated yeast dispersion to produce casted films (Delgado *et. al.,* 2018). Yeast films were fully characterized in their visual, thermal, infrared spectroscopy (FTIR). Plasticizer is known to improved film integrity, flexibility, and mechanical properties since they tend to increase the molecular space between polymer chains.

**6. Yeast Cells as Encapsulation /carrier material**

Inarguably, encapsulation is a process of hiding one compound within the matrix of another. The compound that is encapsulated may be the most needed core material, and the compound that serves to encapsulates is and used as mere coating materials. In this case *Saccharomyces* yeast cells are used to serves for the encapsulation purpose. It's also used as biomass for the encapsulation of different biological molecules, needed in many industrial sectors (Paramera *et. al.,* 2014).
Furthermore, in the field of biotechnology, there are different microencapsulation techniques in used today such as spray-drying, lyophilization - freeze-drying, fluidized bed coating, extrusion, emulsification, coacervation- separation of an aqueous polymeric solution into 2 liquids and electrostatic methods (Mokhtari, *et. al.,* 2917). Several industries can use any of these processes in their production. For instance, it's a process that takes place in the following:

i. Food industry ,
ii. Perfumery,
iii. Agrochemical,
iv. Chemical, and
v. Pharmaceutical industries etc.

*Saccharomyces cerevisiae* is an ideal micro-organism, to be exploited as encapsulation materials for and as carrier of active compounds because of their biodegradability, food value, cost-effectiveness and availability.

In pursuance of it's used as microcapsules, Paramera *et. al.*, (2014), listed different technologies that are used to include mostly plasmolysis of the cells for elimination of cytoplasmic contents. Secondly, spray-drying and thirdly, freeze-drying. Furthermore, they reported that the molecules to be encapsulated can be both hydrophobic and hydrophilic due to their behavior as a liposome (Paramera *et. al.*, 2014; Salari *et. al.*, 2913). Nya, (2022), reported one of it applications or uses in encapsulation of probiotics in order to optimize their viability within a thermostable environment. This is in line with other studies which showed that yeast cells are stable up to temperatures close to 250 ◦C, and thus makes them good candidates as encapsulation materials for protecting bioactive compounds in-vivo (Nya, 2022).

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