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Bioethanol Production from Decaying Oranges and Pineapple Juice Using Ethanol Tolerant-Yeast

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Authors' contributions

This work was carried out in collaboration among all authors. Author OJB wrote the first draft of the manuscript and managed the literature searches. Author ASM designed the study, performed the statistical analysis and wrote the protocol. Authors OJB and ASM carried out the practical aspect of the research. Authors AFT, OSE and ASM managed the analyses of the study and were involved in writing the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Scientists across the globe ought to harness ways of getting alternative sources of energy which will be renewable, sustainable, efficient, eco-friendly, and cost effective because of the global energy crises owing to the cost of production, transportation and distribution of fossil fuel products. In Nigeria, decaying fruits always constitute a major environmental pollution during the harvesting season. This study screened, selected the best starter, and produced bioethanol from the juice obtained from decaying oranges and pineapple through the process of fermentation and distillation.

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Samples were collected from different locations within Ile-Ife and transported aseptically to the Laboratory. Microbiological and physicochemical assessment of the isolated strains were on yeast maintenance media. The cell biomass, pH, temperature, brix level, titratable acidity, specific gravity and ethanol yield were monitored during fermentation from day zero to day fourteen. Screening of the isolates obtained from a previous study was carried out to select the best starter for the production of bioethanol.

S.cerevisae and *K. marxianus* and showed efficient physico-chemical attributes from the screening of the yeast isolates; a temperature of 30ºC and pH 6 was the optimum for the growth of isolates tolerating 20% v/v absolute ethanol. Cultures were inoculated singly and in combination, *S. cerevisiae* gave the highest reduction in brix level from 2.2º at the onset and it reduced to 0.3º at the 21st day of fermentation while the least reduction was seen in *K. marxianus*. Mixed culture of *S. cerevisiae* and *K. marxianus* gave the highest reduction in brix level from 2.0º at the onset to 0.1º, pH reduced from 4.7- 3.3 while the cell biomass increased, and the temperature increased from 30ºC to 34.5ºC at the end of fermentation. Titratable acidity in the fermenting fruits juice increased from 0.23 to 1.76, the specific gravity reduced while the alcohol content increased from zero to 25.63 as the fermentation progressed and a reduction on day 21 (1.67) was observed.

The use of decaying plant biomass or fruit waste can be a rich and cheaper source of substrate for different yeasts strains endogenous to the biomass for the production of environmental-friendly biofuel. This can also be employed as a waste management option and an alternative solution to environmental pollution and the global energy crises.

Keywords: Bioethanol production and yield; distillation; eco-friendly; waste conversion.

1. INTRODUCTION

In view of the global rise in energy crisis the world is facing, predictions have been made that the global crude oil production is going to decline five times below its current level by 2050. According to the World Energy Council (WEC) calculations, the world-wide primary energy consumption is approximately 12 billion tons coal equivalent per year. Furthermore, United Nations calculations have shown that the world's population will increase to about 10 billion people by 2050 which will in turn increase energy demands to at least 24 billion tons of coal equivalent per year (twice of what we consume today) depending on economic, social and political developments [1,2].

The increasing demand for fossil fuels caused by burgeoning anthropogenic activities and rapid economic growth provoked wicked environmental issues and resource depletion [3,4], which is a direct boost to reconstruct the energy structure, develop and industrialize renewable biofuels [5-7].

Continuous depletion of conventional fossil fuel reserves with increasing energy demands and climate change [8,9] have led to a move towards alternative, renewable, sustainable, efficient and cost-effective energy sources with smaller emissions [9]. Renewable energy is one of the most efficient ways to achieve sustainable development. Increasing its share in the world matrix will help prolong the existence of fossil fuel reserves, address the threats posed by climate change, and enable better security of the energy supply on a global scale [10].

Numerous potential alternative fuels have been proposed, including bioethanol, biobutanol, biodiesel, methanol, hydrogen, CNG, biogas, Fischer–Tropsch fuel, electricity, and solar fuel [11]. Biofuels are produced in response to the proper time and conditions coping with world environmental concerns and the exhaustion of non-renewable fossil-based fuels [12,13,14].

Biofuel originates from processing plant oils, sugar beet, cereal, organic waste and processing of biomass. Among liquid biofuels, bioethanol is particularly attractive, having the potential to accelerate sustainable use of resources and change the global economy toward a greener future [15-17]. Continuous biotechnology innovation strongly promotes the upgrading and mass production of biofuels represented by bioethanol. Bio-fermentation based on important model microorganisms is a technology with great development potential beyond all doubt for biofuel production at present and in the future [18,19].

As few yeast strains have been found to possess appreciable characteristics for ethanol production, there is a dire need to explore the potential of indigenous strains of yeasts to meet the national requirements for biofuel [20].

Yeasts are important microorganisms in food manufacturing and fermentation. Yeast is widely spread in different habitats and these include terrestrial, aquatic and aerial environment. However, yeasts are considered as an important group of microorganisms in the biosphere. They have been isolated from natural substances like leaves, flowers, sweet fruits, grains, fresh fungi, exudates of trees, insects, dung and soil [21, 22,23]. Yeasts, being sugar-loving microorganism have been isolated from sugar-rich materials. One of such is fruits. Fruits contain high sugar concentration and hence yeast species are naturally present on these and can be easily isolated from fruits. Distinct wild yeast species are supposed to be present and associated with different fruits in natural environments [23]. Because of yeast unique fermentative characteristic, there is always a need for yeast strains with better features of fermentation especially high ethanol tolerance for production of ethanol as biofuel on commercial scale [24].

Since ancient times, *S. cerevisiae* has had a long historical standing in human civilization and social development, mainly reflected in food production and fermentation such as bread, beer, and wine [25 and 26].

The biodiversity of microorganisms on the substrate depends always on the pH of the substrate. Since fruits are acidic in nature they are predominantly inhabited by yeasts [23]. Yeast strains found on fruit surfaces are capable of converting a wide range of sugars into alcohol. Successful fermentation of biomass to produce ethanol requires tolerance to high concentrations ethanol, sugar and invertase activities. These cellular characteristics are important because of high gravity (VHG) fermentations, which are common in the ethanol industry, give rise to high sugar concentrations, at the beginning of the process, and high ethanol concentration at the end of the fermentation.

The enormity of fruits wastage during the harvesting season in Nigeria constitutes environmental problems. However, little effort has been made in order to explore conversion of sugar present in these decaying fruits waste juice for potential application in bioethanol industry. This study seeks to utilize the waste generated from fruits as low-cost raw material for the production of renewable energy (bioethanol).

2. MATERIALS AND METHODS

2.1 Collection of Samples

Decaying orange and pineapple wastes were collected at various markets in Ile-Ife and its environs as well as decaying fruits dumpsite within Obafemi Awolowo University Staff Quarters. It was collected into sterile Ziplocs material and was transported immediately to the laboratory for microbiological analysis.

2.2 Isolation and Screening of Ethanol-tolerant Yeasts

Some pieces of decayed oranges and pineapples were taken and crushed into fine paste. One (1gm) of the sample mixture was serially diluted 10-fold in Maximum Recovery Diluent (MRD) consisting of 0.1 g of peptone and 0.85 g of NaCl in 100 ml of water. Aliquot (100 µl) of appropriately diluted sample was inoculated into Yeast Maintenance Media (YMM) using spread plate method (Kreger-van Rij, 1984). The YMM plates were incubated aerobically in an incubator (DSI300D) at 30°C for 3 days. A single colony formed was picked and the cells were observed under microscope.

2.3 Microscopy

Microscopic examinations of the isolated yeasts were carried out and these include, direct mount, Gram’s staining and lactophenol mount. Physicochemical characterization of the isolate includes sugar fermentation, carbon assimilation and growth in 1% actinidine (Omoolorun *et al*., 2023a).

2.4 Production of Bioethanol from Decaying Fruits Juice

2.4.1 Fermentation media preparation

Decaying fruits waste of oranges and pineapple was used as a fermentation media for the study. The fruits waste were collected from local markets in Ile-Ife, Osun State.

2.4.2 Composition of fermentation media for yeast

The fruits juice consists of a mixture of oranges and pineapple in ratio 1:1 to make 250g. Urea was added (0 .10 g), Conc. H_2SO_4 (0 .30 Ml) for bioethanol hydrolysis and sucrose (7.5 % (w/v)). The composition was added up to 1000 mL with distilled water. The pH was adjusted with a pH meter to 6.0 and it was autoclaved at 121 °C for 15 mins.

2.4.3 Preparation of yeast cell suspension

A 48-hour old culture of yeast cell was added aseptically to autoclaved fermentation broth media (10 mL) singly (yeast only) and in combination (yeast and yeast) and the tube was shaken gently to form a homogeneous suspension.

2.5 Fermentation of Fruits Juice for Bioethanol Production

Fermentation was carried out in Erlenmeyer conical flasks. Two hundred and fifty milliliters (250 mL) fermentation media were taken into 500 mL Erlenmeyer flasks and homogenous suspension of yeast was inoculated into the media in an aseptic condition. The flask was cotton plugged and incubated at 30°C for 21 days. Samples was taken at intervals of day zero, three, seven, ten, fourteen, and twenty-one for bioethanol production to monitor the following parameters: pH, temperature, optical density, total titratable acidity, brix (sugar content), specific gravity, alcohol content.

2.6 Physicochemical Analysis to Monitor the Progress of the Fermentation of Decaying Oranges and Pineapple Juice for Bioethanol Production

The physicochemical parameters carried out on the sample during fermentation included optical density, temperature, titratable acidity, brix level (total sugar), pH, alcohol content and yield.

2.7 Determination of pH of Ethanol

The pH of the fruits juice sample was read from a pH meter (Hanna instruments 8021) standardized with buffer solutions (4 and 7) (A.O.A.C, 2000).

2.8 Determination of Yeast Cell Growth

The yeast growth determination was carried out using spectrophotometer by the method of (Olutiola *et al*., 1991).

2.9 Determination of Titratable Acidity (TTA) % of Ethanol

It was expressed as percent acidity and analyzed using the method of [27]. TTA was determined by titrating known quantity of the sample against standardized 0.1N NaOH using a few drops of phenolphthalein solution as indicator to achieve pink colour end point which should persist for 15 seconds as shown in equation 1:

%ethanol = (mL of 0.1M NaOH (titre)× normality of NaOH×6 / Ml of sample) ×100 equation 1

2.10 Brix Level (Total Soluble Sugar) Determination of Ethanol

Sugar content was determined as Brix using a refractometer (Bs eclipse, Belllingham Stanley 45-02 company UK). A clean dry applicator was used to place two drops of the sample on the prism of the refractometer and the value (original gravity of the refractive index) was read [27].

2.11 Specific Gravity Determination of Ethanol

The specific gravity was estimated using hydrometer as outlined by Iland *et al*. [28].

The hydrometer was slowly inserted into a test jar filled with the banana must, spanned in the liquid to dislodge any air bubbles clinging to the glass, which could cause a test error. At eye level, the specific gravity figures on the glass stem were read where the surface of the liquid cuts across it at 20 ℃.

2.12 Determination of Alcohol

The alcohol content was measured in percentage volume by volume (%v/v) also by refractometry method as described by Nwachukwu [29]. A clean dry applicator was used to place 2 drops of the sample (must i.e., before fermentation) on the prism of the refractometer and the value (original gravity) of the refractive index was taken. Two drops of the sample collected at 24 hours interval was applied on the prism of the refractometer and the value (final gravity) was taken.

The percentage alcohol content was calculated using the formula:

$$\text{Alcohol by volume} = \frac{(76.08)\text{ x }(\text{O.g} - \text{Fg})}{1.775 - \text{O.g}}\text{ x }(\text{F.g}/\ 0.794)$$

Where O.g is the original gravity
F.g is the final gravity.

2.13 Determination of Bioethanol Yield

The ethanol yield was estimated according to AOAC (1990) by calculation using the formula:

$$\text{Ethanol yield} = \frac{\text{Ethanol produced}}{\text{Sugarconsumed}} \times 100$$

3. RESULTS AND DISCUSSION

In this study, a total number of fifteen (15) yeast isolates were isolated from the decaying oranges and pineapple. The culture was identified as yeast based on colony morphology, microscopic examination, budding formation and biochemical tests.

The temperature changes in fermenting fruits juice inoculated with different yeast strains and a mixed culture of the isolated yeast strains for bioethanol production is shown in Fig. 1. In general, fermenting fruits juice with single yeast strains culture resulted in the normal growth of the organism which is 30 °C. The mixed culture of the isolated yeast strains which are S. *cerevisiae* and *Kluvyeromyces marxianus* have a higher temperature on day 21 which is almost the same with the control.

The changes in cell biomass in the fermenting fruits juice is shown in Fig. 2. Samples were inoculated with different yeasts strains and a mixed culture of the isolated yeast strains for bioethanol production. There was an increase in cell growth at the beginning of the fermentation and it decreases as fermentation progresses.

The pH changes in fermenting fruits juice inoculated with different yeast strains and a mixed culture of the isolated yeast strains for bioethanol production is shown in Fig. 3. Fruits juice with single yeast strain culture shows a decrease in pH of the fermenting medium the onset of fermentation to day 14. It is worth noting that a sudden change in pH occurred on day 21 with a little increase from the value recorded on day 14.

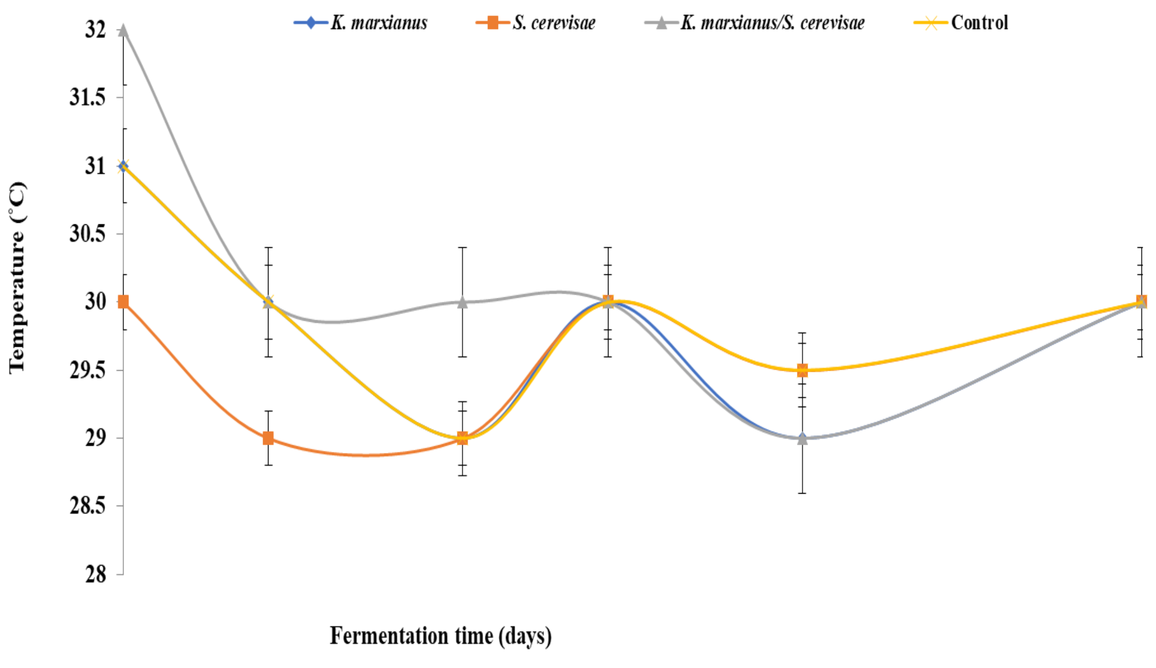

Fig. 1. Changes in the temperature with time in fermenting fruits juice inoculated with different yeasts and a mixed culture of yeasts for bioethanol production

Table 1. Biochemical Characteristic of Yeast Associated with Decaying Oranges and Pineapple

Isolate code	Glucose	Sucrose	Xylose	Lactose	Mannitol	Raffinose	Maltose	Meliobiose	Mannose	Galactose	Growth in 0.1% Actinide	Nitrate Reduction Test	Probable identity of isolate
1	++	++	++	++	++	-	++	+	+	++	+	+	*Trichosporon asahii*
2	++	++	++	++	++	+	+	+	+	+	+	+	*Trichosporon aesteroides*
3	++	++	++	++	++	-	-	-	+	+	+	+	*Rhodotorula mucilaginosa*
4	+	+	+	-	-	-	-	+	+	+	+	+	*Pichia meri*
5	++	+	++	++	+	+	-	+	+	+	+	+	*Trichosporon mucoides*
6	++	++	+	-	++	-	-	-	++	++	+	+	*Candida fructus*
7	+	+	+	++	-	-	++	+	+	++	+	+	*Trichosporon cutaneum*
8	+	++	++	++	++	+	+	+	+	-	+	+	*Candida albica*
9	-	-	++	-	-	-	-	-	+	-	+	+	*Candida catemulata*
10	+	+	+	-	-	-	-	-	+	+	+	+	*Candida parapsilosi*
11	++	++	++	++	++	-	-	-	+	+	+	+	*Kluyveromyces marxianus*
12	++	+	++	-	-	-	+	+	++	+	+	+	*Saccharomyces cerevisiae*
13	++	++	++	-	++	-	-	-	-	-	+	+	*Candida albican*
14	+	-	+	-	-	-	-	-	-	-	+	+	*Kluyveromyces fragilis*
15	-	-	-	-	-	-	-	-	-	-	+	+	*Candida valida*

KEY: ++ Positive and can produce gas, + positive and cannot produce gas, - Negative

Table 2. Carbon Assimilation Table for Two Yeasts used in Bioethanol Production

Probable identity of Organisms	Glucose	Mannose	Xylose	Sucrose	Maltose	Lactose	Raffinose	Galactose	Meliobiose
S. cerevisiae	+	-	-	+	+	-	+	+	-
K.marxianus	+	-	-	-	-	+	-	-	-

Key: + Positive; - Negative

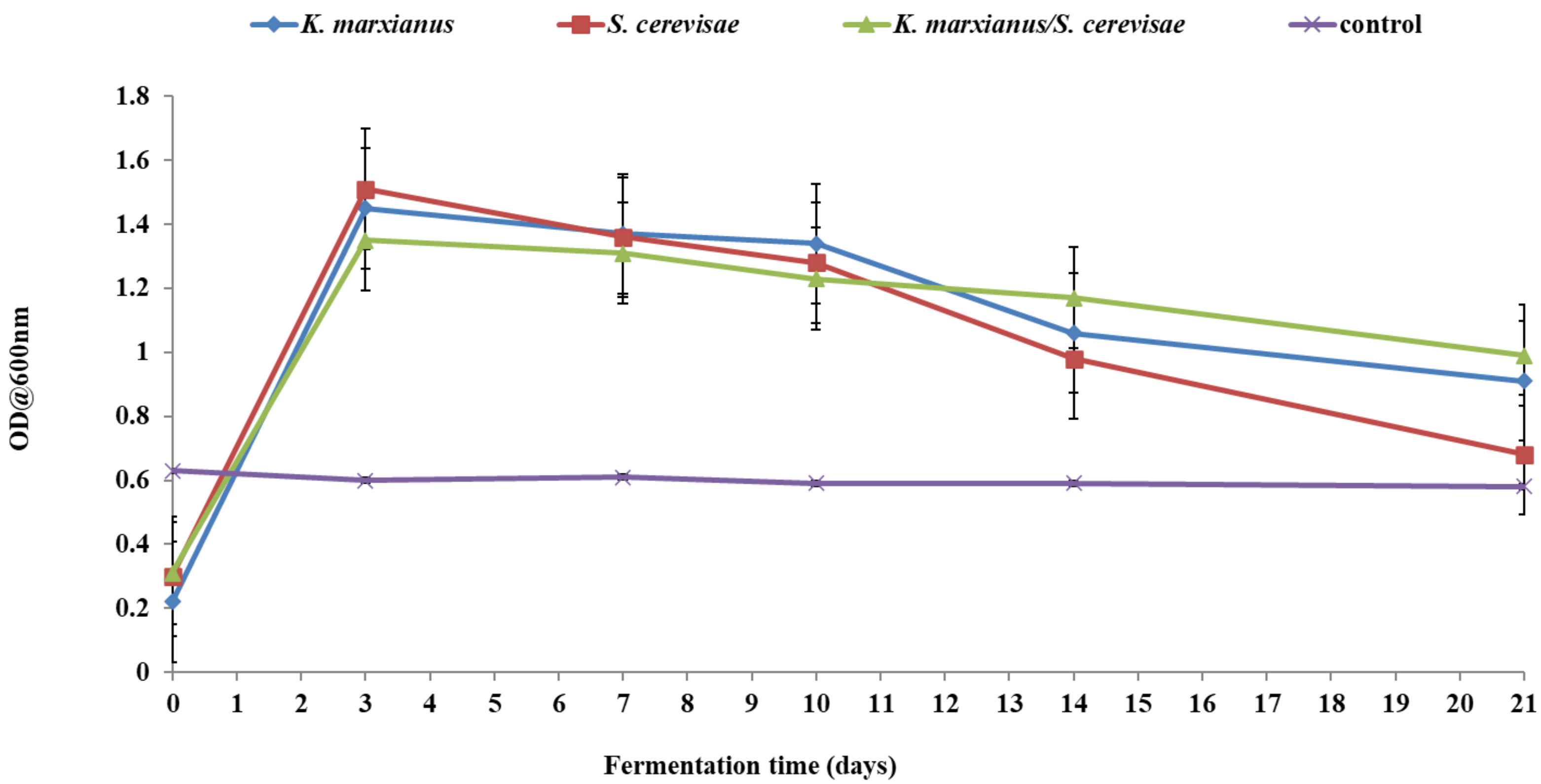

Fig. 2. Changes in the cell biomass with time in fermenting fruits juice inoculated with different yeasts and a mixed culture of yeasts for bioethanol production

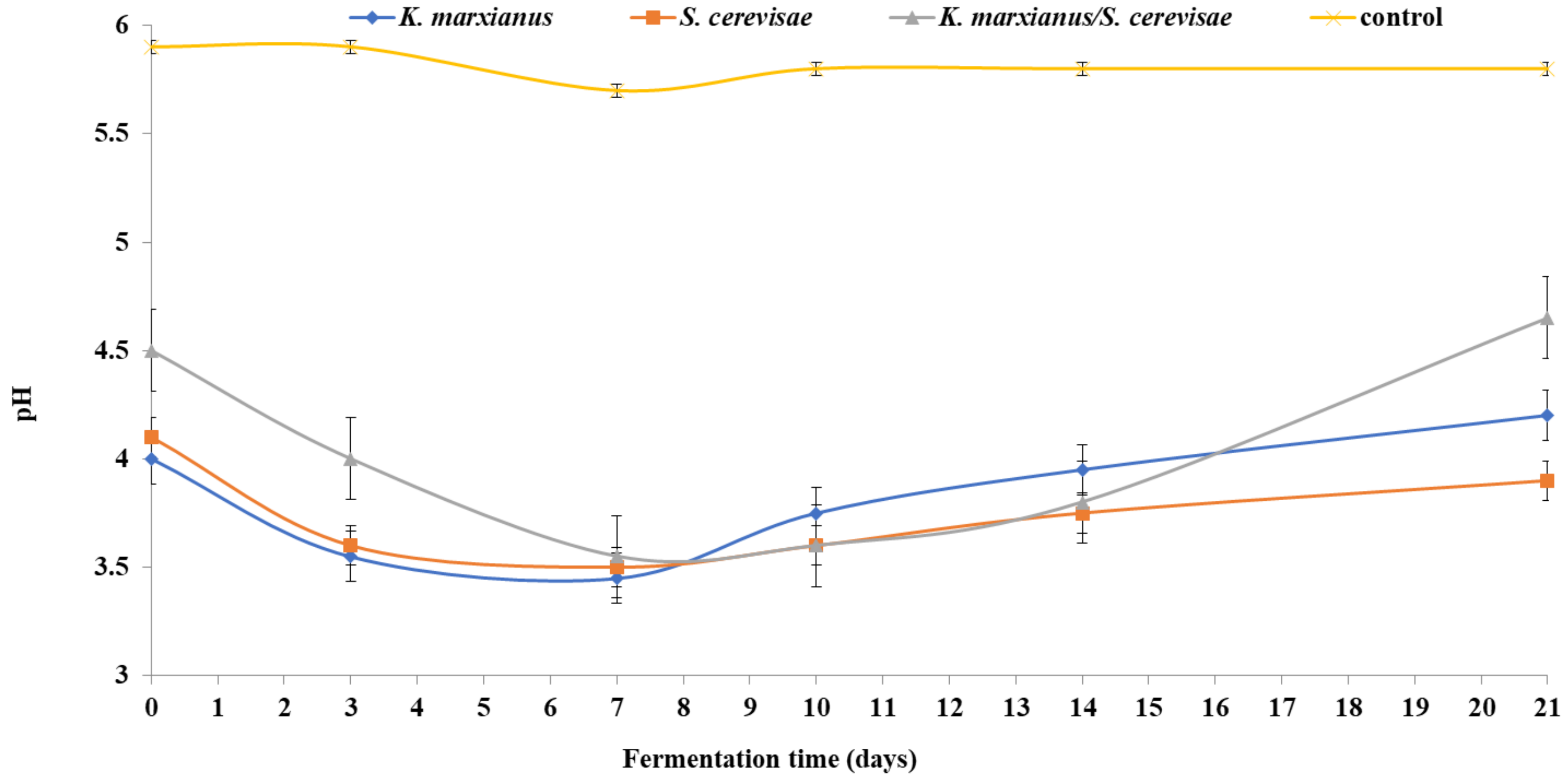

Fig. 3. Changes in the pH with time in fermenting fruits juice inoculated with different yeasts and a mixed culture of yeasts for bioethanol production

The changes in brix level in fermenting fruits juice inoculated with different yeast strains and a mixed culture of *S. cerevisiae* and *K. marxianus* for bioethanol production is shown in Fig. 4. In all the fermentation sets, the brix level decreased as fermentation progresses from a starting brix of 2.2^0 at the onset of fermentation to a range of between 0.1^0, 0.3^0 and 0.45^0 respectively at the end of the 21 days' fermentation process. In the single strains yeast series, *S. cerevisiae* gave the highest reduction in brix level (from 2.2^0 at the onset to 0.3^0 at the 21 day of fermentation) while the least reduction was seen in *K. marxianus*. The mixed culture of *S. cerevisiae* and *K. marxianus* gave the highest reduction in brix level (from 2.0^0 at the onset (0 day) to 0.1^0 at the end of the 21 days fermentation) which was significantly different from fermentation between the single yeast strains.

Titratable acidity in the fermenting fruits juice inoculated with single yeast strains increases as fermentation progressed. The fermenting fruits juice inoculated with *S. cerevisiae* gave the highest level of titratable acidity to day 14 of the fermentation process (Fig. 5). The titratable level of *K. marxianus* also increases but not at the same rate as the *S. cerevisiae*. The titratable acidity of the mixed yeast isolates increases with little significance in growth different up to the 14 days of fermentation and then remained stable.

The changes in specific gravity of the fermenting fruits juice inoculated with single and mixed strains of yeast respectively is shown in Fig. 6. The changes in specific gravity in single and mixed strains of yeast fermentation culture showed the same trend of gradual decrease as fermentation progressed. The mixed culture of *S. cerevisiae* and *K. marxianus* gave the lowest specific gravity value (1.001) as fermentation progressed. *S. cerevisiae* gave the highest specific gravity value. It is significant to note that the mixed culture of yeast strains significantly reduced the specific gravity of the fermented product compared to the value obtained for the single strains of yeast series involving in the fermentation.

The changes in alcohol content follow the same trend in all the single and mixed yeast strains fermentation has shown in Fig. 7. They all showed a gradual increase between zero to 14 and a decrease on day 21 of fermentation, with fermentation involving *S. cerevisiae* as a single yeast strain giving the highest alcohol content value of 5.05 in day 14 and a sharp decrease on day 21.

Saccharomyces cerevisae and *Kluvyreomyces marxianus* were selected based on their ability to tolerate high concentration of ethanol which is one of the essential attributes necessary for the production of bioethanol.

One of the parameters monitored during fermentation of fruits juice by single strains of yeast and mixed culture for bioethanol production is temperature. Temperature plays an important role in the production of ethanol, since the rate of alcoholic fermentation increases with the increase in temperature. The optimum temperature of ethanol ranges between 25°C to 40°C which depends on the room temperature. When temperature goes below the optimal range, their ability to catalyze the intended reaction slows down. In this study, the change in temperature observed during fermentation of fruits juice for bioethanol production ranges from 29-32°C. The result is similar to the work of Reddy and Reddy [30] who recommended that the fermentation temperature for ethanol production up to 30°C should be considered. It also agreed with the results of Maysa [31] who reported that the highest ethanol levels by two *Saccharomyces cerevisiae* strains at 30°C.

The observed changes in cell biomass of the optical density within the period of fermentation could be due to increase in microbial load arising from microbial succession with changes in fermentation end products. These results agree with reports of previous workers [32,33,34].

The pH value has significant influence on alcoholic fermentation. Enhanced ethanol production through fermentation can be obtained by controlling pH of the broth as it is one of the key factors for ethanol production having direct influence on organisms as well as on their cellular processes [35. In general, hydrogen ion concentration in fermentation broth can change the total charge of plasma membrane affecting the permeability of some essential nutrients into the cells. The pH values of ethanol produced by the process of fermentation ranges from 4 to 6. In this study, the pH of the fermenting medium decreases as fermentation progressed to day 14^{th}. A sudden increase in pH was observed at the end of the 21st day of the fermentation. The mixed culture of *K. marxianus* and *S. cerevisiae* gave the highest sudden increase in pH value of

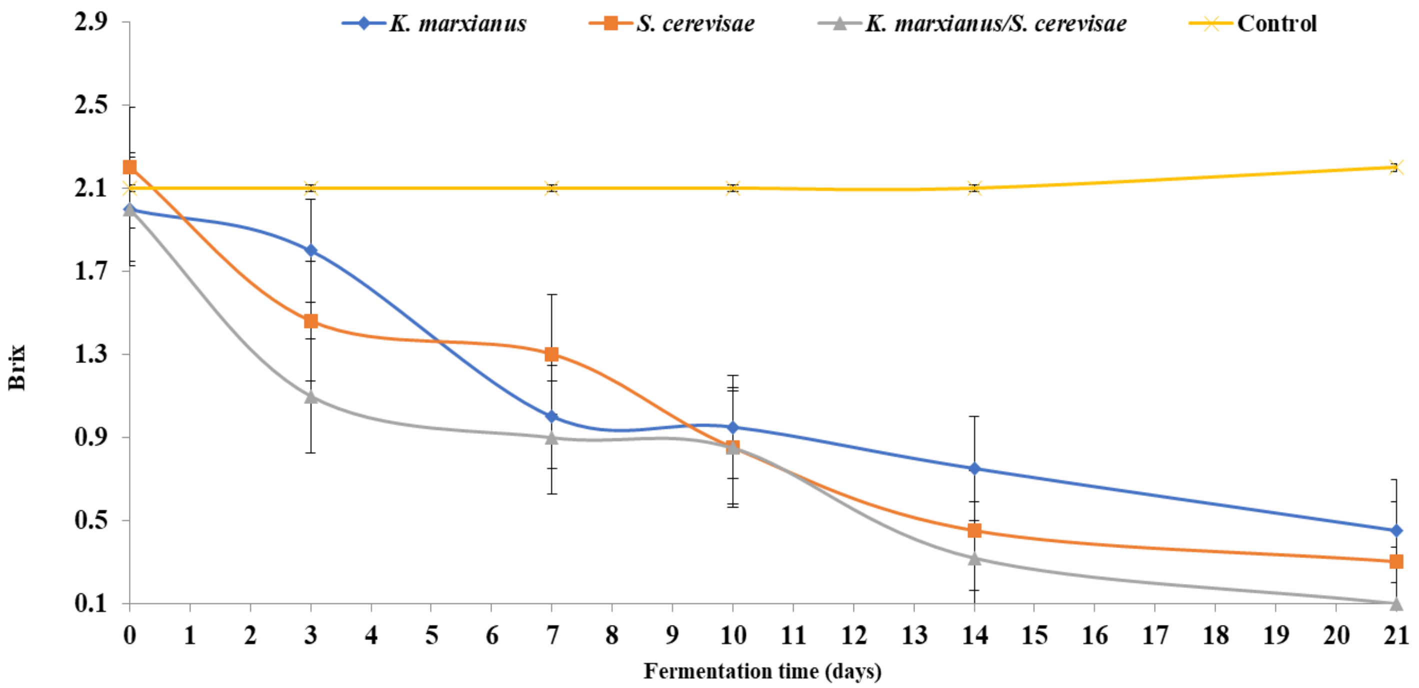

Fig. 4. Changes in the level of brix with time in fermenting fruits juice inoculated with different yeasts and a mixed culture of yeasts for bioethanol production

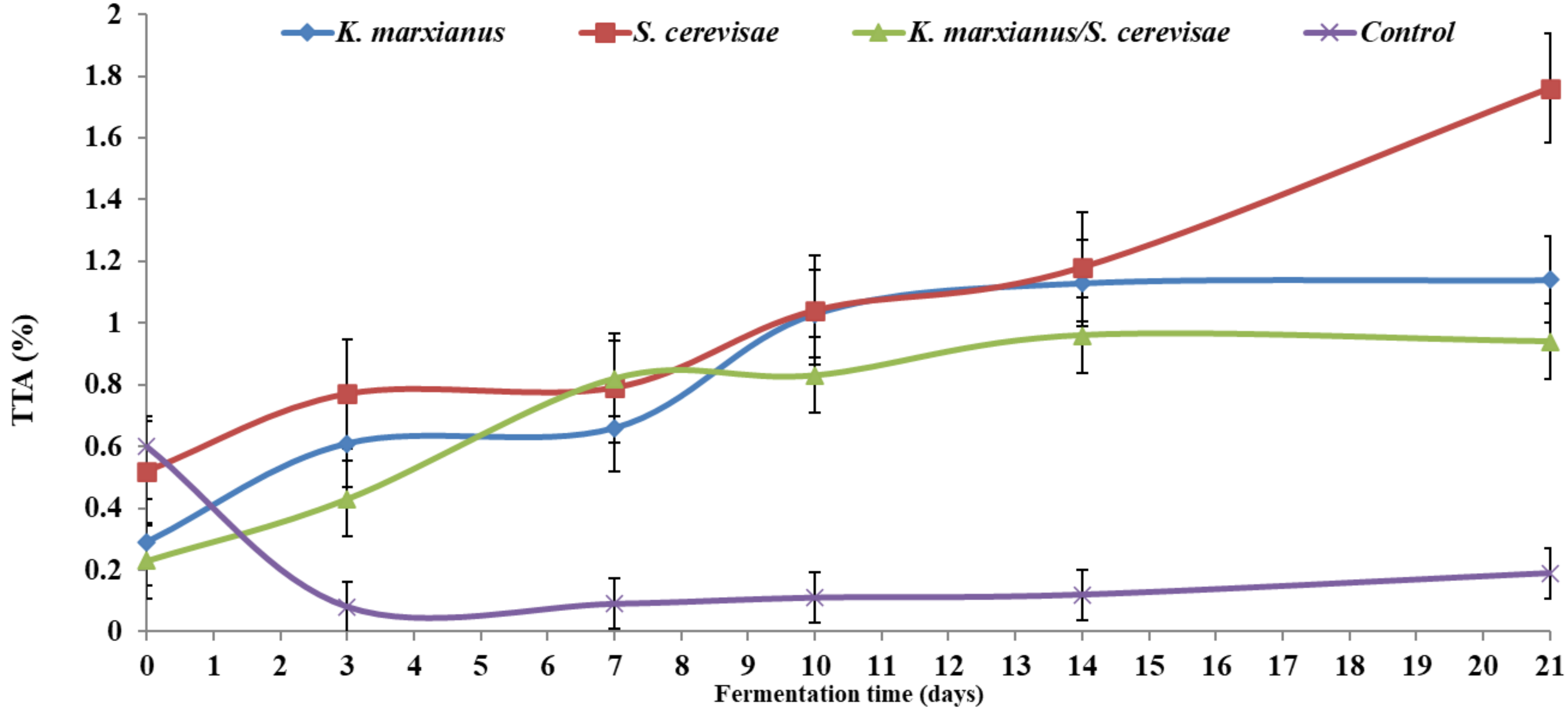

Fig. 5. Changes in the titratable acidity with time in fermenting fruits juice inoculated with different yeasts and a mixed culture of yeasts for bioethanol production

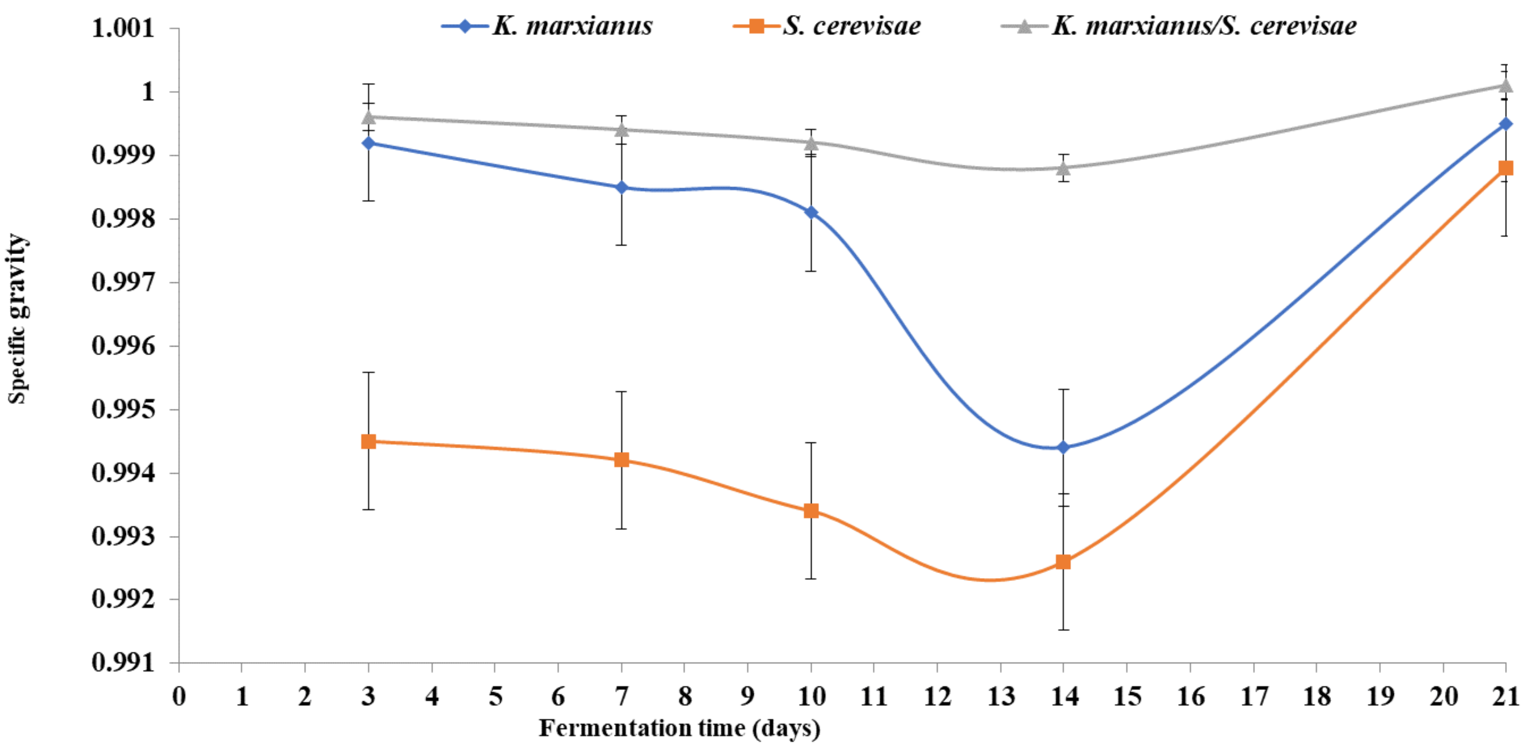

Fig. 6. Changes in the Specific Gravity with time in fermenting fruits juice inoculated with different yeasts and a mixed culture of yeasts for bioethanol production

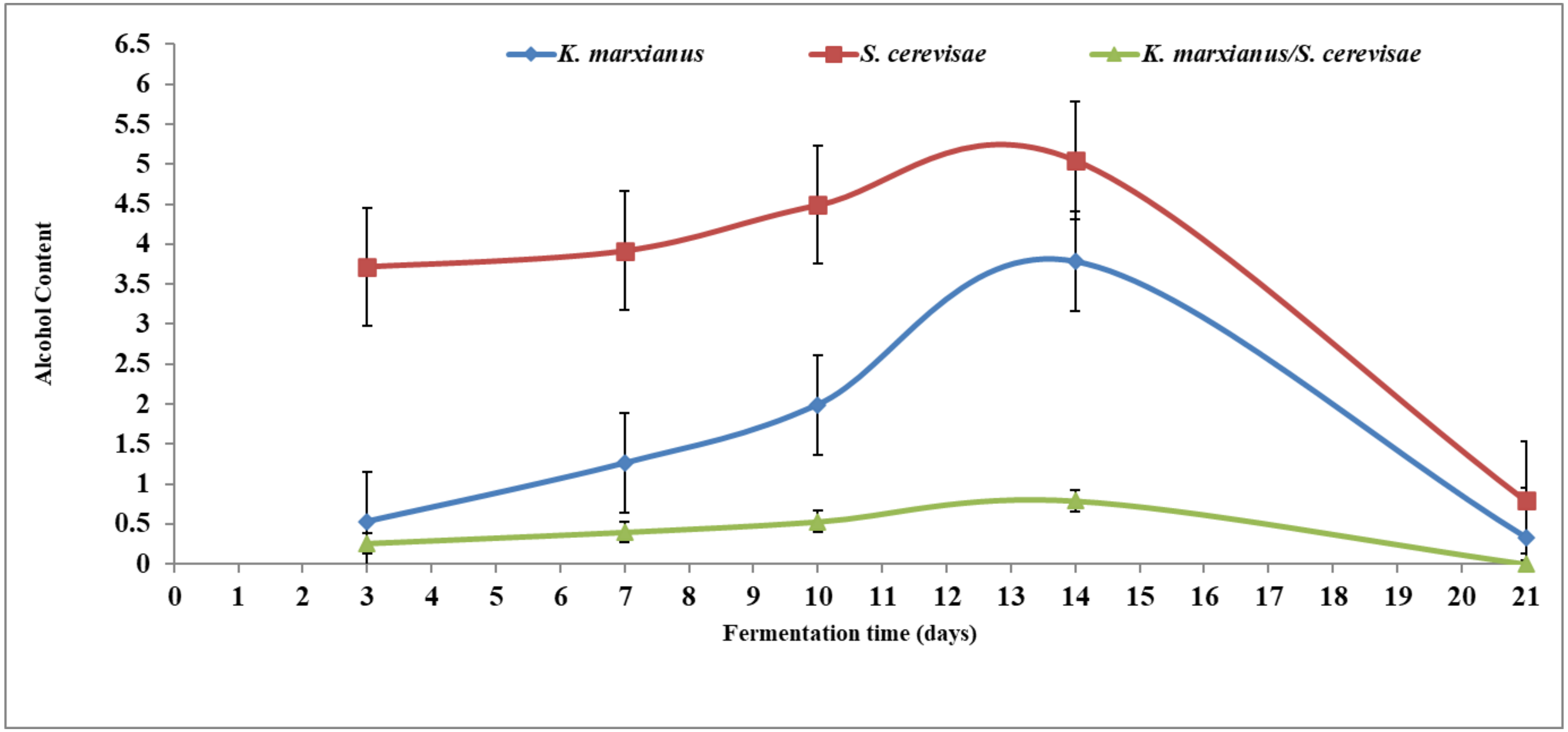

Fig. 7. Changes in the alcohol content with time in fermenting fruits juice inoculated with different yeasts and a mixed culture of yeasts for bioethanol production

Table 3. Percentage Yield of Bioethanol Produced from Decayed Fruits Juice

DAYS	*K. marxianus*	*S. cerevisiae*	*K. marxianus* and *S. cerevisiae*
3	2.69	18.88	1.67
7	6.39	19.89	2.69
10	10.10	22.79	6.30
14	19.18	25.6 3	10.10
21	1.67	4.01	0
Total Yield	**40.03**	**91.20**	**20.76**

4.65 while *S. cerevisiae* gave the lowest pH value of 3.9 on day 21. The result of this study agrees with Chanprasartsuk *et al*. [36] who reported a final pH value of 3.9. The final pH value of *K. marxianus* is 4.2. The final pH value obtained was similar with results reported by Chanprasartsuk *et al*. [36] who obtained final pH value of 3.9. This value was however high compared to those of (3.4 to 3.5) obtained by Idise [37] at the end of pineapple juice fermentation but was concordant with the pH of the wines after fermentation which is generally 2.0 to 4.0 [38].

In addition, titratable acidity is an important characteristic during fermentation process and it depends on the biochemical composition of fruit juice used in the alcoholic fermentation and process parameters of fermentation. The titratable acidity increases throughout the fermentation process. Similar observations were made by Chowdhery and Roy [39] when they reported an increase in titratable acidity (from 0.51 to 3.30%) during the alcoholic fermentation. This result does not agree with Vaidya *et al*. [40] who reported decrease in titratable acidity (from 1.07 to 0.52%) after fermentation of kiwi from fruits juice.

The brix level is the sugar content of the fermenting fruits juice. The brix level decreases from 2 to 0.1 throughout the fermentation process. The result of this study does not agree with Akubor *et al.* [41] observed the decrease in TSS of banana juice from 18 to 4.8^{o} brix at the end of 14 days fermentation at 30 ± 2 °C temperature.

In addition, specific gravity is used to measure the sugar and alcohol content. As the fermentation progressed, the specific gravity considerably decreased and reached a value. The decrease in specific gravity is a clear indication of yeast fermenting the sugar resulting in ethanol production. There is an inverse relationship between specific gravity and alcohol content. The lower the specific gravity, the higher the alcohol content. The increase in acidity may be due to the activities of the microorganisms breaking down sugars to produce both alcohol and carbon dioxide. This study agrees with the work of Duarte *et al*. [42] who reported higher alcohol inoculated with *S. cerevisiae* UFLA CA 1162 isolated from fermented fruits.

The ethanol yield mentioned in this study showed that *S. cerevisiae* gave the highest ethanol yield of 91. 20 at 30^{o} C at the end of the fermentation process. The result of this study shows does not agree with the work of Lin and Shen *et al*. [43] who reported ethanol yield of 75.79% at 28^{o}C and 89.89% at 30^{o}C from sweet sorghum juice using immobilized yeast cell.

4. CONCLUSION

In conclusion, the result of this study has revealed the usefulness of waste. It can be used in the production of bioethanol. Bioethanol is an eco-friendly fuel that can be used in unmodified petrol engines [44]. Combustion of ethanol results in relatively low emission of volatile organic compounds, carbon monoxide and nitrogen oxides [45-48]. This reduces greenhouse gases thereby leading to a clean environment. Lignocellulosic biomass has been projected to be one of the main resources for economically attractive bioethanol production. One of such biomass is agricultural wastes which are renewable, less costly and abundantly available in nature. Agricultural wastes do not demand separate land, water, and energy requirements. Effort should be made in converting this waste to wealth [49-53].

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. United Nation. World Population Prospects, the 2006 Revision, Highlights; Working Paper ESA/P/WP; 2007.
2. Schiffer HW. WEC energy policy scenarios to 2050. Energy Policy. 2008;36(7):2464-70.
3. Solomon CG, Salas RN, Malina D, Sacks CA, Hardin CC, Prewitt E et al. Fossil-fuel pollution and climate change—A new NEJM group series. N Engl J Med. 2022;386(24):2328-9.
4. Thurston GD. Fossil Fuel Combustion and PM2.5 Mass Air Pollution Associations with mortality. Environ Int. 2022;160.
5. Eswaran N, Parameswaran S, Johnson TS. Biofuels and sustainability. Methods Mol Biol. 2021;2290:317-42.
6. Abid N, Ceci F, Ikram M. Green growth and sustainable development: dynamic linkage between technological innovation, ISO 14001, and environmental challenges, ISO 14001, and Environmental Challenges. Environ Sci Pollut Resour Int. 2022;29(17):25428-47.
7. Golroudbary SR, Makarava I, Kraslawski A, Repo E. Global environmental cost of using rare earth elements in green energy technologies. Sci Total Environ. 2022;832:155022.
8. Agbor VB, Cicek N, Sparling R, Berlin A, Levin DB. Biomass pretreatment: fundamentals toward application. Biotechnol Adv. 2011;29(6):675-85.
9. Nigam PS, Singh A. Production of liquid biofuels from renewable resources. Prog Energy Combust Sci. 2011;37(1):52-68.
10. Chiranjeevi T, Hari Prasad O, Navya A, Praveen CV, Nanda K, Ismail et al. Isolation and characterization of ethanol tolerant yeast strains. J Bio Inf. 2013;9(8):421-5.
11. Limayema A, Steven C, Ricke CV. Lignocellulosic biomass for bioethanol production: current perspectives, potential issues and future prospects. Prog Energy Combust Sci. 2012;38(4):449-67.
12. Sharma S, Kundu A, Basu S, Shetti NP, Aminabhavi TM. Sustainable environmental management and related biofuel technologies. J Environ Manage. 2020;273:111096.
13. Liu Y, Cruz-Morales P, Zargar A, Belcher MS, Pang B, Englund E et al. Biofuels for A sustainable future. Cell. 2021;184(6):1636-47.
14. Hasan M, Abedin MZ, Amin MB, Nekmahmud M, Oláh J. Sustainable biofuel economy: A mapping through bibliometric research. J Environ Manage. 2023;336:117644.
15. Bai FW, Anderson WA, Moo-Young M. Ethanol fermentation technologies from sugar and starch feedstocks. Biotechnol Adv. 2008;26(1):89-105.
16. Gray KA, Zhao L, Emptage M. Bioethanol. Curr Opin Chem Biol. 2006;10(2):141-6.
17. Singh A, Singhania RR, Soam S, Chen CW, Haldar D, Varjani S et al. Production of bioethanol from food waste: status and perspectives. Bioresour Technol. 2022;360:127651.
18. Chen GQ, Liu X. On the future fermentation. Microb Biotechnol. 2021;14(1):18-21.
19. Shi S, Valle-Rodríguez JO, Siewers V, Nielsen J. Prospects for microbial biodiesel production. Biotechnol J. 2011;6(3):277-85.
20. Qureshi JA, Stansly PA. Integrated approaches for managing the Asian citrus psyllid (Homoptera: Psyllidae) in Florida. Abstracts of the for the 2007 Joint Annual Meeting of the Florida State Horticulture Society. 2007;4:342-5.
21. Tournas VH. Moulds and Yeasts in fresh and minimally processed vegetable and sprouts. Int J Food Microbiol. 2005;99(1):71-7.
22. Li H, Veenendaal E, Shukor NA, Cobbinah JR, Leifert C. J Appl Microbiol. 2008;21:322-6.
23. Tsegaye Z. Isolation, identification and characterization of ethanol tolerant yeast species from fruits for production of bio-ethanol. Int J Mod Chem Appl Sci. 2016;3(3):437-43.
24. Colin M, Jennife M, Lopes DE, Miguel JV. America Journal of ecology. 2006;57:423-30.
25. Arranz-Otaegui A, Gonzalez Carretero L, Ramsey MN, Fuller DQ, Richter T. Archaeobotanical evidence reveals the origins of bread 14,400 years ago in Northeastern Jordan. Proc Natl Acad Sci U S A. 2018;115(31):7925-30.

26. Ting TY, Li Y, Bunawan H, Ramzi AB, Goh HH. Current advancements in systems and synthetic biology studies of Saccharomyces cerevisiae. J Biosci Bioeng. 2023;135(4):259-65.
27. Wilson P, David T, Sam B. Microbial and biochemical changes occurring during production of traditional Rwandese Banana Beer Urwagwa, Fermentation Technology, An open Access [journal]. 2012;1:104.
28. Iland P, Ewart A, Sitters J, Markides A, Bruer N. Techniques for chemical analysis and quality monitoring during winemaking. Patrick Iland Wine Promotions Aust. 2000;111:123-205.
29. Nwachukwu JA. Production and quality evaluation of banana (*Musa sapientum*) wine. M.Sc. Thesis, Caritas University. 2010;5-38.
30. Reddy LVA, Reddy OVS. Rapid and enhanced production of ethanol in very high gravity (VHG) sugar fermentations by Saccharomyces cerevisiae: role of finger millet (*Eleusine coracana* L.) flour. Process Biochem. 2006;41(3):726-9.
31. Maysa MA, Ali AO. Studies on production of ethanol and single cell proteins by local yeast strains [M.Sc. thesis]. Egypt: Botany Department, Faculty of Science, Assiutet University; 2010.
32. Amerine MA, Kunkee RE. Microbiology of winemaking. Am Revision Microbiol. 2005;22:232-58.
33. Robinson J. The Oxford companion to wine. 3rd ed. Oxford University Press; 2006. p. 268-780.
34. Okafor N. Microbiology and Biochemistry of Oil Palm wine. Adv Appl Microbiol. 1978;24:237-56.
35. Kasemets K, Nisamedtinov I, Laht TM, Abner K, Paalme T. Growth characteristics of Saccharomyces cerevisiae S288C in changing environmental. Int J Microbiol. 2007;3(1):134-9.
36. Chanprasartsuk O, Kornwika P, Donlaphorn T. Pineapple wine fermentation with yeasts isolated from fruit as single and mixed starter cultures. Asian J Food Agric Ind. 2012;5(02):104-11.
37. Idise OE. Studies of wine produced from pineapple (*Ananas comosus*). Int J Biotechnol Mol Biol Res. 2012;3(1):1-7.
38. Perrin L. Contribution methodology and analysis of sensory Date. Doctorate thesis Centre International for Sciences in Agronomics. Biotechnology Microbiology. 2008;132:67-87.
39. Chowdhury P, Ray RC. Fermentation of Jamun (*Syzgium cumini* L.) fruits to form red wine. Asean Food J. 2007;14:15-23.
40. Vaidya D, Vaidya M, Sharma S, Ghanshayam S. Enzymatic treatment for juice extraction and preparation and preliminary evaluation of kiwifruits wine. Nat Prod Radiance. 2009;8:386-91.
41. Akubor PI, Obio SO, Nwadomere KA, Obiomah E. Production and quality evaluation of banana wine. Plant Foods Hum Nutr. 2003;58(3):1-6.
42. Duarte WF, Dias DR, Oliveira JM, Teixeira JA, de Almeida e Silva JB, Schwan RF. Characterization of different fruit wines made from cacao, cupuassu, gabiroba, jaboticaba and umbu. Food Sci Technol. 2010;43(10):1564-72.
43. Liu R, Shen F. Impacts of main factors on bioethanol fermentation from stalk juice of sweet sorghum by immobilized Saccharomyces cerevisiae (CICC 1308). Bioresour Technol. 2008;99(4):847-54.
44. Hansen AC, Zhang Q, Lyne PW. Ethanol–diesel fuel blends—a review. Bioresour Technol. 2005;96(3):277-85.
45. Mansy AE, El Desouky EA, Taha TH, Abu-Saied MA, El-Gendi H, Amer RA et al. Sustainable production of bioethanol from office paper waste and its purification via blended polymeric membrane. Energy Convers Manag. 2024;299:117855.
46. Amira HA, Asma AA, Sumayh AA, Ahmed MA, Lena AA, Maryam HA. lulwah, Y. A and Hesham, M.E. 2023. Bioethanol production from lignocellulosic biomas using Aspergillus niger and Aspergillus flavus hydrolysis enzymes through immobilized S. cerevisiae. Journal of Energies MDPI;16(2):823.
47. Audu RO, Ijah UJJ, Mohammed SSD. Pre-treatment, physicochemical properties and production of bioethanol from rice husk using fungi isolated from waste dumpsite in Kaduna, Nigeria. J Appl Sci Environ Manag. 2023;27(7):1359-70.
48. Sharma S, Kundu A, Basu S, Shetti NP, Aminabhavi TM. Sustainable environmental management and related biofuel technologies. Journal of Environmental Management. 2020 Nov 1;273:111096.
49. Kreger-Van Rij NJ. The Yeast a Taxonomic Study. New York: Elsevier Science Publishing Company. 1984;1082.
50. Melaku M, K, Addis S, Yisehak TR, Hallay MG, Addisu DB et al. Evaluation of sugar

content and bioethanol production of Ethiopian local varieties'Nech tinkish and Hawage sweet sorghum (sorghum bicolor (l). Res Gate J RS. 2023;3:3452-62.

51. Muregi MA, Abolarin MS, Okegbile OJ, Eterigho EJ. Influence of temperature and agitation spreed on fermentation process during production of bioethanol fuel from cassava. Int J Eng Adv Technol Stud. 2021;9:40-6.

52. Panagiota T, Georgios M, Dimitris Z, Julian M, Michael K. Assessment of substrate load and process pH for bioethanol production- development of a kinetic model. J Sci Direct. 2022;313:123007.

53. Shaswat B, Debojeet S, Firdous S, Swagata B, Sadhan M. Bioethanol, internal combustion engines and the development of zero-waste biorefineries: an approach towards sustainable motor spirit. J R Soc Chem. 2023;1:1065-84.

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