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Review Research

BIOETHANOL PRODUCTION FROM AGRICULTURAL WASTE: A REVIEW

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Abstract: The importance of this research lies in keeping pace with the global trend to diversify energy sources and reduce climate change and air pollution by shedding light on how to benefit from agricultural waste by using it as a raw material for the production of bioethanol, which is one of the most important types of renewable fuels. This review highlighted the; ways of converting agricultural and fruit waste into bioethanol and its environmental and economic benefits-including adding it to gasoline used as car fuel in different proportions, as it works to raise the octane number of gasoline and improve its quality, thus reducing its production costs and reducing gas emissions from vehicle exhaust. In addition, the global production of bio-ethanol was reviewed and is expected to reach it by the end of 2023. It also highlighted the results of several studies that dealt with the properties and uses of ethanol and the best agricultural wastes used for this purpose. It is suggested to focus on the agricultural waste in Iraq, such as rice husks, in terms of cost and conditions for improvement to increase bio-ethanol production using fermentation processes.

Keywords: *Agricultural Waste; Bioethanol; Fermentation; Rice Husks; S.cerevisiae.*

1. Introduction

The world is confronted with an important challenge arising from the rise in population growth and at the same time the escalating demand for energy sources. This urgent issue revolves around the necessity to fulfill energy deficiencies for transportation, heating, and industrial processes [1], taking into account the necessity of addressing environmental pollution and limiting global warming and climate changes, where gas emissions resulting from the use of fossil fuels are among the most prominent its sources [2], For these reasons, biofuel production is one of the ideal energy sources that contribute to meeting needs and achieving development sustainable [3]. Biofuel is any fuel produced from biomass, whether solid, liquid, or gas, and is considered a biofuel. Examples include food crops, specific bioenergy crops (such as switch grass or prairie perennials), agricultural leftovers, wood/forestry waste, by-products, animal manure, algae, and so on, the biological material or organic matter transformed into biofuels. Biofuel feedstock is the raw material or biomass that makes biofuel [4]. Ethanol/ethanol blends and biodiesel/biodiesel blends are the two most prevalent biofuels manufactured commercially. These biofuels, which come in liquid form, are widely employed in the transportation sector [5]. Bioethanol is considered a fundamental denomination within the field of biofuels, serving dual roles as both a petroleum

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supplement and a viable transportation fuel due to its high-octane properties [6]. Biofuel is generated from the fermenting of potatoes, corn, cereal grains (rye, wheat, and barley), sugar cane, beet sugar, & fruit and vegetable leftovers [7-9]. During the previous and current periods, researchers have directed their attention toward enhancing the economic viability and ecological sustainability of the ethanol production process. Emphasis has been placed on the conversion of agricultural waste, as well as fruit and vegetable residue, and other biomass-rich materials into ethanol. The focus on such feedstocks is due to their perennial availability and renewable nature [10]. Depending on the feedstock utilized for bioethanol production, sugar-based raw materials for fermentation are known as (first-generation) bioethanol [11, 12]. In contrast, lignocelluloses for fermentation are known as (second generation) bioethanol [13]; cellulosic plant materials represent a source of fermentable polysaccharides, especially non-food agricultural waste products such as wheat straw, rice straw, bagasse, rice husk, Etc.[14]. Polysaccharides are connected sugar molecules; in these compounds, cellulose, and hemicellulose are intimately connected to lignin in the plant cell wall; lignin acts as a barrier and must be eliminated before carbohydrates may be further transformed; microorganisms are used to convert cellulosic biomass to fermentable sugar to manufacture ethanol, the biological conversion of cellulosic biomass to fermentation for ethanol generation is carried out by using microorganisms that are both inexpensive and readily available. Bioethanol production is thus cost-effective, environmentally benign, and renewable [7, 15, and 16]. This paper aims to encourage the utilization of agricultural residues and convert them from a source of environmental pollution to a raw material used to produce bioethanol fuel, especially since Iraq is distinguished by the cultivation of rice, where it is possible to benefit from rice husks for this purpose.

2. Bioethanol

2.1. Properties of Bioethanol

Bioethanol, shown in Fig. 1, is an organic substance categorized among the denomination of ordinary alcohols and is produced through the fermentation of carbohydrates sourced from plant materials. Advances in technology have expedited the use of cellulosic materials, encompassing trees and plants, in the manufacturing process of bio-ethanol. [17]. It has the chemical formula C_2H_6O [18].

$$\begin{array}{c} H \quad H \\ | \quad | \\ H-C-C-O-H \\ | \quad | \\ H \quad H \end{array}$$

Figure 1. Bioethanol Structural Formula

Bio-ethanol is a volatile and combustible liquid with a distinct odor. It exhibits polar characteristics, attributed to its ability to form hydrogen bonds. Notably, it has a boiling point of 78.32°C as shown in Table 1. Its solubility extends to polar solvents, such as water, owing to its capability to attract hydrogen bonding with water molecules. Additionally, it can dissolve in various organic solvents, including but not limited to glycerin, acetone, carbon tetrachloride, benzene, and chloroform [19].

Table 1. Bio-ethanol properties synthesis using microorganisms

Properties	Value

Boiling point	78.32°C
Freezing point	-114.1°C
Density	0.7893 g/mL
Refractive index nD/t, 20-30°C	0.000404
Thermal conductivity 20°C	0.170 W/m.K
Viscosity 20 °C	1.17 cP

2.2. Bioethanol Uses

Ethanol is a chemical frequently employed daily for personal or domestic consumption or cooking, lighting, heating, and steam production. Additionally, ethanol is utilized to create vinegar and a variety of alcoholic beverages. Alternately, in academic studies, medicinal production. It is used in various therapeutic medicines administered orally, topically, or intravenously. Ethanol is a powerful solvent in the pharmaceutical industry [20]. Ethanol is used in personal care products because it has skin-cleansing properties at low doses. As a preservative, it aids in the cosmetic's homogenization of its ingredients. Its incorporation into hair sprays improves the adhesion of the spray to the hair. Ethanol possesses antimicrobial properties, exhibiting effectiveness against bacteria, fungi, and viruses; it is highly effective at a concentration of 70-80% against germs and most viruses related to hospitals [21]. One of the viruses sterilizing with ethanol is the Coronavirus (COVID-19); human endemic coronaviruses can persist on non-living surfaces such as metal, glass, or plastic for up to 9 days but can be effectively inactivated by 62-71% surface disinfection procedures [22]. When it comes to household items like paint, ethanol is used as a solvent to help bring paint's components together. It may also be used as fuel for vehicles and engines when mixed with other compounds. An estimated 30 million gallons of ethanol are used worldwide as a motor fuel [23]. Ethanol can be combined with gasoline or employed as a fuel additive in any proportion. Presently, modern gasoline-fueled automotive engines can ingest a mixture of (bioethanol/gasoline) with ethanol concentrations of up to 15%. [17]. Agricultural and cellulosic waste can produce ethanol, such as wood, weeds, and local garbage. That has contributed to its popularity as a car fuel [20].

2.3. The Economic Significance of Agricultural Residue-Derived Ethanol Production

Since bio-ethanol has a wide range of applications, its output is predicted to expand significantly because of rising investment and its economic and environmental benefits in decreasing carbon emissions from energy, which contribute to climate change. New ethanol facilities will be erected in the next several years, and production will reach 110 billion liters by 2023 [24]. Besides being used in various sectors, numerous methods for producing raw materials as renewable resources have been devised [25, 26]. According to [19], Brazil and the United States produce the most bioethanol worldwide. Since 1975, Brazil has made ethanol from sugarcane as automobile fuel, whereas the United States has produced ethanol from corn. Most of the bioethanol generated worldwide is derived from sugar cane and corn. Many countries seek to increase the use of bio-ethanol and reduce their dependence on fossil fuels through their politicians in the search for renewable energy sources, to address environmental and economic issues affecting our planet. Raw materials for bioethanol synthesis include sugar- and starch-rich crops [27]. These raw materials may include rice,

sweet corn, potatoes, wheat straw, barley, wheat, and sugar by-products such as molasses and date residues, as well as forest remnants [28]. Ethanol production from agricultural waste is cost-effective and ecologically benign. As a result of their inappropriate disposal, agricultural wastes are seen as a significant environmental burden—more agricultural waste results in increased health and ecological and economic harm [6].

2.4. Bioethanol Quantification.

Many methods have been used to estimate the presence of ethanol in solutions; an HPLC (High-performance liquid chromatogram) system with a suitable column should be used to achieve high precision in detecting the concentration of bio-ethanol produced. Monochromatic light interactions with the molecules in the sample, photon scattering, and vibration are used to create diagrams illustrating the measurements [29]. Quantitative optical spectroscopy relies on Beer's law and Lambert's rule, which asserts that the intensity of light absorbed by a sample is proportional to the concentration of the chemical. The wavelengths 1200 and 950 cm^{-1} are used to determine ethanol concentrations [30]. Beer assessment using a Gas–liquid chromatography (GLC) device is currently used as a standard protocol in the U.S. and has been the most popular technique for assessing ethanol and blood [31]. This device is associated with a high analytical speed and provides a high accuracy in measuring GLC [32]. Gas chromatography analysis (GC) was employed to determine the quantity of ethanol in alcoholic drinks by injecting the sample straight into the GC apparatus after adding an adequate amount of acetonitrile solution. This approach yielded a result less than 8 minutes after the sample was inserted. In addition to dichromate oxidation, an enzyme oxidation approach uses alcohol dehydrogenase. GC is the most often utilized approach since it provides results more expediently [33]. Dichromate oxidation is the simplest and most appropriate approach for determining ethanol concentration for research applications, such as choosing a high-yielding strain, designing bio-ethanol manufacturing techniques, monitoring processes and managing alcoholic drinks, and measuring the ethanol concentration in clinical samples; this technique determines the amount of ethanol solvent removed from the fermentation medium in this procedure. Its solution's color of the solution changes, the color may change from orange to green when there is an abundance of ethanol in the water. [34]. Due to the standard curve of absolute ethanol, To determine the ethanol content, the absorbance at a wavelength of 584 nm was measured using the chromic acid procedure, which involved the use of a spectrophotometer [35].

3. Previous Research on the Production of Bioethanol from Agricultural Waste

Producing ethanol from agricultural waste is cost-effective and environmentally harmless, as improper disposal of such waste is seen as a significant environmental burden leading to increased health, ecological, and economic harm [6]. We will discuss bioethanol production processes using many agricultural wastes as raw materials, including:

3.1. Production of Bioethanol from Corn Grain

Corn grain is one of the sources of bioethanol production, and several studies dealt with the process of analyzing it to produce ethanol, including Braide et al. [36] researched ethanol

production using corn, potato peel wastes, and continuous improvement. They conducted this research to determine the best conditions for ethanol production. PH, substrate concentration, and particle size were among the parameters investigated. Fermentation was investigated in both solid and submerged forms. The results of submerged fermentation were positive. For 72 hours, the Simultaneous Saccharification and Fermentation technique (SSF) was used in tandem with yeast fermentation. An attempt to make ethanol from potato peel waste was made. However, corn proved to be a more efficient substrate. At pH 5.5, 0.157mm intermediary particle size, and 10% salt concentration (W/V), a significant yield of ethanol of 15.88g/l has obtained a significant yield of ethanol of 15.88g/l was obtained. Udhayaraja et al. [37] investigate the possibility of producing agro-waste ethanol. Sugarcane Saccharum officinarum (sugarcane bark, sugarcane bagasse) and maize plant Zea mays (corn husk, corncob, corn stalk) have been acid hydrolyzed. Lignin, which functions as a natural wall to cellulolytic enzymes, was removed using agricultural waste. The ethanol production, specific gravity, pH, and total reducing sugar were all assessed after 5-day fermentation with Saccharomyces cerevisiae. According to the findings, the specific gravity, sugar content, and pH declined over time. After 72 hours of fermentation, the percentage ethanol outputs from sugarcane bark, sugarcane bagasse, cornhusk, corncob, and cornstalk were 6.23, 6.72, 3.45, 6.17, and 4.17. The maximum ethanol yields were obtained at pH 3.82, 3.60, 3.65, 3.64, and 4.00. Ahmad et al. [38], used Saccharomyces cerevisiae to optimize bioethanol production utilizing sorghum stover as a substrate; the ethanol was fermented using crude hydrolyzed enzymes from sorghum, with the effect of pH, temperature, and inoculum level studied. They found the highest ethanol production at pH 6.5, 35°C, and an inoculum level of 10%.

3.2. Production of Bioethanol from Rice Husks

Rice husks, classified as agricultural residues, hold significant prominence as crucial contributors to bioethanol production. Numerous research studies have addressed the utilization of rice husks in this context: Sopandi and Wardah's study explored the potential for bioethanol production from rice husks. The research involved three main stages: alkali pretreatment, enzymatic hydrolysis using *Aspergillus niger* and Trichoderma harzianum, and sugar fermentation with Saccharomyces cerevisiae. The analysis indicated that rice husks contain 38% cellulose and 35% hemicellulose. Notably, after 120 hours of hydrolysis, significant differences ($p<0.05$) were observed in the yields of reducing sugars produced by *Aspergillus niger* (2.81 g/L) and Trichoderma harzianum (2.77 g/L). Additionally, the bioethanol yields from Aspergillus niger (6.99%) and Trichoderma harzianum (6.25%) differed significantly ($p<0.05$) after six days of fermentation at 30°C, pH 3.5. Overall, Aspergillus niger demonstrated superior efficacy for bioethanol production from rice husks compared to Trichoderma harzianum. Cheng and Zhu [40] Explored the potential for bioethanol production from rice husks in a liquid medium through mono and co-culture fermentation. Co-culture fermentation, utilized as a developmental strategy, aims to improve cellulose hydrolysis rates, substrate enrichment, and ethanol generation. This approach involves combining multiple metabolic pathways to

mitigate the adverse effects of inhibitors in the process. Ayeni et al. [41] researched the sugar absorption and ethanol production potential from waste rice husk in batch fermentation. *Saccharomyces cerevisiae* was employed in both mono and co-culture with *Candida tropicalis*, *Zymomonas mobilis*, and *Penicillium resticulosum*. The fermentation process occurred over three days in a waste rice husk hydrolysate basal medium containing specific nutrients. Under controlled conditions (30°C, 60-70% relative humidity, darkness, 150 rpm agitation), the co-culture of S. cerevisiae and *C. tropicalis* exhibited the highest ethanol yield at 2.1250 g/L (259% efficiency) and a fermentation efficiency of 89.25 ± 10.95%. The findings highlight the effectiveness of S. cerevisiae and *C. tropicalis* co-culture in fermenting rice husk residue and converting it into ethanol. The study of Pabon et al. [42], aimed to enhance the enzymatic conversion and ethanol fermentation potential of rice husk cellulosic biomass through statistical modeling and optimization of the alkaline peroxide oxidation pretreatment process. Alkaline conditions were employed using peroxide oxidation on the rice husk biomass, with key variables such as temperature (100–120°C), time (1–2 hours), and hydrogen peroxide concentration (1–3% v/v) investigated across low and high levels. The research identified and confirmed the optimal conditions as 109°C temperature, 2 hours duration, and 1.38% H_2O_2 concentration, resulting in significant improvements: 56% (w/w) cellulose content, 55% (w/w) hemicellulose solubilization, and 48% (w/w) lignin removal. Subsequent enzyme hydrolysis experiments, conducted under the established optimal pretreatment parameters, involved 3% biomass loading, a hydrolysis temperature of 45°C, 24 hours of hydrolysis time, and a cellulose enzyme load of 35 FPU/g. These findings provide valuable insights into maximizing the efficiency of the rice husk pretreatment process for bioethanol production. Srivastava et al. [43] they studied rice husk delignification and bioethanol production, rice husks were chemically treated with NaOH and $NaClO_2$ at 1 to 5% concentrations, and the optimal results were at 5% with both solutions. It also increased the sensitivity to the hydrolysis process substantially at 30°C. Chemical pretreatments resulted in deep deacetylation and lesser delignification of the rice husk but no obvious cellulose loss. Additionally, pretreatment samples were given a fungal treatment (*Trichoderma reesei*) to increase the conversion of cellulosic material to sugar. After 6 days of fermentation with Saccharomyces cerevisiae, the approach of alkali pretreatment followed by fungus processing (with different concentrations) offers the highest lignocellulose conversion in rice husk and, as a result, the highest ethanol yields of 250 mg/gram dry biomass. Edor et al. [44] studied rice husk hydrolyzed by *Aspergillus niger* cellulolytic enzymes. Cellulase is produced by *Aspergillus niger*, which destroys the cellulose component of rice husk. Cellulase activity was determined by measuring the reducing sugar released when living things broke down cellulose. The decreasing sugar content of the biodegraded rice husk increased significantly as the number of days in the biodegradation process increased (0.560-1.020mg/ml from zero hours to 120 hours, then 216 hours). At a pH of 5.4, the maximal production of glucose concentration was obtained after 120 hours of microbial degradation. After 216 hours of biodegradation, the lowest amount of glucose is found at pH

6.18. Microbial degradation can convert rice husk into fermentable sugars and other essential compounds like ethanol. This event highlights rice husks' industrial possibilities as potential substrates for *Aspergillus niger*'s cellulase enzyme manufacturing, which could help to reduce agro-waste pollution. Nachaiwieng et al. [45] explored the utilization of *Kluyveromyces marxianus* CK8, a thermotolerant yeast capable of ethanol fermentation at 45 °C, in simultaneous saccharification and fermentation (SSF) of rice husk. Four parameters—substrate content, temperature, incubation duration, and pH—significantly influenced SSF. Employing response surface methods, optimal conditions were identified as 9.44% (w/v) substrate concentration, 43 °C, and pH 4.2, resulting in an ethanol production of 15.63 g/L. This output exceeded the anticipated maximum value by 101.5%, and the ethanol yield increased by 1.44-fold compared to separate hydrolysis and fermentation (SHF) processes after 96 hours of incubation. Singh et al. [46] examined rice husk subjected to microwave-alkali pretreatment and enzymatic digestion with crude unprocessed hydrolytic enzymes. Enzymatic hydrolyzates with initial reducing sugar concentrations ranging from 10 g/L to 70 g/L were used for ethanol production. Fermentation was conducted using Saccharomyces cerevisiae, Scheffersomyces stipitis, and their co-culture. At an initial reducing sugar concentration of 50 g/L, both S. cerevisiae and S. stipitis produced the highest ethanol yields of 0.42 g/g and 0.36 g/g, respectively, while the co-culture yielded 0.40 g/g. Wu et al. [47] investigated the underlying differences between rice straw and rice husk in terms of the composition of the pre-treatment liquors and the effects of these liquors on saccharification and fermentation. It has been accomplished through the development of quantitative NMR screening techniques. Koshy and Nambisan [7] used paddy straw to grow P. ostreatus and P. eous. For ethanol manufacturing, powdered spent substrate from mushroom culture was utilized. Fermentation research employed Saccharomyces sp. As a control, they utilized untreated paddy straw. In comparison to untreated paddy straw, the generation of ethanol from P. ostreatus substrate was 5,5 times greater, but the production of ethanol from P. eous substrate increased by five times. Tests revealed that the wasted substrates of both species included several extracellular enzymes that aided in the production of more ethanol.

3.3. Bioethanol Synthesis using Banana Peels

Banana peels are also considered agricultural waste that can be used in the production of ethanol, as the studies below dealt with this topic: Harish et al. [48] investigated cellulolytic thermophilic Clostridium thermocellum CT2 in Ethanol production through the fermentation of banana agricultural waste; the best conditions for cellulose fermentation were 60°C, pH 7.5, a 5% inoculum size, and a 120-hour incubation period. The amount of ethanol produced and the amount of reduction of sugars present were calculated using gas chromatography. In coculture fermentation with CT2, Clostridium thermosaccharolyticum HG8 and Thermoanaerobacter ethanolicus ATCC 31937 were utilized. Regarding ethanol generation, cellulosic breakdown, and sugar consumption reduction, at a substrate concentration of 100 g/l, coculturing CT2 with HG8 yielded the highest ethanol of 22 g/l. Singh et al. [49] investigated bioethanol production from the banana peel; Banana peels were simultaneously

saccharified and fermented to produce ethanol. Aspergillus niger and Saccharomyces cerevisiae cocultures were used in the study, At different temperatures and pH levels (20°C-50°C) (4–7). The concentration of the produced ethanol was evaluated daily during the fermentation period, as the total period of fermentation of this peel was seven days, note that the best pH for fermenting banana peels is six, and the best temperature is 30°C. With the best pH and temperature, it was found that there is a relative relationship between the time required to complete the fermentation process and the yeast concentration. Using yeast concentrations at 3, 6, 9, and 12 percent, the highest ethanol production was at 7, 5, 3, and 2 days, continuously. Shyam et al. [50] examined the viability of using dried and crushed banana peel biomass in synthesizing bioethanol by S. cerevisiae. At a substrate concentration of 10 percent, S. cerevisiae produced the most ethanol from ripe red bananas and their hydrolyzed peels at around 1.3% and 0.27 % (v/v). In undissolved green banana peels with a concentration of 1 percent substrate, the minimum alcohol generation was around 0.02 percent.

3.4. Production of Bioethanol from Dates

Dates are one of the most important sources of bioethanol production, as several researchers have studied this subject, including Louhichi et al. [51] Louhichi et al. [51] investigated the production of bioethanol from three varieties of dates (Kunta, Eguoua, and Bouhatem) cultivated in the Gabes region of Tunisia. The alcoholic fermentation of the date juice was examined using Saccharomyces cerevisiae, with conditions set at approximately 200 g L-1 sugar content, 30 °C temperature, and natural pH. The findings indicated that all tested date varieties could yield ethanol concentrations of around 25% (V/V). Furthermore, the yeast employed in the fermentation process demonstrated the capability to produce ethanol even at a pH of 3.8. Zohri and Etnan [52] employed substandard dates to affordably produce juice. The seedless date solution underwent thorough mixing, decanting, clarification, and micro-filtration, resulting in date juice with varying total sugar concentrations (13.5%, 18.0%, and 22.5%). Both Saccharomyces cerevisiae and S. bayamus proved effective in converting 18% sugar date juice to ethanol, identified as the optimal and most cost-effective concentration. Moreover, S. bayamus exhibited higher activity than S. cerevisiae during date juice fermentation. The highest ethanol yield was achieved with S. bayamus cultivated on 18% sugar content date juice at 30°C and pH 3.5. Taouda et al. [53] examined fermentation, and it uses Saccharomyces cerevisiae to produce biomass from date trash. Yeast can convert fermentable carbohydrates into bioethanol. A study found that date trash may produce biomass "yeast" YX/S = 0.45 and bioethanol YP/S = 0.51. Taghizadeh-Alisaraei et al. [54] designed three scenarios in the latest technology for ethanol synthesis from date wastes. In addition, they explained that three primary energy sources (ethanol, electricity, and compressed natural gas) could be explored from date waste.

3.5. Production of Bioethanol from Grapes

Among the fruit residues used to produce bioethanol are grapes, so there are many research studies on the production of ethanol from it, including Korkie et al. [55] identified and analyzed yeast strains from grape pomace on their capacity to hydrolyze the complex

polysaccharides in grape pomace and use the fermentable sugars to form ethanol. Two isolates of Pichia rhodanese could partly hydrolyze the pomace polysaccharides, although fermentation of the pomace resulted in only a modest increase in ethanol production. Raikar [56] discussed the experimental results of ethanol generation from grape waste. The results of the tests are used to demonstrate the impact of several factors, including pH, Benzylpenicillin, temperature, starting sugar concentration, and specific gravity, on the amount of ethanol generated. During fermentation, the addition of Benzylpenicillin increased the amount of ethanol generated. The ethanol generation rose as fermentation progressed and peaked after 48 hours, as shown by the sample's decreasing specific gravity. In addition, the optimal rate of ethanol synthesis was recorded at a pH of 5 and a sugar content of 16% at a temperature of 35°C.

3.6. Production of Bioethanol from Molasses

Molasses is widely utilized in the ethanol industry due to its elevated sucrose content, making it a prevalent source for ethanol production. Among the papers dealing with this topic are: Manoochehri et al. [57] emphasized the microbial utilization of sugar, particularly by Saccharomyces cerevisiae, a crucial microorganism that rapidly transforms sucrose into glucose and fructose during the initial fermentation phase. This process involves the action of invertase, an enzyme found in the yeast cell wall and membrane. The molasses is then appropriately diluted to achieve the desired sugar concentration, and its pH is adjusted for the fermentation process. Raharja et al. [58] studied the effect of H_2SO_4 pretreatment and sugar content on ethanol production. The ethanol production with and without pretreatment molasses was studied at three different sugar concentrations, i.e., 20%, 25%, and 30% Brix. Analysis of Variance (ANOVA) was used to examine the collected data (ANOVA). The ethanol concentration can be raised by 3.5–5.5 percent under ideal conditions (30 percent sugar content with H_2SO_4 pretreatment). Jayanti et al. [59] investigated the impact of sugarcane molasses pretreatment using H2SO4 and fermentation temperature on bioethanol production with Saccharomyces cerevisiae instant dry yeast. Utilizing a 2-factor Factorial Randomized Block Design, the study varied pretreatment conditions and fermentation temperatures (29, 32, and 35 °C). Significant effects were observed on bioethanol output ($p<0.05$). Optimal results were achieved when sugarcane molasses underwent H_2SO_4 pretreatment and fermentation at 32°C. This resulted in a 10.9% decrease in total soluble solids (% Brix), a 12.15% reduction in sugar content, a sugar consumption decrease of 57.21 g/L, an ethanol content of 8.30%, and an ethanol yield of 68.67%. Rahman et al. [60] studied the impacts of several elements on the growth and ethanol generation of yeasts isolated from natural materials. Saccharomyces cerevisiae was separated from date juice and grapes and developed on a YEPD medium. They were tested for the fermentation process using sugarcane molasses, and their growing conditions' pH and sugar content were improved. 30ºC, pH 6.0, and a sugar concentration of 6.5 %t were the best fermentation conditions. The yeast produced 7.75 % ethanol when separated from date juice and cultivated under optimum conditions.

3.7. Production of Bioethanol from Potatoes

Potatoes can also be considered as one of the sources of bioethanol production. Duhan et al. [61] investigated the possibility that bioethanol can be generated from the starchy section of a plant (potato) using Saccharomyces cerevisiae, MTCC-170 Carbon was obtained from the flour of a particular kind of potato, Kufri Bahar (KB) flour. When it came to getting the most starch into fermentable sugar, researchers found that 104 - 105°C, 0.15 percent volume weight (300 U/ml), and 30 grams of dry potato mash per 100 ml of distillate water were the best conditions for liquefaction. This method resulted in a dry weight reduction of 68%. After one hour of amyloglucosidase infusion, the glucose concentration was 16.95 percent at pH 5.0 and 60°C, which was 0.35 percent w/v (300 U/ml). After 48 hours, a 10% inoculum size at a pH of 6.0 yielded the highest ethanol concentration of 7.89% (v/v). Moreover, peptone at 1.5 g/l was shown to be the best of the three nitrogen sources examined for ethanol synthesizing (7.58 percent) (yeast extract, peptone, and ammonium sulfate). Rath et al. [62] used cocultures of *Aspergillus niger* and *Saccharomyces cerevisiae* to produce bioethanol from discarded potatoes for environmental waste management and sustainable energy. They cocultured *Aspergillus niger* and *Saccharomyces cerevisiae* fermented unhydrolyzed potato waste to ethanol with the same laboratory conditions for the optimum temperature, pH, fermentation time, and the concentrations of yeast used that were explained [36]. Waste potatoes produced the highest amount of ethanol (12.124%). The ethanol production of *Aspergillums Niger* strain B was greater, and with increasing fermentation time, the ethanol produced also increased.

3.7. Production of Bioethanol from other agricultural wastes

Other research and studies looked at how to make ethanol from a variety of agricultural wastes and fruits that have worked well for this purpose, such as Chandra et al. [63] focused on the most efficient way to hydrolyze orange peels using *Z. mobilis* supplied by IMTECH, Chandigarh. Bioethanol production from fruit and vegetable waste was experimented with using S. Cerevisiae; after collecting samples, waste juice was transferred to a 1 L Schott container, and trash was fermented for three days at 30 °C before being analyzed. The experiment demonstrated that Orange peels contain a high concentration of sugar and complex carbohydrates and thus can be fermented into ethanol and produce fuel at the most economical cost. Osanaiye et al. [64] explored the influence of yeast types, their concentrations, saccharification, and nutrient supplementation on enhancing ethanol production from *Carica papaya* (pawpaw) residues. Ethanol yields from fermenting agricultural residues varied between 3.83% and 5.19% (v/v). The sugar content in pawpaw was measured before and after saccharification, showing the highest decrease (7.6 to 13.6 g /100g) after 48 hours of saccharification with *Aspergillus niger*. Brewer's yeast outperformed baker's yeast in ethanol production. Significant ethanol enhancement resulted from 48-hour saccharification and nutrient additions. Bhatt and Shilp [65] studied the possibility of preparing ethanol from groundnut shell waste, which is in large quantities in many countries. To find the most effective technique of pretreatment for saccharification, Raw materials are first treated physically by steam jetting, then inorganic chemical solutions (0.25N hydrochloric acid, 0.25 N sodium hydroxide), and organic chemical solutions (0.25 N $C_2H_4O_2$

and 0.25 N $C_3H_6O_3$). Pretreatment was done in this order: HCl > Lactic Acid > Acetic Acid > NaOH. Fourier Transform Infrared Spectroscopy (FTIR) analysis showed that pretreated GS degraded in the 1100-1400 cm^{-1} region. With Bacillus stearothermophilus and Saccharomyces cerevisiae, an ethanol yield of 16.11% was produced after 14 days at 50 °C with 2 %t w/v pretreatment groundnut shell. Cherian et al. [66] looked into the sequential fermentation of agricultural waste to produce cellulosic bioethanol; Aspergillus fumigatus JCF is used as a microbe in this study, primarily focusing on the generation and optimization of cellulose using jackfruit waste as a substrate. The best pretreatment procedure was 0.5 N NaOH, which was applied to the substrate after it had been prepared with several chemicals. Agricultural waste was employed as the substrate for the simultaneous saccharification and fermentation, producing bioethanol with an enzyme activity of 3.3 IU/ml. Yeast and cellulose considerably lower the sugar that builds up in the fermentation media. Both treated and untreated substrates were used in attempts to produce bioethanol. Pretreated sugarcane leaves produced the most bioethanol (18g/l) out of all the substrates tested. Upendra et al. [67] studied the manufacture of ethanol from previously underutilized agricultural waste (Field bean and Green Pea pod waste); they are designed and built as low-cost anaerobic bioethanol fermenters that use yeast in suspension cultures (Saccharomyces cerevisiae). Before saccharification with a consortium of fungal species, agricultural residue biomass was pre-treated (physically and moderately acidic processing) (Aspergillus sp.). They obtained 90g of glucose per liter using Saccharomyces cerevisiae, and the final product ethanol was assessed qualitative as well as quantitative by using a specific gravity technique (7.725g compared to 7.639g for pure ethanol) and gas chromatography (70.2 percent ethanol). It was calculated that 250 mL of ethanol would be converted for every kilogram of agro–wasteCutzu and Bardi [68] studied bioethanol synthesis from agricultural wastes utilizing excess thermal energy from a cogeneration unit]; Alcoholic fermentations were carried out using a technology adapted to utilize generating plant's remaining heat energy (heat at 83–85 ^oC) and enhance agricultural residues. They used apple, kiwifruit, peach waste, and corn threshing residue (CTR) as substrates. Saccharomyces bayanus has been the beginning yeast. Fresh or blanched fruits are crushed; CTR was then solubilized and dissolved with Liquozyme. Spirizyme was used to perform simultaneous saccharification and fermentation. Raw fruits, blanched fruits, and CTR were used in lab-scale static fermentations, which were monitored for ethanol generation at 28 0C and 35 0C. CTR (10.22 % (v/v)) and apple (8.71 % (v/v)) were the fruits that produced the most ethanol. Distillations at low temperatures and under a vacuum were tested using hot water from a cogeneration station. At 80 ^oC (heated bath) and 200 mbar or 400 mbar, Vacuum simple batch distillation by rotary evaporation produced 93.35 percent (v/v) and 89.59 percent (v/v) ethanol, respectively. These findings suggest a fermentation process linked to a generating plant and supplied with apple garbage (or CTR if apple trash is unavailable) and heated water from the generating plant for blanching and distilling steps. Izah and Ohimain [69] examined the formation of bioethanol from cassava mill effluents mixed with solid agricultural leftovers. Using Yeast

Saccharomyces cerevisiae, they examined bioethanol production from cassava mill effluents (CME) supplemented with chaff, empty fruit bunch (EFB), and cassava peels using separate hydrolysis and fermentation (SHF) procedures. They concluded that cassava mill effluents combined with Empty fruit bunch, chaff, and cassava peels, can produce ethanol and hence are used as a lignocellulosic feedstock. Hossain et al. [70] discussed biomass preparation and fermentation methodologies for bioethanol synthesis utilizing yeast (for example, Saccharomyces cerevisiae) (algae, fruit, fish, and chicken). They found fruit biomass (pineapple) was higher and easier to get than algae and fish. Nassir and Al-Sahlany [71], shedding light on bioethanol production utilizing *Zymomonas mobilis*, stated that *Z. mobilis* had 5–10 times more bioethanol production capability than Saccharomyces cerevisiae. Huang et al. [72] studied ethanol production from high-solids food waste (35 percent w/w). Reduced yeast ethanol inhibition; a vacuum recovery device was designed to extract ethanol from fermentation broth. Food waste fermented without a vacuum recovery device yielded 144 g/L of ethanol. Vacuum recovery reduces ethanol content in fermentation broth to less than 100 g/L, reducing yeast ethanol inhibition. The remaining glucose in the traditional broth was 5.7 g/L, suggesting inadequate glucose consumption, while the vacuum fermentation used all the glucose. Vacuum fermentation yielded 358 g/kg of food waste (dry basis), compared to 327 g/kg for normal fermentation (dry basis).

4. Conclusions

The production of clean fuels such as bioethanol is essential because of its environmental and economic importance. These eco-friendly processes can be developed and made more environmentally and economically feasible through continuous scientific research to find highly effective techniques for converting low-cost agricultural waste into usable fuel. The generation of bioethanol using lignocellulose material is one of the most cost-effective methods, according to the results of the studies. Although sugar and starch have a higher potential for ethanol production than lignocellulose, these sources are inadequate for global bioethanol production since they are also considered sources of global food supplies. While agricultural residues are by-products that do not require independent needs for land, water, or energy, their use in bio-ethanol does not affect global food security. It will achieve sustainable development through recycling and managing it and maintaining a clean environment from these wastes in addition to the production of alternative fuels for fossil fuels. It is suggested for future research. Focus on the utilization of agricultural waste available in Iraq, such as rice husks for bioethanol production purposes and improving production conditions in terms of cost, effectiveness, and optimization conditions, such as pH, temperature, incubation period, and supplemental nutrients to increase bioethanol production using fermentation processes.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

Author Mohammed N. Abbas: proposed the research problem.

Author Seroor A. K. Ali: Develop the research formula and adopt the reference methods in writing it

Gaith M. Hamdi: searched for and compiled research similar to the nature of the research problem.

All authors discussed the results and contributed to the final manuscript.

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