



## The Role of Microorganisms in Food Production

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### Abstract

Microorganisms play a vital role in production of foods and food additives such as edible mushroom which serve as an excellent source of carbohydrates, vitamins, minerals, proteins, and low-fat content. However, mushroom's protein contains essential amino acids required by humans. Seaweeds (edible algae) have high protein contents and also rich in vitamin B<sub>12</sub>, iron, and a trace amount of Mg, Zn, Cu, Ca, K, and folic acid. Microorganisms produce single cell protein (SCP) which acts as a protein supplement for animals and human feed. *Lactobacillus* species, *Pseudomonas fluorescens*, *Bacillus megatarium*, *Aspergillus* species among others, is utilized to produce SCP. Many bacterial and fungal genera, which include *Aspergillus*, *Leuconostoc*, *Bacillus*, *Candida*, *Saccharomyces*, *Lactobacillus*, *Gluconobacter*, and so on, produce enzymes and organic acids used to ferment various foods and dairy products such as cheese, yogurt, wine, bread, beer and others. They are also used as additives in foods, preservatives, and flavoring agents. This includes genera like *Saccharomyces*, *Bacillus*, *Aspergillus*, and many others. Microorganisms play a significant role in enhancing food production which improves the life of humans and other animals and promotes health and well-being.

**Keywords:** Microorganisms, Organic acids, Microbial enzymes, Food production, Benefits

### Introduction

According to Rahman, (2007), food are the substances that can be consumed freshly, cooked or prepared by human beings and other animals for body building and development to satisfy their nutritional requirements; these come from various sources such as carbohydrates, proteins, lipids, vitamins, minerals, and water. Microorganisms are the smallest organisms that cannot be seen with naked eyes. Bacteria, algae, protozoan, fungi, and viruses are the important microbes living in our body, soil, water, and air. Microorganisms are beneficial to us while others are harmful (Institute for Quality and Efficiency in Healthcare, 2019).

Preservation of food involves many production steps used to preserve and prevent food spoilage by the action of food contaminants or spoilers, to reach its satisfactory level in order to achieve maximum benefits and nutritional value. The methods of preserving food spoilage involve a series of steps from cultivation, harvesting, processing, packaging, and delivering foods (Amit, Uddin, Rahman, Islam & Khan, 2017). Food items can be categorized into three groups based on their shelf-life, namely, perishable, semi-perishable, and non-perishable (Doule, 2009). Perishable foods are the types of food that spoil quickly and need to be preserved by refrigerating; while non-



perishable are those foods item that can be stored for a long period of time at room temperature without spoiling (Bryne, 2022).

Microbes can be utilized by humans to make food and other beneficial substances. They deserve for this role because they multiply rapidly and they don't require complex nutrient materials/diet but can produce large-scale products (BBC Bitesize, 2022). For example, microbes are utilized to make bread, cheese, wine, and yoghurt for a long period of time. Nowadays food producers still utilize microbes to produce large-scale of food products through fermentation technique. However, apart from providing taste, texture, and aroma, fermentation alters and lowers the growth of food contaminants or spoilers; which are used to increase the shelf-life and safety of a food. Currently, large-scale food and drinks are produced through fermentation processes. For a millennium, fungi are utilized as an origin of foods and in making foods. Moreover, despite consuming mushroom sporocarps as food directly, moulds are also utilized locally for synthesizing industrial enzymes and ripening cheeses, (Microbiology Society, 2022).

## The Aim of the study

The aim of this research is to assess how microorganisms specifically bacteria, algae and fungi contribute to the production of food. Edible microorganisms serve as food like seaweeds and mushrooms while others are used as food additives in food processing industries for large scale production. They include products like breads, cheese, milk, beverages and so on.

## Background of the study

Montville, Matthews, & Kniel, (2012) explained that 'Fermentation is the method of energy production from carbohydrates by bacteria anaerobically'. It is a bioprocess that modifies food characteristics and produces energy in the absence of air by microorganisms such as bacteria. Fermentation involves bioprocesses used to produce various products, such as vinegar, antibiotics, amino acids, and citric acid, either aerobically or anaerobically. Fermentation also enhances flavor compounds and carbon dioxide production, it also change texture and improve nutrient bioavailability (p.269).

## The importance of fermentation in Food Production Industries

1. It preserves vegetables and fruits
2. It enhances flavor, an aroma, and texture
3. It prevents damages caused by natural occurring toxins and undesirable properties of fresh food items
4. It enhances products with desired microbial metabolites (Montville *et al*, 2012)

## Types of foods produced by Microorganisms

Many microorganisms are consumed as food or used as food additives.

**Edible Mushrooms:** mushrooms are good source of nutrients (21 - 30% protein, mineral elements such as Calcium, sodium, potassium and phosphorous and low-fat content [0.35-0.65% dry weight] and carbohydrate [0.02% dry wt]) (Yadav, 2010).



**Seaweeds:** seaweeds are consumed directly as a daily meal at home. In food industry seaweeds are used because of their minerals, vitamin and protein contents (Babahan, Kirim, & Mehr, 2019) p.1.

**Fermented dairy products:** are dairy products that are fermented through the activities of beneficial microbes (Garcia-Burgos, Moreno-Fernandez, Alferez, Diaz-Castro & Lopez-Aliaga; 2020 p.1).

**Cheese:** According to Zheng, Shi & Wang (2021) cheese is a product made from milk by coagulating semi-skimmed milk, cream or buttermilk from ruminants such as cows and goats, or blending of these products and later separates them from the whey.

**Yoghurt and Fermented milk foods:** according to Hadjimbei, Botsaris, & Chrysostomou (2022) it is important to note that fermented milk is extremely nutritious and is an excellent source of minerals and vitamins. Both milk and yogurt become acidic when fermented with probiotic bacteria, primarily by *L. bulgaricus* and *S. thermophiles*. This process not only thickens the product, but also extends its shelf-life, (p.1)

Bacteria form the paramount group due to their speedy growth rate, capability of utilizing food nutrients, and tolerance of a wide range of temperature, pH, oxygen content, and water activity. The following groups of bacteria are used for commercial production of foods:

- i. **Lactic acid bacteria (LAB):** they synthesize a large amount of lactic acid from carbohydrates. Important bacterial genera involved in lactic acid production include *Lactobacillus*, *Leuconostoc*, *Pediococcus*, *Streptococcus thermophiles*.
- ii. **Acetic acid bacteria (AAB):** Acetic acid bacteria such as *Acetobacter aceti*, are responsible for producing acetic acid.
- iii. **Propionic Acid bacteria:** the propionic acid is used to ferment milk and other dairy products. Bacteria used include *Propionibacterium freudenreichii*.
- iv. **Proteolytic bacteria:** they degrade proteins and produced enzymes such as extracellular proteinases. The bacterial genera in this group include **Micrococcus**, **Staphylococcus**, *Bacillus*, *Clostridium*, *Pseudomonas*, *Alteromonas*, *Flavobacterium*, *Alcaligenes* and other group which comprise Enterobacteriaceae and *Brevibacterium* (Ray & Bhunia 2014).
- v. **Lipolytic bacteria:** they break down triglycerides and release extracellular lipases. The bacteria responsible for the production of lipases include the genera *Micrococcus*, *Staphylococcus*, *Pseudomonas*, *Alteromonas*, and *Flavobacterium* (Ray & Bhunia, 2014). One of the benefits of lipases is the enhancement of flavor in food item derived from milk and production of additional foods containing lipids food substances, its catalytic action increases the texture and softness of cheese, and elongate the shelf-life of baking products (Aravindan, Anbumathi, & Viruthagiri, 2007) p.19.
- vi. **Saccharolytic bacteria:** are bacterial genera that can grow at 50°C and above. Saccharolytic bacteria include *Bacillus*, *Clostridium*, *Aeromonas*, *Pseudomonas*, and *Enterobacter* (Ray & Bhunia, 2014).
- vii. **Aciduric Bacteria:** they are bacterial genera that can grow at low pH (<4.0), members include, *Lactobacillus*, *Pediococcus* (Ray & Bhunia, 2014).

## Microorganisms used as Food (Edible Microbes)



As an alternative to traditional food and feed sources edible microbial biomass is a promising technological choice to combat ruining the environment due to high food demand. Microbes like bacteria, fungi and algae possess numerous useful properties such as speedy growth rates, and ability to incorporate simple organic substrate like hydrocarbon (alkanols and organic acids) (Linder, 2019). Active microbial population (Microbial biomass) is rich in macromolecule (protein), fats and oils, and vitamins (Ritala, Häkkinen, Toivari, & Wiebe, 2017).

**Edible Mushrooms:** Mushrooms are regarded as the constituents of high-quality food worldwide; mostly due to their distinctive flavoring taste, people recognize them as culinary wonder. Almost about 25 different mushroom species were recognized as edible and are produced commercially, among over 2000 species living in nature. Mushrooms are regarded as pleasing food with excessive dietary usefulness, they are also recognized as functional and nutraceuticals foods, they are highly demanded due to their palatability, therapeutic, and economic importance (Chang & Miles, 2008; Ergonul, Akata, Kalyoncu, & Ergonul, 2013).

Mushrooms have an extraordinary nutritional value due to their high and abundant protein content; they are a good source of essential amino acids, fiber, and low-fat content. In addition, edible mushrooms are a good source of vitamins which includes vitamin B<sub>1</sub>, B<sub>2</sub>, B<sub>12</sub>, C, D, and E. Consequently, they may be an origin of various functional foods which are likely utilized directly in people's food to boost health for the combined effects of the entire bioactive compounds present (Valverde, Talia, & Octavio, 2015) p1. The most cultivated mushroom throughout the world is *Agaricus bisporus*, *Pleurotus* sp., *Lentinus edodes*, and *Volvarella* sp. (Assemie & Abaya, 2022). Globally, China remains the largest producer of edible mushrooms (Chang & Miles, 2008).

**Seaweeds:** Edible algae are used for hundreds of years ago; these are algae suitable for eating across various coastal regions globally. The seaweed may belong to one of the 3 classes of multicellular algae that are red, green, and brown algae. In many countries around the world including China, Japan, Korea, and relatively Ireland, Iceland, Chile, and New Zealand, seaweeds form part of their daily meal (Libre, 2021a). Algae have excellent nutritional benefits because they contains substantial protein, fiber, and at times with abundant omega 3 fatty acids. It is also an excellent source of vitamins like vitamin A, C, B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub>, and B<sub>6</sub> and minerals such as Iodine, Ca, K, Mg, and Fe. It can be eaten as fresh, cooked, or dried (Libre, 2021a).

Seaweeds are classified into three categories; *Rhodophyta* (Red), *Phaeophyta* (Brown) and *Chlorophyta* (green) algae. The most common edible red algae are Carola, Carrageen moss, Dulse, Gelidiella, Gracilaria, Ogonori, Grape stone and so on. Also, edible brown algae include Kelp, Facules, and Ectocarpales; whereas the most common edible green algae include Chlorella, Gutweed, Seagrapes and Sea lettuce (Babahan *et al*, 2019). Seaweeds have high vitamins content compared to vegetables cultivated on land (Martinez, 2019).

## Baked and Baking Products

Baked products are nourishment from malleable flour mixture or batter cooked by baking (Merriem-Webster, 2022). According to Cooper (2018), baking and brewing yeasts are the most common yeasts utilize in fermenting alcohol and dough for commercial production of beer and bread in food industries.



Baked foods such as bread are highly significant and common humans staple foods consumed as daily meal worldwide, (Qian *et al*, 2021) numerous baked products like cake and bread can be categorized according to their short life span for about 3-5 days at normal temperature without adding preservatives.

They go through different series of physical and chemical transformations that will alter the texture and taste of the food items, which lost it freshness later, although, multiplication and growth of food spoilage microbes such as bacteria, yeast and moulds caused unpleasant appearance of the food items (Qian *et al*, 2021). Bakery products are putrescible products that need to be prevented by preserving them to prolong their shelf-life in order to suppress and inhibit the proliferation and growth of food spoilers (Umaraw *et al*, 2020).

## Bread

Bread is a staple food for humans consumed daily for a long time ago; it is beneficial to human health due its many nutrient constituents, antioxidants, and vitamins. Baked bread is an integral part of healthy diet (Valavanidis, 2018). The essential phase in making bread is the fermentation of the dough by *Saccharomyces cerevisiae* (Struyf *et al*, 2017).

Baker's yeast is mixed with sucrose and hot water to produce bread. *Saccharomyces cerevisiae* utilized the sucrose as its nutrient. The yeast obtained its energy by degrading the sugar for their growth. *S. cerevisiae* asexually reproduce and develop by budding as a result bubbles of CO<sub>2</sub> are produced in the flour mixture (Microbiology Society, 2022). The CO<sub>2</sub> gas released caused the dough to rise by making bubbles. Ingredients are added into the dough such as potatoes or potato boiled liquid, eggs and sugar, in order to hasten the growth of the yeast cells to ease fermentation (Cooper, 2018). Heating of the dough kills the yeast which stop the fermentation, and the entrapped CO<sub>2</sub> gas expands and soften the bread by giving it the spongy texture and stop it from further expanding (Cooper, 2018).

In bakery products proteases are incorporated into the flour during the production of biscuit to lessen the gluten protein composition in the flour otherwise it becomes not easy to handle. Applying protease in the mixture to reduce the gluten strength will not affect the nutritional composition of the dough (Deng *et al*, 2016). Xylanase is also incorporated in bread making for commercial production to convert water-insoluble polysaccharide (hemicellulose) into soluble form which binds with water in the dough to reduce and lessen firmness of the dough (Butt, Tahir-Nadeem, Ahmad & Sultan, 2007).

## Brewer's Yeast

**Beer:** Yeast is a unicellular fungus that utilizes sucrose as its food. In beer production, the *Saccharomyces cerevisiae* ferments glucose into CO<sub>2</sub> and ethanol. The beer comprises of ethanol, while the CO<sub>2</sub> gas make the beer emits gas (bubbles) (BBC Bitesize, 2022). It ferments the sugars coming from different sources e.g., grapes for wine, barley for beer, to alcohol and CO<sub>2</sub>. Brewer's yeasts are very rich in essential minerals and B vitamins, with the exception of vitamin B<sub>12</sub> (Libre, 2021b).





Alcohol fermentation involves microbial activities at each stage of production, starting with crude raw materials, and then malting and its stability during packaging stage (Bokulich & Bamforth, 2013). Despite that all *Saccharomyces* sp produce alcohol as their end product of fermentation; practically ale and larger yeast are the strains utilize globally in making beer (Boulton & Quain, 2001). The quality of alcohol depends on the activity of yeast during fermentation. In addition, to alcohol production, the quality of beer is directly related to the fermentation activity of the yeast that synthesized products that contribute to improve the content and organoleptic characteristics (Iorizzo, Coppola, Letizia, Testa, & Sorrentino, 2021) p1. Water, malted cereals and hop are the ingredient or substrate fermented by brewer's yeast to produce alcohol. Beer processing normally involves these steps malting, mashing, alcoholic fermentation and maturation. Through the glycolytic pathway glucose is converted to pyruvate by enzymatic action of brewer's yeast. Anaerobically the yeast degrades pyruvate to produce ethanol and CO<sub>2</sub> (Iorizzo *et al*, 2021).

## Role of Microorganism in Organic Acid Production

Organic acids comprise one or more carboxylic acid groups. Microbes play a vital role in producing various products that can be utilized in many sectors, for example, energy in the form of ATP, nutrients, a single-cell protein and many others. Numerous microorganisms such as bacteria like *Arthrobacter paraffinosis*, *Bacillus licheniformis*, *Corynebacterium* sp., *Lactobacillus casei*, *L. helveticus*, *L. paracasei*, and *Streptococcus thermophiles*; Mould like *Aspergillus niger*, *A. aculeatus*, *A. carbonarius*, *Rhizopus oryzae*, and *Penicillium jenthinellum*, Yeast like *Candida tropicalis*, *C. oleophila*, *C. guilliermondii*, *C. citroformans*, *Hansenula anamola* and *Yarrowia lipolytica* are used to synthesize organic acids in food industries (Yadav, Chauhan, Singh & Halabi, 2022).

### Citric acid

Bikash, Rashmiranjan, and Sonali (2020) stated that "Citric acid is a tricarboxylic acid which normally originates from various fruits such as lemons, oranges, pineapples, vines and so on. It is a natural constituent that helps in removing toxins, stabilize the amount of energy, and helps the healthy breakdown of food and renal functions. The citric acid produced by microorganisms is a useful organic acid widely utilized in medicinal, food, beverages, soap/detergents, and cosmetic industries. Citric acid is manufactured by numerous species of microbes, but mould *Aspergillus niger* is the predominant source of citric acids". *A. niger* produces high amount of citric acid in a shorter amount of time making it a preferred choice over other microbes. It ferments a wide range of inexpensive and cheap resources easily and is simple to handle (Show *et al*, 2015).

Commercially prepared citric acid is often utilized as food supplements and cleaning agents, (Van de Wall, 2021). Citric acid is utilized in food industries to package food and drinks; it also assists in maintaining and preserving canned and jarred food as fresh for long duration. Citric acids served as food thickener which slightly adds sour taste to the food substance. It is also used as flavoring agents in different food industries (Booth, 2022).

The secretion of citric acid is a standard and usual phenomenon by which microbes produce large amounts of citric acid, when various species of bacteria and fungi are cultivated under specific conditions (Yadav *et al*, 2022). *A. niger* produces citric acid by breaking down glucose to produce



2 molecules of pyruvate which further converted into oxaloacetate through the Embden-Meyerhop Parnas pathway. Later it produces citrate by condensing oxaloacetate with acetyl-COA in the presence of an enzyme citrate synthase. The occurrence of the Tricarboxylic acid (TCA) cycle enzymes has been shown in the organism on many circumstances.

## Lactic Acid Production

Lactic acid is produced during anaerobic fermentation which is a metabolic process. During glycolysis glucose is broken down into pyruvate, which is then further converted into lactic acid by an enzyme lactate dehydrogenase. The process produces nicotinamide adenine dinucleotide (NADH), which can use for glycolysis. The lactic acid bacteria (LAB) is capable of synthesizing either Dextrorotatory (-)-lactic acid, or Levorotatory (+)-lactic acid or the racemate isomers of Dextrorotatory and Levorotatory. Organisms that produce L (+) or D(-) lactic acids possess two stereospecific enzyme's lactate dehydrogenases. In commercial production of lactic acid the most common source of carbon for LAB are dextrose, molasses and whey (Yadav *et al*, 2022).

There are two categories of LAB-heterofermentative and homofermentative. The heterofermentative group produces several byproducts, apart from lactic acid, which are unsuitable for commercial production. One of the LAB species in this group is *Luconostoc mesenteroides*. While homofermentative LAB such as *Lactobacillus* species are utilized to produce large quantity of metabolites with small amount of substrate, in which most of it carbon source is transformed into lactic acid, in the ratio of 2 molecule of lactic acid per mole of hexose sugar used (Yadav *et al*, 2022).

In milk fermentation, lactose is transformed to lactic acid by the great action of LAB, which raises the acidic pH that alters the growth conditions of microbes except LAB. The main bacteria that produce lactic acid in milk are *Lactobacillus acidophilus*, *Lactococcus lactis*, *Streptococcus sp*, *Thermophilus*, *Leuconostoc mesenteroides*, and *Enterococcus faecium* (Quigley, *et al*, 2011; Ruhul & Kazi, 2021). Large production of lactic acid is determined by pH condition (3.5 – 9.6), temperature (5 – 45°C), nutrients (amino acids, peptides, nucleotides and vitamins) (Abedi & Hashemi, 2020).

Food manufacturers use Lactic acid to preserve food products like bread, desserts, olives, and jams by packaging and wrapping them, thus to elongate their shelf-lives and prevent deterioration. Lactic acid can be used as preservatives to prevent food spoilage by reducing the bacterial load or growth, as well as killing it. Lactic acid serves as solidifiers, and also prevents discoloration of food. Lactic acid promotes health by building up of defense mechanisms (antibodies). Normally, any fermented food is full of lactic acid and other useful bacteria. Only few categories of foods contain high lactic acid. It is well-known that the highest percentage of lactic acid is contain in dairy foods like curdle or fermented milk, cheese, yoghurt, and so on (Brennan, 2021). LAB produces organic acids, H<sub>2</sub>O<sub>2</sub>, diacetyl and bacteriocins with unfriendly microbiological characteristics that reduce and inhibit the growth of unwanted microbes (Ross, Morgan & Hills, 2002; Liua *et al*, 2014). LAB also increase amino acids, and vitamin like B vitamins in fermented foods (Kabak & Doboson, 2011; Bogsan, Nero, & Todorov, 2015)

## Gluconic Acid (GA) Production



Food, beverages, and pharmaceutical industries utilized gluconic acid (GA) to produce foodstuffs. It is used as food additives that give a refreshing sour taste on various foods substances like alcohol and fruit juices (Kirimura, Honda & Hattori, 2011). GA is a mild organic acid used in food industries, which is naturally a component of fruit juices and honey; it is utilized to preserve food. It adds a sweet taste which slightly turned acidic by the action of glucono- $\delta$ -lactone (ester). It is applied in meat and dairy products, especially in baked food raising the dough. It also serves as a flavoring agent e.g., in the production of Sherbets, and is also used to lower the lipid assimilation in doughnuts and cones food such as bean curd, yoghurt, cottage cheese, bread, confectioneries, and meat that possess D-glucono- $\delta$ -lactone. Gluconic acid also prevents formation of milkstone, in the milk production industries which is used to clean aluminum tins to remove the minerals accumulated (Yadav *et al*, 2022).

Fungal fermentation: Glucose oxidase is an enzyme present in *A. niger* which oxidize glucose to form GA. Glucose oxidase is a protein containing nucleic acid derivatives of riboflavin predominantly found in both cell walls and substances outside cells, which their biochemical function accounts for nearly 80 percent of all catalytic reactions as in *Aspergillus* sp and *Penicillium* sp (Johnstone-Robertson, Clarke & Harrison, 2008). The process of aerobic fermentation that is catalyzed by glucose oxidase is reliant on a large amount of oxygen. D-glucose transformed to D-glucono- $\delta$ -lactone by the removal of hydrogen to form  $H_2O_2$  as byproduct. Then in the presence of catalase  $H_2O_2$  is further break down into  $O_2$  and  $H_2O$  (Ma *et al*, 2022 p3-4). For commercial production of GA by using *Aspergillus niger* submerged fermentation methods is employed in food industries.

Bacterial fermentation: in contrast to fungal GA production, bacterial glucose oxidation is catalyzing by glucose dehydrogenase. *Gluconobacter oxydans* is consistently preferred over *A. niger* fermentation because chemostatic culture is impossible to conduct on the latter. In the metabolic process of *G. oxydans*, organic matter is incomplete oxidation (especially overflow metabolism) due to the absence of EMP pathway and Enzymes of the tricarboxylic acid (TCA) cycle. Glucose is oxidized to form intermediate products such as GA in a contrary to  $CO_2$  and  $H_2O$ . Synthesis of GA can be performed in two alternative ways. Initially, the direct oxidative pathway of glucose occurs in the periplasmic space and is catalyzed by membrane-bound pyrroloquinoline quinone-dependent glucose dehydrogenase. The other pathway is found in the cytoplasm and its oxidation products at pH 7.5 pass through pentose phosphate pathway (Ma *et al*, 2022).

## Vinegar

Vinegar has been used as a condiment and food preservative, a safe vigorous drink for centuries. In addition, vinegar used a traditional drug long years ago (Solieri & Guidici, 2009). Any type of carbohydrates can be used to produce vinegar such as amlyceous (starchy), or sugary substance using two series fermentation process: alcoholic fermentation which perform with yeast and acetic fermentation which involve the use of acetic acid bacteria as supportive (Luzon-Quintana, Castro, & Duran-Guerrero, 2021).

Vinegar is a liquid consisting acetic acid and water; it has concentration of about 5% acetic acid, various quantities of fixed fruit acids, coloring matter, salts and different fermented products which





add flavor, taste and aroma. Vinegar is used traditionally to preserve food substances (Bhat, Akhtar, & Amin, 2014 p.1). *Acetobacter* sp convert ethyl alcohol by oxidation to produce acetic acid. Therefore, vinegar can be synthesized from any alcoholic material to form various fruit wines. Initially, yeast ferment sugars anaerobically to form ethanol then in the second step AAB aerobically oxidize ethanol into acetic acid (vinegar). Microbes involved in vinegar production are mainly yeast which carries out the alcoholic fermentation and AAB which converts ethanol to form acetic acid (Bhat *et al*, 2014).

Initially, vinegar is made through a two-stage fermentation processes, first of all, yeast, mainly *S. cerevisiae* converts fermentable sugars to ethanol. The second stage is the oxidation of ethanol to form acetic acid (vinegar) by *Acetobacter* species. Fermentation is the important methods in production of fruits vinegars, through microbial and chemical activities transform various volatile compounds, polyphenols and organic acids (Luzon-Quintana, Castro & Duran-Gurrero, 2021).

Vinegar is a low concentration solution of acetic acid utilized in preparing food and serve as flavoring agent (Aroson, 2016). Acetic acids are also utilized as food additives and preservatives, which can be used for cooking and baking foods. The important species of microorganisms that produce vinegar includes the genera *Acetobacter*, *Gluconobacter*, *Komagataeibacter*, and *Gluconacetobacter* due to their ability to oxidize ethanol to form acetic acid (Tcek & Barja, 2015; Gomes *et al*, 2018).

## Microbial Enzymes used in food production

### Proteases:

Many microorganisms, including bacteria and fungi, synthesized protease. *Aspergillus*, *Trichoderma*, *Penicillium* and many others are the predominant fungal genera used for commercial production of proteases in food industries (Gurumallesh, Alagu, Ramakushna & Muthusamy, 2019). The bacterial species that are well known for commercial production of proteases are *Bacillus* species (Preeti, Chayanika, Anil, Ravi & Abhishek (2021). Proteases control gluten strength in the bread as well as lessening the dough mixing time. It also enhances the flavor (Miguel, Martin-Meyer, Figueired, Lobo & Dellamora-Ortiz, 2013).

Brewers use protease to prevent the formation of chill haze of beer which caused by protein effects. In meat processing, proteases speed up tenderization of meat by incorporating an additional proteolytic enzyme, while in bakery during crackers and wafer production they utilize proteases in order to partially hydrolyze gluten to produce small or weak gluten (Li, Yang, Zhu & Wang, 2012).

### Cellulase

Cellulose improved the yield of purees during industrial production of fruit and vegetable purees to maintain its consistency, by reducing destruction caused by heat. The following types of fruits



are treated with cellulase during their puree's production. These include; peach, mango, pear, guava, pawpaw, and so on (Okpara, 2022).

Cellulase used for commercial production of food in food industries is produced by microorganisms like fungi – *Aspergillus*, *Trichoderma reesei*, *Chaetomium*, *Penicillium*, *Fusarium* and *Phoma* and bacteria sources such as *Acidothormus*, *Paenibacillus*, *Bacillus*, *Erwinia*, *Streptomyces* and so on (Soares, Tavora, Barcelos & Baroni, 2012).

The ruminant animal diet always contains abundant cellulose, pectin, lignin, and hemicellulose which can be broken down by the animal. To ease digestion and absorption, cellulases are introduced during production of ruminant animal feed which will assist in breaking down such complex polysaccharides (Okpara, 2022). In their natural condition, fruit spoil easily, but using cellulase in converting them into juices and purees enhance and elongate their shelf life, and yield good product and reduced discoloration (Kumar, Suresh, Snishamol, & Nagendra, 2019). Cellulose causes cellulolysis which breakdown the  $\beta$ -1-4 glycosidic bond in long chain polymer of carbohydrates such as cellulose, hemicellulose, lichenin, and glucans to form short chains monomers of glucose (Pandey, Kuila & Tuli, 2021).

## Pectinase

This is another microbial enzyme utilized to breakdown a plant cell wall made of up heteropolysaccharide (pectin). Various genera of microorganisms are used to produce pectinase by degrading pectin into sugar monomer, using the pectin as carbon source (Wong, Saad, Mohamad, & Tahir, 2017). Pectinase breaks down pectin in fruit cell wall which aid in juice extraction, flavoring, and filterability and generally produce high yield (Anand, Yadav & Yadav, 2017; Sudeep, 2020). Mould genera such as *Aspergillus* and *Penicillium* are the predominant fungi that produce pectinase; also, some bacterial genera like *Bacillus*, *Erwinia*, and *Enterobacter* adequately synthesized pectinase (Palagiri, Mayukha, Sagar, Chourasiya, & Sibi, 2019).

## Xylanase:

In baking industries, xylanase is incorporated into the flour mixture to assist in breaking down complex sugar in the wheat flour like, xylan and arabinoxylan. Therefore, it balances the dough and become well malleable and enhances gluten firmness. Xylanase enhance the dough by maintaining its moisture content, as well as elongating its shelf-life and produce a qualitative and good product. Xylanases are produced by microorganisms like *Aspergillus* sp., *Bacillus subtilis* and *Trichoderma longibrachiatum*. In fruit production, xylanase degrade the fruit cell wall and thus increased fruit extraction, its nutrient content, as well as an aroma. Likewise, in combination with other enzymes such as pectinases and cellulases, it tremendously increases the production of juices more especially in citrus juices (Eric, 2016).

## Lactase

Lactose is broken down by lactase enzyme to form galactose and glucose, which are simple sugars. In lactose intolerant individuals who suffer from lactose intolerance, their small intestine cannot



synthesize enough lactase. The effects caused include stomach cramps, gas production and looseness of the bowels in the digestion of milk and its products (Tanasupawat & Komagata, 2001). Lactase is utilized industrially to synthesize free lactose milk and other products for the benefit of people that cannot tolerate lactose. Other products synthesized with lactase include ice creams and frozen yoghurt with very good aroma and taste. *Apergillus* species and *Kluyveromyces* species are common examples of lactase producing microbes for commercial uses (Mir-Khan & Selamoglu, 2020).

## Conclusion

Microorganisms are very important in the production of food due to their ability to produce various sources of high-quality food and food additives. Edible mushrooms and seaweeds are a good source of protein, carbohydrates, minerals, and vitamins necessary for good health and growth of the body. In general, microorganisms play significant roles in enhancing food production which improves the life of humans and other animals, and promotes good health and well-being.

## Recommendations:

- i. The Government and relevant institutions should increase and promote public awareness about the advantages of consuming food produced by beneficial microorganisms. These have high nutritional value and low-cost to obtain.
- ii. In addition, the government should provide research grants to various scientists across the nation to advance research on the effects of microorganisms on food production.

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