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Enhanced shelf life with improved food quality from fermentation processes.

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Abstract

Currently our consumers prefer good quality food products with extended shelf life which can be achieved by natural fermentation process. And fermentation process has helped the food products to develop the enhanced shelf-life with best nutritional or organoleptic properties and is attracted by world level people. Finished fermented foods have shown the improved microbial stability and safety with some capability to keep at ambient temperature and it has enhanced the nutritional or digestibility value to food with increased palatability for consumers. Natural food fermentation processes are done by diversity of fermenting microbial communities and shown their properties to make energetics process via improving product quality. It is a metabolic process for deriving energy from organic compounds without any oxygen molecules involvement. It has preserved the food materials via formation of organic acid (as inhibitory metabolites to avoid contamination) as reported in lactic acid fermented food as diet of developing nations. Bread, cheese, and sausages are example for fermented foods. Traditional fermented foods in recent times have shown many health benefits as vehicles of probiotic organisms and health-promoting metabolites. Fermented foods are promoted to prevent or cure a range of diseases from obesity to cancer. Kimchi have anticancer, antiobesity, antiaging and anticonstipation effects where as kefir can reduce lactose intolerance symptoms or cholesterol level with stimulation of the immune system and antimutagenic and anticarcinogenic properties. Bionade, flavored malt-based beverages are now available in market which is utilized by most of world level people. Other fermented food with starter culture of kombucha and Rythem, coconut milk-based and fruit juice-based beverages also found with kefir grains. Several soy- and cereal-based probiotic products are also available in the market in response to growing prevalence of allergies to dairy proteins, lactose and gluten intolerances and life style choices.

Keywords: Food products, Food quality, Fermentation process, Shelf life period, Health benefits, Microbial community.

Abbreviations:

ACE: Angiotensin 1-Converting Enzyme; antiSMASH: Antibiotics and Secondary Metabolite Analysis Shell; BAGEL16: Brilliantly Advanced General Electronic-Structure Library; BAs: Biogenic Amines; CLA: Conjugated linoleic acids; GMP: Good Manufacturing Practice; GRAS: Generally Recognized as Safe; HACCP: Hazard Analysis and Critical Control Points; LAB: Lactic Acid Bacteria; LISA: Library and Information Science Abstracts; MFC: Microbial Food Cultures; QSA: Qualified Security Assessor; TQM: The Total Quality Management

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Introduction

Traditional fermented foods in Indonesia country are found to highly dependent on the microbial community activity and its specific functions which are naturally present in the food raw materials or food environment. And there, some fermented foods are reported which are mainly tape ketela (fermented cassava tuber), brem (rice wine), tempe kedelai (fermented soybean), urutan (fermented pork sausage) and terasi (fish or shrimp paste) and these products are consumed via condiments, flavouring and sea soning agents in a variety of foods. Microbial activity with their various enzymes has shown active role in overall quality improvement of finished fermentative products at small scale with labour intensive and low profit margin operation. This process is found ideal for industrial participation of low income population [1].

Food fermentation is utilized as food processing process and it helps in stabilization and transformation of food materials via metabolic activity of microorganisms especially in different type of perishable foods such milk, vegetable or fruits or any other water rich foods. It is also applied as food preservation tool for creating desirable organoleptic, nutritional and functional attributes in fermented food with significant contribution in diet of developing countries. There is still found a renewed interest in fermented food products due to purported health benefits for metabolic syndromes such as obesity, various food allergies and intolerances (lactose intolerance, gluten intolerance, etc.) and lifestyle choices (vegetarianism and veganism). Natural fermented food has shown the increased interest by consumers in everything perceived natural and promote health and longevity. Conversion of agrofood waste into high-value products such as food ingredients, nutraceuticals, biofuels, and industrial chemicals has reported by fermentation processes which played a significant role in the transition from the current fossil fuel-based economy to the bio-based economy of the future [2].

In Nigeria, locally fermented foods are available as tubers (gari and fufu), cereals (ogi and pito), legumes (dawadawa and iru), milk (local cheeses) and beverages (palm wine) which is preferred and consumed by their people. In fermentation process, biochemical reactions are involved during lactic acid fermentation to yield organic acids, alcohols, aldehydes and ketones and Lactobacillus, Lactococcus, Leuconostoc, Enterococcus, Streptococcus, Penicillium and Saccharomyces are found to involve as main microbial strains in locally fermented foods. It can play significant role in provision of employment opportunities, market improvement, availability of food supplement and poverty alleviation and also enhanced the organoleptic and preservative properties with provision of nutritional quality, detoxification and production of antibiotics. Temperature, water activity, hydrogen ion concentration (pH), oxygen availability and substrate are main parameters to influence the food fermentation process [3].

Residues of pesticides in food are also influenced by fermentation and led to large reductions in original residue levels in the fermented food via new pesticide by-products which could not have health issue. Pesticides presence in food can decrease the growth rate of fermentative microbial strains (yeasts and bacteria) via making slow down fermentations process which can cause unwanted changes in food sensory quality (physical-chemical properties via different polyphenolic content and aromatic profile development) of fermented food. Fermentation can help us challenging needs in science-based quality management of pesticides residues in food [4]. Breads, cheeses, various soybean products, cassava, vegetables, and sausages are available as fermented foods and made important contributions to human diets for thousands of years. Most significant role of fermentation in human nutrition are done by making the nutrients naturally in the starting food materials with more palatable compared to without fermentation. This process has shown it's important to the food supply with significant and direct effects on the nutritive qualities of foods [5].

In fermentation processes, yeasts play its important role in food (well-known bread formation) and alcoholic beverage production (beer and wine). Molecular analytical technologies (gene expression) have facilitated the ecological study of yeasts for many other products development via putting impact on product quality. Yeasts growth and metabolic activities are depended on network of strain and their species interactions with bacteria and other fungi strain. Some yeast strains have utilized as agents for the biocontrol of food spoilage with fungi and others strains as novel probiotic organisms. The association of yeasts can solve new issues in field of food safety which is noticed as opportunistic infections and other adverse responses in humans being [6].

Lactic acid bacteria (LAB) have capability to produce the antimicrobial peptides (i.e. bacteriocins) which is found to act against food spoilage and pathogenic bacteria and it helps in extending the shelf life of many food products (yoghurt and nono). Bacteriocin has applied in food samples of ogi and fufu to evaluate its bio-preservative potential up to period of 60 days. Extension of shelf life of ogi and fufu are reported 60 days and beyond 60 days under refrigeration conditions respectively as compared to the uninoculated samples [7].

The application of mineral salt in natural fermentation of white cabbage is used to evaluate the lowering of amount of NaCl into sauerkraut and sauerkraut juice. Mineral salt (KCl) is found to differ from ordinary salt (NaCl) and can be partially replaced. Various amounts (0.8-1.5% KCl) and combination with garlic and algae can be used for fermentations of cabbage slice to replace the final NaCl concentrations (0.5-0.9%). The yield of sauerkraut juice is more fermented by using 0.8% mineral salt (0.5% NaCl) best sensory quality due to decreased coarseness of the cabbage mix [8]. In this proposed paper, author will discuss about different types of fermented food product with their nutritional and health benefits as well respective shelf life periods.

Fermented Food

Fermented foods are found rich in nutritional values (vitamin K, trace minerals, B-vitamins and probiotics) with their easy preparation and available as more economical diet as health point view. Bulgarians are involved in high consumption of fermented milk and Kefir whereas Turkish people are very famous for their Ariana drink alongside their meals/ Asians has habit to prefer and take pickle cabbage, turnips, eggplant, cucumbers, onions, squash, and carrots whereas middle easterners use yoghurt to accompany almost every meal and different type of fermented foods are shown in Figure 1 [9].

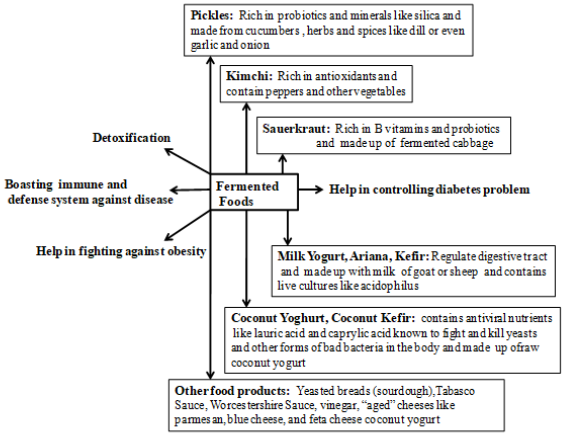

Figure 1: *Fermented foods with enhanced quality and health benefits [10].*

Beneficial effects of fermented foods on health are reported and fermentation is used by many people due to its capacity to preserve foods, enhance shelf life, and improve flavour. Fermented foods have important part in most of world people diet due to have many cultures which is associated with many health benefits. Microorganism's contributions in fermentation process are associated with many health benefits and in this regards, lactic acid bacteria (LAB) are most studied microorganisms which synthesize vitamins and minerals as well as also produce biologically active peptides with enzymes

(proteinase and peptidase) with removal some nonnutrients. Biologically active peptides are produced by the bacteria and responsible for human health benefits [10].

Conjugated linoleic acids (CLA) have shown it's important by lowering the blood pressure and exopolysaccharides has exhibited prebiotic properties whereas bacteriocins have shown anti-microbial effects. Other components are sphingolipids with anti-carcinogenic and anti-microbial properties and bioactive peptides has exhibited anti-oxidant, anti-microbial, opioid antagonist, anti-allergenic, and blood pressure lowering effects. These are health benefits of fermented foods. Some other property of fermented food are reported which are anti-oxidant, anti-microbial, anti-fungal, anti-inflammatory, anti-diabetic and antiatherosclerotic activity [11,12].

Fermented foods and beverages are reported as first processed food products consumed by most of humans being at worldwide and these are mainly yogurt and cultured milk, wine and beer, sauerkraut and kimchi and fermented sausage and these products has shown their initially values due to having their improved shelf life, safety and organoleptic properties. Fermented foods have shown their important due to enhanced nutritional and functional properties via transformation of substrates and formation of bioactive or bioavailable end-products which are recent interest about their food choice. Many fermented foods have living microorganisms with genetically similar to microbial strains used as probiotics. Limited number of clinical studies has done on fermented foods with their health benefits well-beyond the starting food materials and shown in Figure 2 [13].

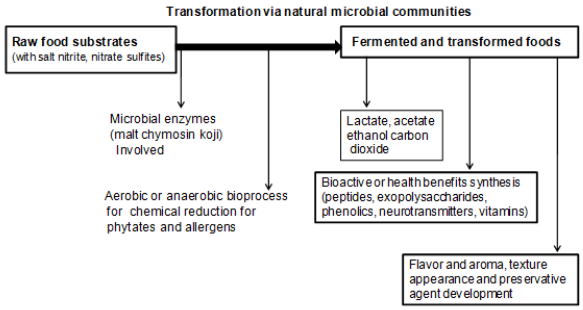

Figure 2: *Natural fermentation process for transformation of food component into valuable one.*

Characteristics of Fermented Food Products

The production technology for fermented products is a period of fermentation and ripening which is differently long due to number of biochemical processes and two and four weeks is reported for traditional fermented products [14-22].

Long technological process can lead to complications in operational as a poor estimate of supply and demand frequently with shortfall of fermented salamis at shipping warehouses. Dry fermented meat products have minimum shelf life of 21 days at a temperature of 20°C. Vacuum packaged meat-products (including salamis) has regularly provided a period of minimum durability of as much as 90 days [23].

LAB can convert fermentable sugars of sausage batter to lactic acid via ensuring product safety by creating unfavourable conditions for pathogens and spoilage organisms. Lactic acid plays role in improving of sensory product quality with mild acidic taste and drying process declines the pH. LAB microbial communities has influenced the sensory characteristics of the fermented sausages by the production of small amounts of acetic acid, ethanol, acetoin, pyruvic acid, carbon dioxide, as well as production of aromatic substances from proteinaceous precursors (Table 1) [24,25].

Fermented foods and beverages has shown its significance for human economy, nutrition and health at worldwide and huge diversity of microorganisms are involved in fermenting of enormous variety of raw materials with exhibition of the different fermentative behavior towards fermentative products. Presence of microbial pathogens and toxic by-products of microbial origin, (mycotoxins, ethylcarbamate and biogenic amines) are found to reduce the safety of the consumer product. Use of preservatives with respect to specific physico-chemical parameters and starter cultures technology has been developed for successfully dominate action by indigenous microflora with drive of spontaneous food fermentation to create the desired attributes of the matrix, assuring quality and safety [26].

Starter cultures in fermentation are reported as preparations of live microorganisms or their resting forms and their metabolic activity are responsible for development of desired effects in the fermented food. Antifreeze or antioxidant compounds are reported as unavoidable residues in the preparations of starter and the culture substrate and additives are found to support the vitality and technological functionality of the microorganisms.

Table 1: *Different type of fermented food products with respective shelf life improvement via fermentation process.*

S. No.	Fermented Food item	Shelf life improvement
1	Fermented dairy food (Yoghurt) [14]	12-14 day to 30-40 days at 40C temperature
2	Curd with Brevibacillus brevis MMB 12 and good flavour, colour, cutting quality and acidity (sourness) [15]	72 hours to 192 hours (8 days)
3	Kimchi preparations is done by fermenting vegetables with probiotic lactic acid bacteria (Leuconostoc citreum GJ7 with 2 log CFU/mL higher) incubated at 7°C [16]	20 days to 125 d days at stored at ?1 0C.

4	Fermented vegetable pickles from carrot, green chilli and brinjal at 10% salt solution and in 8% salt plus 1% sugar solution with unchanged color, flavor and texture [17]	Few (30 days) to 4 months of storage at room temp- erature due to acid formation rate
5	Carrot yoghurt prepared by blending milk with 5, 10, 15 and 20% carrot juice [18]	Refrigerated storage at 4°C from few days to three weeks
6	Lactic fermentation of juice, pulps and tea infusions led to pleasant beverages with preserved antioxidant properties and improve the nutritional qualities [19]	Up to 16 days at 4°C after 48 h of fermentation compared to shelf life of control juice
7	Fresh leaves of sweet basil fumigated with upland rice fermented vinegar vapor 4% acetic acid [20]	Control (14.5 days).sweet basil to fermented sweet basil (19.5 days)
8	Fermentation of white cabbage into sauerkraut and sauerkraut juice with total acidity in per cent lactic acid of sauerkraut ranged between 0.045 and 1.70. And change in bacterial and fungal flora of sauerkraut during fermentation and storage are found [21]	The day of preparation up to 120th day of storage
9	Quality of vacuum-packed dry fermented sausage Poli?an (finished salamis with maturing period of 30 days) and quality analysis (physical/chemical, sensory, microbiological) done at storage temperatures of 5°C and 15°C with formation of total content of biogenic amines [22]	From 30 days to 120 days at 15°C temperature

Microbial food cultures (MFC) are healthy live bacteria, yeasts or molds in food production like curd or yogurt and its developments are based on formulations via consisting of one or more microbial species and/or strains, including media components during fermentation and its components or metabolite formation are necessary for their survival, storage, standardization, and to facilitate their application in the food production process [27,28].

Winemakers are constantly utilizing new techniques for improving the wine production style with more exploitation of indigenous yeasts in grape as provided commercial option in several wine regions via showing a greater diversity of flavors [29]. And shifting to cheese-making practice is with industrial starters and cheese made in the mountains regions exhibits slightly different from cheese made in the plains. Microbialterroir dimension is association with specific fermented productions via influencing perceived quality. Driver of sensory innovation in the gastronomy /artisanal fermented food production fields can utilize the scientific point of view about spontaneous fermentation by autochthonous microorganisms [30].

The quality is property of matter of choice with imperative for survival on the market due to economical reasons as well as international regulations. Durability of a product is dependent on procedure of collection of milk, processing, distribution and storage in retail stores. The quality is connected with the highest satisfaction of consumers requests and improvements of manufacturing procedures. Modem concepts of management are done via maintaining the total quality management (TQM), qualified security assessor (QSA), good manufacturing practice (GMP), library and information science abstracts (LISA) and hazard analysis and critical control points (HACCP) and observation of regulations of the International Standardization Organization (ISO 9000, 9011 etc) for great importance in reaching the adequate shelf life for each product [14]. The production, purification and characterization of bacteriocins are very important due to preservative nature and *L. acidophilus* are produced to appreciable quantity of bacteriocin which is enough to inhibit the growth of pathogenic organisms associated with spoilage of ogi and fufu. Bacteriocins are important in the improvement of shelf life of foods products and are regarded as safe (GRAS). It can able to extend the shelf life of both ogi and fufu by 15 and 5 days, respectively. Bacteriocin can be frozen or refrigerated for storage purposes and it's production in fermented food products can be caused maximum reduction of bacterial load [31].

A variety of fermented foods are available throughout the world which are beer, bread, sauerkraut, pickles, cheese, yoghurt and sausages, etc. and their principles can offer more wealth possibilities via new product development which has more health and nutritional benefits. Food fermentation involves microbial and enzymatic processing of food and food ingredients to achieve desirable characteristics (prolonged shelf-life, improved safety, attractive flavour, nutritional enrichment, and promotion of health) for attracting the modern consumers at worldwide [32].

Fermentation are used for the production of acids, alcohols, enzymes, antibiotics, carbohydrates and lactic acid bacteria (LAB), moulds and yeasts are found to involve in this process by conversion of suitable raw carbon substrates into desired products. Fermented dairy products, vegetable and sour dough fermentation are reported by lactobacilli and pediococci with good shelf life [33]. These starter cultures are also used in meat fermentation to produce desirable acids and flavour compounds. Industrial control of fermentation processes is required up-to-date knowledge of the physiology, metabolism and genetic properties of potential natural fermenting microorganisms via knowledge of their impact on food quality, safety and shelf-life as character of food fermentation more complex [34].

Agricultural products obtained from animal or vegetable, are also fermented by indigenous microflora or by an added starter culture to improve or obtain shelf life, nutritional value, health benefit, flavour or texture. Asia has developed many foods based on vegetable proteins using fungi via utilization of solid-state fermentation process. Food fermentation has preserved food by acid fermentation with good taste, nutritional value and health effects [35]. Microbial fermentation has been applied for preservation of foods and also the health benefits

for human foods. Dairy fermentations is occurred by spontaneous activity of the indigenous microbiota, present in milk. Modern dairy fermentations have started with defined starter cultures which can exhibit desirable characteristics to ensure consistency and commercial viability [36].

In this regards, selection of defined starters is found to depend on specific phenotypes with benefit of the product for guaranteeing shelf life and ensuring safety, texture, and flavour. And lactic acid bacteria have shown their capabilities to produce a number of bioactive metabolites during fermentation (bacteriocins, biogenic amines, exopolysaccharides, and proteolytically released peptides). Prebiotics are added to during the food fermentations to improve the performance of probiotics culture [37]. Fermentation of prebiotics such as fructo-oligosaccharides has shown help in the prevention of diseases such as osteoporosis, obesity, and colorectal cancer. The potential to prevent or treat disease via fermentation of food is a medically and commercially attractive goal and is showing increasing promise for our food industry [36,37].

Metabolites Formation in Fermentation Affecting the Food Quality

Bacteriocins (as positive impact on food quality)

Bacteriocins are small ribosomally synthesized antimicrobial peptides produced by great number of Gram (+) and Gram negative (-) bacteria (during their growth, possessing as antimicrobial activities and the producer species is immune with it. It has restricted their activity to strains of species related to the producing species and particularly to strains of the same species. Nisin is the only bacteriocin which is officially employed in the food industry and its use is approved at worldwide. Gram (+) bacteria (lactic acid bacteria (LAB)) especially Lactobacilli have gained particular attention recently [38].

The identification of bacteriocinogenic strains has done on agar diffusion-based assays. Increasing interest in bacteriocins utilization is found as alternatives to antibiotics and chemical food preservatives. In silico screening using programs such as BAGEL16 and antiSMASH17 has help in the discovery of new bacteriocin operons in whole genome data of microbial system. Purification and characterization of several bacteriocins with industrial potential have been reported and their kinetics determination of bacteriocin production by LAB through mathematical modeling and positive predictive microbiology. Fermented sausage (anti-listerial effect), and cheese (anti-listerial and anti-clostridial effects) have been studied during in vitro laboratory fermentations as well as on pilot-scale level. Bacteriocin has played important role in the food industry as starter cultures, co-cultures, or bioprotective cultures to improve food quality and safety [39].

Biogenic amines (as negative impact on food quality)

Biogenic amines (BAs) are biologically active, low-molecular weight organic bases produced mainly by lactic acid bacteria isolated from cider via decarboxylation of certain amino acids, accumulate during fermentation. The presence of BAs in food products is associated with undesirable microbial activity (causing food spoilage or defective manufacture) and histamine and tyramine are biogenic amines produced by LAB microbiota growing in ciders. Dairy products (particular cheese), can accumulate high levels of Bas known to be toxic nature legal limits in fish products. During fermentation of dairy production, control of levels of BA should be minimized [40].

Exogenous BAs are mostly found in fermented foods (wines, beers, dairy products, meat and vegetables) and they are rich in protein content. Different type of biogenic amines is found in many fermented foods which are histamine, tyramine, cadaverine, 2-phenylethylamine, spermine, spermidine, putrescine, tryptamine, and agmatine. Secondary control measures are available to prevent biogenic amine formation in foods or to reduce their levels. These approaches are to limit microbial growth may by hydrostatic pressures, irradiation, controlled atmosphere packaging, or the use of food additives. Histamine can be degraded by the use of bacterial amine oxidase or amine-negative bacteria [41].

Bioactive peptides (as positive impact on food quality)

Bioactive peptides are low molecular weight protein fragments of 2-20 amino acids residues with exhibiting of beneficial physiological effects. These peptides are released from the precursor proteins during fermentation or ripening processes by endogenous or microbial enzymes that derived from starter or nonstarter cultures. LAB has capability to posses the proteases and peptidases activity and released encrypted peptides during milk fermentation. It is released after proteolysis and associated with health promotion such as inhibition of angiotensin 1-converting enzyme (ACE) activity, antithrombotic activity, antihypertensive activity, antioxidant activity, immunomodulation, apoptosis modulation, and by opioid and anti-opioid activities [42].

Potential anti-carcinogenic peptides (cationic lactoferricin) are found in bovine milk casein and whey proteins. Cancer-preventative peptide (lunasin) has been proteolytically released during sourdough fermentation by LAB. Increased protease resistances are found during in vitro gastrointestinal transit in the presence of naturally occurring protease inhibitors to allow lunasin to reach the large intestine. Fermented milk and soybean products are naturally high in nutritional value with many health-promoting effects due to release of bioactive peptide sequences. Such peptides and peptide fractions has shown bioactive properties (e.g. immunomodulatory, hypocholesterolemic, anti-hypertensive) and isolated from fermented dairy products and in many traditional fermented soy foods [43].

Conclusion

Fermentation process is found a good food processing technique for enhancing shelf life with health inductive compound formation. Biochemical reactions are playing important role during lactic acid fermentation and yield the various organic acids, alcohols, aldehydes and ketones via

involvement of Lactobacillus, Lactococcus, Leuconostoc, Enterococcus, Streptococcus, Penicillium and Saccharomyces are found to involve as main microbial strains in locally fermented foods. Preference of good quality food products with extended shelf life is selected by many modern consumers which is mostly achieved by natural fermentation process at world level. Improved microbial stability and safety is found in fermented finished foods with enhanced the nutritional or digestibility value and more palatability for consumers. Natural food is a metabolic process for deriving energy from organic compounds and help in preservation of the food materials via formation of organic acid (lactic acid) in fermented food. Bread, cheese sausages bionade, flavored malt-based beverages and coconut milk-based and fruit juice-based beverages are example for fermented foods which has shown many health benefits as vehicles of probiotic organisms and health-promoting metabolites. Kimchi has anticancer, antiobesity, antiaging and anticonstipation effects. And kefir can reduce lactose intolerance symptoms or cholesterol level with stimulation of the immune system and antimutagenic and anticarcinogenic properties. Potential anticarcinogenic peptides (cationic lactoferricin) are reported in bovine milk casein and whey proteins whereas cancer-preventative peptide (lunasin) is released during sourdough fermentation by LAB.

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