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Ethnopharmacology of Assamese Fermented Foods: Traditional Wisdom, Therapeutic Potential, and Evolutionary Insights

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Abstract

The migration patterns of humans from various regions over extended periods form the ancestors of the present-day ethnic communities in Assam, a region located in Northeast India. Throughout the process of assimilation, the people of this area developed the skill of fermenting different types of perishable and inedible raw agricultural products into tasty, preserved, and superior foods and drinks pleasing to the senses. Fermented foods have played a crucial role in the cultural and dietary practices of diverse ethnic communities worldwide since ancient times. Particularly in developing countries, their inclusion holds significant importance as it provides a cost-effective method of preserving food while enhancing its nutritional and sensory attributes. The native population of Northeast India, particularly in Assam, has a long-standing tradition of preparing and consuming various smoked, sun-dried, fermented, and salted fish products. This practice, which originated from the astute observations of our ancestors, has resulted in a wide range of fermented food items and beverages that are unique to this region. Among these, Judima, Rice beer, Apong, Jou, Sujen, Khorisa, Kahudi, Napham, Kharoli, Xaj-pani, Chokot, Shidol, and traditional fermented fish products like karati, bordia, and lashim hold significant prominence. These ethnic fermented foods not only influence the local healthcare system but also possess potential therapeutic benefits for disease prevention and managing physiological disorders. The phytochemical constituents present in these fermented foods, individually or in combination, exhibit noteworthy therapeutic potential. The objective of this review is to provide an in-depth understanding of the diverse range of ethnic fermented foods in Northeast India, specifically Assam, their impact on health, and the evolutionary development of their preparation techniques.

Keywords: *Assam, Fermented food, ethnic food, North east India, Nutrition.*

1. Introduction

Fermented foods have played a significant role in many ethnic groups' cultures and traditions globally since the beginning of human civilization. Due to its economical nature, fermented food is essential for human diets, especially in developing countries. It helps communities all over the world preserve food while also improving its nutritional value and flavour (Steinkraus, K.H. (1996) Handbook of Indigenous Fermented Foods. 2nd Edition, Marcel Dekker, Inc., New York. - References - Scientific Research Publishing) (Gadaga et al., 1999). Fish products that have been historically processed, smoked, sun-dried, fermented, and salted are prepared and consumed by the indigenous people of North East India, primarily in Assam (Thapa, 2002). Fermented foods are the product of our ancestors' keen observation rather than a human creation. In the North East, a wide range of fermented foods and drinks unique to different areas have been well documented (Handbook of Food Spoilage Yeasts). Fermented Foods and Beverages of North-East India (Das, A.J. and Deka, S.C. 2012). International Food Research Journal, 19, 377-392. - Citations - Teramoto et al. (2002), Scientific Research Publishing, n.d. It has been noted that Judima, Rice beer, Apong, Jou, Sujen, Khorisa, Kahudi, Napham, Kharoli, Xaj-pani, Chokot, Shidol, and traditional fermented fish products like karati, bordia, and lashim are common in the states of North East India, especially Assam. These foods are very influential in the healthcare system and may benefit health by preventing disease and treating physiological issues. When taken separately or in combination, the phytochemicals found in these fermented foods show impressive therapeutic promise for treating a wide range of illnesses. This review aims to clarify the wide range of ethnic fermented

foods available in Northeastern India, particularly Assam, their potential health benefits, and how their preparation methods have changed.

2. Materials And Methods

The literature on fermented food products from North East India, particularly Assam, was thoroughly and rigorously investigated in this review using systematic methodologies. Several internet resources, including Google Scholar, PubMed, and Scopus, were used to compile the research review. Search terms like "fermented food," "ethnic food of Assam," "tribal community food," "fermentation," "microbes of fermented food," "positive impacts of ethnic food," and "process of producing fermented food" were used in addition to other terms that were related to the review topic or Assamese fermented food products. When choosing articles for review, the following standards are closely adhered to.

1. Articles that concentrated on producing and consumption of fermented food products in North east India, Assam.
2. Articles that focus on advantages of fermented foods.
3. Articles related to microbial diversity associated with different fermented food products.

The criteria for exclusion were:

1. Publications in non-English-language.
2. Articles without peer review.
3. Publications that did not emphasise on the fermented food products of north East India.

3. Results and Discussion

Judima- One of the earliest indigenous ethnic groups in northeastern India is the Dimasa Kacharis. They reasoned that the therapeutic qualities of the herbs used to prepare starting cultures may account for rice beer's health benefits and ability to treat various illnesses. The Dimasa Tribes of Northeastern India are known for their homemade alcoholic beverages, known as judima (Das et al., 2012). One of the oldest indigenous ethnic groups in India, the Dimasa is primarily located in Dimapur, Nagaland, and the North Cachar Hills of Assam (Das et al., 2012). A mixture of fermented rice and plant leaves or barks containing various phytochemicals, such as phytoestrogens, terpenoids, carotenoids, limonoids, phytosterols, glucosinolates, polyphenols, flavonoids, isoflavonoids, and anthocyanidins, is used to make judima. A homemade starch is used as the fermentation's starting material. It has been reported that a semi-sterilized medium, including ground rice (mainly gluten) combined with various plant parts, harbours the therapeutic potential for yeast production (Das et al., 2012). The base cake used to make Judima is known as umhu or humao; it is made of rice and the bark of the thempra (*Acacia pennata*) plant. To provide more taste and variation, they also add powdered leaves from *Piper betel*, *Buddleja asiatica*, and *Hedyotis scandens*. *Acacia pennata* bark is chopped into tiny pieces and sun-dried. Soak *Oryza glutinosa* flour, often known as glutinous rice, in water until it becomes tender. Judima is prepared from a variety of plant parts (leaves and twigs), with popular growth supplements used in the formation of fermentation starter cultures being *Piper betle, Acacia pennata, Buddleja asiatica*, and *Hedyotis scandens*. The most commonly utilized species were the leaves of *Buddleja asiatica*, the twigs and leaves of *Hedyotis scandens*, and the bark and leaves of *Acacia pennata.*

These phytochemicals offer enormous therapeutic potential for treating a wide range of illnesses, either alone or in combination (Prakash et al., 2012). According to Prakash et al. (2012), they have distinct pharmacological effects on human health, including those that are anti-inflammatory, anti-allergic, antioxidant, antibacterial, antifungal, antispasmodic, chemopreventive, hepato-protective, hypolipidemic, neuroprotective, hypotensive, antiaging, diabetes, osteoporosis, DNA damage, cancer, and heart diseases. They also induce apoptosis, diuretics, CNS stimulants, analgesics, protect against UVB-induced carcinogenesis, immuno-modulators, and carminative. The high polyphenol, alkaloids, and flavonoid contents in the plants used to prepare the starting culture are responsible for Judima's antioxidant action. The decanted product of Judima was found to contain 32.43 ± 2.7 mg/ml of total carbs, 0.97 ± 0.18 mg/ml of protein, and 3.21 ± 0.21 mg/ml of free amino acids, respectively. The decanted product's protein, amino acid, and carbohydrate content enhances the cell's energy metabolism. Rice saccharification into simple monosaccharides and rice disaccharide conversion into alcohol via starch hydrolysis. α-amylase and β-glucosidase, which are extracellular enzymes found in many yeast strains and moulds, carry out the saccharification process (Bryzak, 2003Although yeasts are the most common type, various microorganisms are sequentially involved in the fermentation of alcohol. However, the use of plant materials as necessary ingredients in the starch preparation process for the fermentation of alcoholic beverages, such as leaves from *Buddleja asiatica*, twigs and leaves from *Hedyotis scandens*, and leaves and bark from *Acacia pennata*, may result in an excess of phenolics, which may have changed the microbial population over time.

Additionally, it has been reported that fermentation involves two different kinds of yeast. *Marcha amylolytic* yeasts break down starch to generate glucose in Sikkim (Tsuyoshi, 2004). On the resulting glucose, the alcohol-producing yeasts subsequently proliferate quickly to ferment ethanol. It has been suggested that the fermentation of rice and the creation of "Tapeketan" are caused by the common filamentous mold *Amylomyces roucii* and yeasts such as Enclomycopses, Candida, and Hensenuls. It has been demonstrated that the amylolytic capacity of the mold responsible for the characteristic tapeketan flavour affects the growth of different yeasts (Fleet & Heard, 1993). It is anticipated that thorough identification and selection of yeasts, bacteria, and helpful fungi from starter cultures used in traditional brewing in Northeast India will provide microorganisms that are significant to the industry and beneficial to humanity. According to morphological and biochemical studies, *Bacillus circulans, Bacillus latarosporous, Bacillus firmus, Bacillus pumilus, Pediococcus pentosaceus,* and yeast, specifically *Saccharomyces cerevisiae* and *Debaryomyces hansenii*, make up the majority of the microbial diversity (Chakrabarty et al., 2014). Nevertheless, more investigation and characterization of the entire microbial diversity remain.

Rice beer- Commonly referred to as "Apong" (originating from the Mising tribe in Assam and the Adi tribe in Arunachal Pradesh, India), "Xaaj," and "Joubishi" (originating from the Ahom and Bodo ethnic groups in Assam, India), this fermented rice-based alcoholic beverage is popular. Typically, it is created by fermenting cooked rice, straw, and ash from partially burned paddy husks. Then, it is combined with the starter culture, called Epob in the Mising tribe and Siiyey in the Adi tribe, and the mixture is kneaded into little balls coated in dry rice straw and fern leaves. After that, it is put into an earthen pot and left to ferment for nearly 20 days at a temperature of 30-35°C. [Kardong and others, 2012]. According to Pegu et al. (2013), the inoculum combines rice, flour, and plant components from 26 nearby plants. The main ingredients of the rice beer starter culture are yeast (specifically, *Saccharomyces cerevisiae*, *Candida* spp., and *Rhodotorula* spp.) and laccase. At dilutions of 10− 5 and 10− 6, respectively, the total colony count for yeast ranged from 9-11 x 107, while for LAB, it was 13-15 × 108 (Handique, 2019). The microbial diversity in three distinct rice beers—Apong, Xaaj, and Joubishi—from an Assamese village market is investigated in a study by Das, Deb et al. (2019). It was discovered that while all three rice beers had Stenotrophomonas, Pantoea, Neoasia, Rhizobiaceae, and Dickeya, Apong and Xaaj had the preponderance of Paracoccus, Enterococcus, Olivibacter, and Cellulosimicrobium. The most common group was Lactobacillus (42.36%–92.25%), followed by Weissella and Pediococcus (34.36% and 89.09% abundance, respectively). Leuconostoc, Lactococcus, Bacillus, Acetobacter, Acinetobacter, Enterococcus, Exiguobacterium, Enterobacter, Dickeya, Janibacteria, Gluconobacter, Rothia, Pseudomonas, Klebsiella, and Staphylococcus were majorly found in the rice beer varieties (Das, Deb, et al., 2019). Gluconobacter, Lactobacillus, and Lactococcus are the primary producers of aromatic chemicals that contribute to the flavour of rice beer (Zou et al., 2018). Next-generation sequencing (NGS) and metagenomics were used to identify the microbial diversity. The eighteen critical bacteria identified by the culture-independent fermentation included increased abundances of Lactobacillus, Leuconostoc, Pediococcus, Lactococcus, and Weissella in the rice beers. Common environmental bacteria that could have emerged during the mixing or production of rice beer include Enterococcus, Acinetobacter, Exiguobacterium, Gluconobacter, Enterobacter, Pseudomonas, and Janibacteria (Das, Deb, et al., 2019). The existence of Staphylococcus, Rothia, and Klebsiella may be a sign that the rice beer production process is not sterile or sanitary. However, one of the biggest problems with home-brewing is keeping a sanitary atmosphere. Judima has been shown to have potential benefits for hepatoprotection, hypolipidemia, neuroprotection, anti-allergic, anti-ageing, anti-fungal, anti-oxidant, anti-bacterial, anti-diabetic, anti-inflammatory, and antispasmodic conditions (Ray et al., 2016).

Apong- This is a highly well-liked homemade alcoholic rice beverage-specific to the upper Assamese missing tribe. It is made using rice—preferably glutinous rice—soaked in water for about two hours, pulverized, and thoroughly combined with a powdered form of semi-dried leaves, whole plants, or plant parts. It is then given a precise form, and the desired bacterial consortia from the previous batch culture are transferred for fermentation. The fermentation process is a conventional method of adding proteins, vitamins, and vital amino acids to food, increasing the nutritional value of basic materials through microbial activity. The primary macronutrients in apong are also displayed in the data. These macronutrients are very helpful in energy metabolism since they partially satisfy the cell's energy needs. From a metabolic perspective, it is determined that the high levels of free amino acids (2.431±0.12 mg/ml), reducing sugar (3.33±0.06 mg/ml), total protein (1.05±0.06 mg/ml), and carbohydrates (46.621±4.3 mg/ml) are significant (Deori et al., 2012). This result supports the idea that different microorganisms in the starter culture participate in metabolic enrichment during the fermentation process. Only two primary forms of microbial populations—low fermenting yeast and rod-shaped

amylolytic bacteria—were initially identified and isolated from apong, out of the three major types of microbial populations that were first detected and isolated from apong (Deori et al., 2012).

Jou- It is a popular alcoholic beverage in Assam and Northeast India, manufactured from sticky rice (mairong). After the rice is cooked, it is combined with the spices and charcoal in an earthen pot together with the starter culture Amao, which is made of plant parts with aged ferment, and left for three to five days (Ray et al., 2016). Jou aids in the avoidance of jaundice and urinary problems.

Sujen- The Deori tribe of Assam makes sujen, a traditional indigenous rice beer, from fermented rice. "Mod Pitha" or "perk kushi" is the name of the starting culture used to prepare sujen (Handique & Deka, 2016). Rich sources of different microorganisms, starter cakes for sujen synthesis can benefit the food industry. Saccharomyces is the genus from which the dominant strain in each sample is determined, and it resembles *Saccharomyces cerevisiae* quite a bit. Additional strains found in SCS include *Rhodotorula* sp. and *Candida* sp. *Saccharomyces cerevisiae* and strains of Candida species, such as *C. krusei, C. pelliculosa, C. utilis, C. sphaerica, C. magnolia,* and *Rhodotorula glutinis,* have been reported in the literature. Sarma and Deka (2010) Previous reports have indicated that the predominant lactic acid bacteria in starting cultures are *Lactobacillus plantarum* and *Lactobacillus brevis*. (Mayo and others, 2010)

Khorisa- One ethnically traditional product made by the Assamese people, fermented bamboo shoots, is called khorisa. For decades, people have been using bamboo shoots as a dietary supplement. A component of traditional Asian medicine is bamboo. According to Choudhury et al. (2012) and Singhal et al. (2013), it is a source of antioxidants, anti-ageing, anti-cancer, and prevents cardiovascular disorders. Here, LAB naturally prevents food pathogens without harmful or other side effects. This area contains enterobacteria, aerobic mesophiles, and yeast loading. Bamboo shoot fermentation is an everyday use of LAB. A high amount of LAB indicates lactic acid production during fermentation, which stops other bacteria from growing. There are *L. plantarum*, *L. brevis*, *L. paracasei*, *L. pentosus*, and *L. collinoids*. Certain functional features of fermented bamboo shoots include their capacity to break down phytic acid their antioxidant and probiotic qualities (Sonar & Halami, 2014; Sonar et al., 2015).

According to Haller et al. (2001), bamboo shoots are a rich source of several nutritional components, including proteins, carbohydrates, minerals, fibres, phenol, and little fat. In addition to enhancing flavour, texture, and appearance, fermentation—which LAB mainly drives—enhances nutritional value. Organic acids are liposoluble due to their low pH, which enables them to pass through cell membranes and into the pathogen's cytoplasm (Haller et al., 2001). In all Khorisa samples, it was discovered that the iron level had increased while the calcium and phosphorus content had remained the same (Sharma & Barooah, 2017). The observed low pH and high acidity were probably caused by LAB and yeasts using free sugar (Efiuvwevwere & Akona, 1995).

A reduction in sugar content was discovered. There was no discernible shift in the protein content. A reduction in crude fibre was observed. Ascorbic acid levels rose. It has been reported that protein and free amino acid breakdown was seen during sebum fermentation. The amount of cyanide dropped during fermentation. *L. plantarum* exhibited antagonistic action against *L. monocytogenes* in LAB, with *L. brevis* following suit against *L. innocua*. Tamang et al. (2009) have reported that L. plantarum IB2 exhibits an inhibitory effect against *Staphylococcus aureus* that was isolated from Inziangsang. Numerous bacteeriocins generated by LAB inhibit Listeria and work against bacteria closely related to the producer organism. It has been documented that *Lactococcus lactis* subsps cremoris produces bacteriocins sensitive to papain (Bromberg et al., 2004).

Kahudi- Kahudi, or Pani tenga, is an Assamese delicacy made from fermented mustard. It is made by combining extracts of tamarind or the acidic *Garcinia pedunculata* (Thekera) with coarsely crushed mustard (Barooah et al., 2020). A spontaneous and unregulated solid-state fermentation method yields kahudi (Goswami et al., 2017). Rapeseed-mustard seeds are fermented in Assam using a solid-state spontaneous process in two different pH environments (acidic and alkaline). This process produces two distinct gastronomic products: an acidic fermentation produces a pungent, sour paste called Kahudi, and an alkaline fermentation produces a pungent paste with an umami taste called Kharoli (Bora et al., 2022).

S. aureus, *Escherichia coli*, and *L. monocytogenes* were the three indicator bacterial strains used to assess the antimicrobial activity of the kahudi isolates. AAU1, AAU7, AAU8, and AAU9 showed the lowest antimicrobial activity among the isolates, but L. plantarum AAU5 and AAU6 showed the highest activity against S. aureus. Regarding antibiotic activity against *Escherichia coli*, *L. plantarum* AAU5 exhibited the highest level, followed by *E. durans* and *L. casei*. Regarding *L. monocytogenes*, none of the isolates exhibited any antibiotic activity. By generating H2O2, bacteriocin, and some organic acids,

LAB prevents the growth of further harmful organisms. Dasari & Associates, 2014). Numerous studies have examined the antimicrobial activity of LAB against various pathogenic bacteria (Awaisheh & Ibrahim, 2009). In 2012, Djadouni and Kihal

The microbes associated with Kahudi have several potential benefits:

Probiotic properties: The probiotic properties of LAB are well-known. They can support the preservation of a balanced gut flora, which is critical for proper digestion and general well-being.

Antimicrobial activity: Antimicrobial activity in the LAB in Kahudi may aid in inhibiting the growth of pathogenic bacteria.

Metabolization of indigestible sugars: Many indigestible sugars, including D-mannose, mannitol, sorbitol, methyl-a-D-mannopyranoside, methyl-D-glucopyranoside, N-acetylglucosamine, amygdalin, and arbutin1, can be metabolized by the LAB un Kahudi. This may facilitate nutrition absorption and digestion. (Goswami and others, 2017).

Napham- It is a customary fermented food item from the Assamese Bodo (Narzary, 2016). According to Narzary (2019), this fermented fish product from Assam is relatively unknown but a good source of vital amino acids and numerous minerals. It is a fermented food product made primarily of fish that takes on a distinct scent upon complete fermentation and adding other plant species. The fragrance and texture of food are influenced by metabolites produced by various microorganisms, including bacteria, yeast, and ethanol. In 2016. Narzary et al.

The mineral content shows that Napham is a good source of Ca 68.90±0.16 µg/ml, Na 67.26±0.150 µg/ml, Mg 32.20±0.94 µg/ml, K 10.68±0.74 µg/ml and Fe 9.10±0.30 µg/ml.

According to an analysis of amino acids, 32% of the amino acids in Napham were essential, 40% were non-essential, and 28% were contained in other amino acids out of 25. Tryptophan (0.03%), Valine3-Methyl histidine (0.9%), Lysine (0.91%), Leucine (0.97%), Isoleucine (1.04%), Methionine (1.10%), and Histidine (14.24%) were the essential amino acids (Munro & Crim, 1988) present in Napham. Among them, histidine was the most abundant essential amino acid, measuring 23 µg/ml, followed by methionine at 1.8 µg/ml and isoleucine at 1.7 µg/ml. Arginine (0.62%), Aspargine (1.26%), Glycine (1.60%), Alanine (1.90%), Glutamic acid (2.39%), Tyrosine (2.95%), Carnosine (3.1%), Aspartic acid (5.07%), Proline OH (32.17%), and Proline (11.29%) were the non-essential amino acids that were discovered. The most significant composition of non-essential amino acids is found in OH Proline, which has 52 µg/ml, Proline (18.28 µg/ml), and Aspartic acid (8.203 µg/ml). Phoshoserine (0.86%), Cystathionine (1.36%), Ornithine (0.4%), Taurine (1.70%), Amino adipic acid (12.21%), Anserine (0.22%), and Phosphoenolamine (1.05%) are some other intermediate molecules.

Based on the fatty acid profile, the following information can be derived., pentadecanoic acid (C15:0) accounts for 50% of the total fatty acid composition among saturated fatty acids, with tetradecanoic acid (C14:0) contributing 24.67% and tridecanoic acid (C12:0) contributing roughly 15.04%. Octadecenoic acid (C18:1n-14) makes up roughly 3.65% of monoenoic acid 4-. (Narzary et al., 2019.)

karati, bordia and lashim- Fish products that are traditionally processed, smoked, sun-dried, fermented, and salted are prepared and consumed by the ethnic people of Northeast India (Thapa, 2002).

Assamese local markets sell a few essential traditionally processed dried fish goods such askarati, bordia, and lashim. Fish (*Gadusia chapra*, *Pseudeutropius atherinoides*, and *Cirrhinus reba*) are caught, cleaned, and salted before being dried in the sun for four to seven days to prepare dried fish items. For three to four months, the sun-dried fish products are kept at room temperature. Bordia is created from *Pseudeutropius atherinoides*, while karati is prepared from *Gadusia chapra* Hamilton. The preparation of Bloch and Lashim comes from *Cirrhinus Reba* Hamilton.

A total of thirty samples, each of lashim (8), bordia (10), and karati (12) were examined for the microbiological load. The LAB population and aerobic mesophilic counts in all samples of dried fish products varied from 104 to 106 cfu/g, respectively. Spores of bacteria were found at a concentration of <10-103 cfu/g. Enterobacteriaceae, *Staphylococcus aureus*, and *Bacillus cereus* had loads of less than 102, 103, and 102 cfu/g, respectively. Yeasts were found at less than 103 cfu/g. In every sample examined, mold was not found (THAPA et al., 2007).

Kharoli- Kharoli is made by fermenting mashed mustard seeds (*Brassica campestris* var. toria) and adding khar to the mixture. The Assamese produce two varieties of fermented mustard seed products: kharoli and kahudi. Grinded mustard seeds are combined with local soda, or Kolkhar, to make a dough wrapped in banana leaves and left to ferment. Mustard seeds and the pulp of the kera tenga (*Garcinia pedunculata*), which are ground together and left to ferment, are used to make kahudi, also known as

pani-tenga(2019, Bora).*Limosilactobacillus fermentum* starts the fermentation process, followed by *Pediococcus pentosaceus*, *Lactiplantibacillus plantarum*, and *Lacticaseibacillus casei* subsp. *Pseudo plantarum* (Tamang & Tamang, 2007, 2010;). Strong acidification, antimicrobial characteristics, the capacity to break down anti-nutritive elements, and probiotic traits were all displayed by lactic acid bacteria isolated from fermented vegetable products (Tamang et al., 2000). Since there is no cold storage or contemporary refrigerator available during the winter, ethnic groups have invented new ways to preserve the abundance of green crops.

This is an excellent illustration of the "biological preservation" of perishable vegetables using several antimicrobial agents, including lactic acid bacteria that produce bacteriocin (Das et al., 2020b; Tamang et al., 2009).

Xaj-pani or Xaj- The social and religious beliefs of the Ahoms, also known as Tai-Ahoms, are closely linked to Xaj-pani or Xaj (Saikia et al., 2007). Rice is first parboiled in the traditional Xaj fermentation technique, and then combined with Xaj pitha, the fermentation starter culture. High concentrations of fungus, aerobic bacteria, and lactic acid bacteria (LAB) were present in the starters. The two microorganisms with the highest average CFU among the samples were yeast (7.8325 log10 CFU/g) and LAB (8.03 log10 CFU/g). Early in the fermentation process, the amylolytic fungi crucial to the saccharification of rice starch were active. With members like *Lactobacillus plantarum*, *Lactobacillus brevis*, *Leuconostoc lactis*, *Weissella cibaria*, *Lactococcus lactis*, *Weissella para mesenteroides*, *Leuconostoc pseudomesenteroides*, etc., the genus Lactobacillus was shown to be dominant in the bacterial microflora (7.2%). The genus Lactobacillus, which has the highest representation among the lactic acid bacteria, is made up of a very diverse collection of Gram-positive, microaerophilic bacteria that can look as long to short rods or even cocco bacilli under a microscope according to De et al. (2016), a small number of lactic acid bacteria (LAB) are thought to play a significant functional role in proteolysis, lipolysis, and amino acid/lipid catabolism. This helps to concentrate and fortify nutrients (minerals, vitamins, and essential amino acid synthesis) as well as medicinal ingredients (phenolics, maltooligomers, prebiotics, probiotics, antioxidants, and antimicrobials) and nutrients (Holzapfel, 1997). During this process, these bacteria also change the organoleptic properties (taste, scent, texture, consistency, and appearance) and break down unwanted substances (antinutrients, mycotoxin, and other endotoxins) (Holzapfel, 2002). The ultimate product's sensory attributes are affected by the sour flavour and characteristic favour imparted by the lactic acid and acetoin produced during fermentation (Aidoo et al., 2006)—*penicillium* sp. ABTSJ23, *Rhizopus oryzae* ABTSJ63, *Mucor guilliermondii* ABTSJ72, and *Amylomyces rouxii* ABTSJ82 were the four selected molds identified. The fungal strains' alpha-amylase activities varied from 5.92 to 23.16 U/ml. The results showed that *Amylomyces rouxii* ABTSJ82 (5.92 U/ml) produced the lowest amount of α-amylase and *Penicillium* sp. ABTSJ23 produced the maximum amount at 23.16 U/ml. After 120 hours of incubation, *Penicillium* sp. ABTSJ 23 showed the maximum alpha-amylase activity at pH 6.5 and 40 °C. Significant glucoamylase, which is necessary for the conversion of rice starch to glucose, was present in all strains—the glucoamylase activity of *Penicillium* sp. ABTSJ23 was the highest at 15.9 U/ml, followed by *Mucor guilliermondii* ABTSJ72 (8.62 U/ml).

Discussion- Assamese ethnic fermented foods are a fascinating window into the region's diverse culinary traditions, and scientists have been interested in learning more about their possible health advantages. Among these, the Dimasa Kachari group finds particular note in Judima, a fermented alcoholic beverage made from rice. The therapeutic qualities of the plants employed in its preparation may be the source of the belief in its health-promoting qualities (Das et al., 2012). Judima contains phytochemicals that, when taken singly or in combination, have demonstrated considerable therapeutic promise in treating a wide range of illnesses (Prakash et al., 2012).

Comparatively, other regions also have similar fermented rice-based drinks. For example, the Mising tribe of upper Assam produces a popular homemade alcoholic rice beverage called apong. This beverage is created using a traditional bio-enrichment technique that uses microbial activity to increase the nutritional content of raw ingredients (Deori et al., 2012). Its quantities of total proteins, reducing sugars, free amino acids, and carbohydrates are noteworthy and add to its metabolic relevance. Like these fermented rice-based drinks, the Assamese also make a boozy drink called jou from glutinous rice. Assam and other regions of North-East India consume a lot of it, and its preparation calls for a starting culture called Amao. Beyond rice-based drinks, Khorisa is a distinctively Assamese traditional fermented bamboo shoot product. This food item also exhibits the dominance of lactic acid bacteria (LAB) in its fermentation process, indicating the formation of lactic acids that inhibit the growth of other microorganisms, in addition to providing essential nutrients like proteins, carbohydrates, minerals, and fibres (Haller et al., 2001). Assamese-made Kahudi, sometimes called Pani tenga, is a distinctive

product made from fermented mustard. Although there is little detailed scientific research on Kahudi, fermentation produces unique flavours and improved nutritional qualities. According to Dasari et al. (2014), isolates derived from kahudi have demonstrated noteworthy antibacterial activity of *L. plantarum* AAU5 and AAU6 against *S. aureus*, highlighting their potential as natural preservatives in food processing. This discovery raises the possibility that Kahudi's natural antibacterial qualities aid in its preservation. It differs from other traditional fermented foods with this feature, which might have a different level of antibacterial action. The Bodo tribe's fermented fish-based food product, Napham, is an essential nutritional component because of its high mineral content, which includes calcium, sodium, magnesium, potassium, and iron (Narzary et al., 2016). The high concentration of critical amino acids, especially isoleucine, histidine, and methionine, emphasizes its potential as a high-protein food source. This distinguishes Napham from other fermented foods and highlights its distinct nutritional makeup.

However, despite being high in aerobic mesophilic counts and lactic acid bacteria (LAB), traditional dried fish products such as bordia, lashim, and karati also show lower levels of harmful microorganisms and bacterial spores (THAPA et al., 2007). This implies that the fish products' safety and shelf life are enhanced by the fermentation procedure employed to prepare them, which successfully prevents the growth of dangerous microbes.

Kharoli is a product made from fermented mashed mustard seeds. It ferments due to the action of several lactic acid bacteria, which eventually produce antibacterial chemicals (Tamang & Tamang, 2007, 2010). Unlike other fermented meals, this type of biological preservation is unique because the bacteria's antibacterial qualities help to preserve perishable veggies.

Finally, Xaj-pani, also known as Xaj, is connected to the Ahoms or Tai-Ahoms and is notable for its complex relationship to social and religious ideas. The genus Lactobacillus dominates the microbial flora due to the fermentation process, which uses a starter culture rich in fungi, aerobic bacteria, and LAB (Saikia et al., 2007). Xaj-pani is unusual from other fermented foods due to its unique fermentation technique and microbial composition, contributing to its particular flavour and certain health advantages.

Assamese ethnic fermented foods are a diverse mosaic of culinary customs, each with its microbial makeup, nutritional value, and possible health advantages. Gaining an insight into these differences enables one to appreciate these traditional foods' cultural and nutritional value on a deeper level.

4. Conclusion

Fermented foods and drinks act differently from their raw, tasteless beginning constituents. The majority of these goods have yet to be examined for any potential health benefits or other physical, chemical, or microbiological risks. With improved nutritional benefits, these items are bio-enriched with critical amino acids, protein, and vitamins. However, the biggest challenge is the incapacity to generate consistent products and quality. Furthermore, the main drawbacks of the conventional fermentation method are the absence of aseptic conditions, control over the fermentation process, and the potential for hazardous bacteria and byproducts. Therefore, fermented goods must improve quality and safety while simultaneously lowering production costs and preserving their authenticity and distinctiveness. Thus, Assamese low-income groups stand to gain from intense, multi-institutional collaborative research initiatives to develop low-cost industrial technologies.

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Declaration of competing interest

None to declare.

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