CHAPTER 2

Traditional fermented food of Nepal and their nutritional and nutraceutical potential

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2.1 Background

Food is essential for social and cultural heritage. It plays a multifunctional connecting role between society and sustainable food systems (Cavicchi and Stancova, 2016). Traditional foods and practices are a valuable aspect of society's culture and technology and reflect accumulated knowledge, skills, and technology of local people extracted from their direct interaction with local environment (Oniango et al., 2006). It is very important in times of crisis to preserve foods, for biodiversity, nutritional diversity, and in attaining food security (FAO, 2013). Nepal is a country rich in cultural, ethnic groups, and geographical diversity that provide an opportunity for various food production, preparation, and consumption of traditional foods. However, protein−energy malnutrition and micronutrient deficiency are widely distributed across the country. In spite of some improvement in Nepal, still stunting, wasting, and underweight prevail in under-five children, which are respectively 36%, 10%, and 27%. Around 17% women are thin, and 22.5% are overweight and obese. Undernutrition is higher in far west hill and mountain regions than in the *Terai* region. Micronutrient deficiencies such as iron deficiency are high among women (41%) and in children (53%) and are distributed unevenly in the country with higher prevalence in *Terai* regions (Ministry of Health Nepal, 2017). At the same time, noncommunicable disease prevalence is increasing in the country. About 52.2% of households are still food insecure and 10% are severely food insecure, and the condition is more aggravated in the mountain region and far-western hills (Acharya et al., 2018).

The agriculture practices are more seasonal and primitive in Nepal and lead to an occasional shortage of food, primarily nutritionally sensitive food. Traditional foods either fermented or nonfermented can be the basis for preservation and for food and nutrition security, besides their cultural and ethnical identity and role. Traditional foods can be useful for fulfilling the seasonal shortage of food and nutrients and enhance livelihood. Traditional fermented food can be an important nutrient supplement or source of functional components for the people and also enhanced diversity in periods of seasonal shortfall. However, most traditional knowledge and technology are passed as trade secrets of families of certain communities and are protected from tradition. Complete scientific information on the preparation method and mode of consumption and their nutritional value and nutraceutical potential are still lacking. Therefore this chapter mainly focuses to explore the available information of various traditional fermented foods and their nutritional values along with the possibilities of their exploitation as a nutraceutical and functional potential.

2.2 Geography and the natural landscape

Nepal is a Himalayan country, located between latitude 26°22′ to 30°27′ north and longitude 80°4′ to 88°12′ east with a total area of 147,181 square kilometers. It occupies 0.3% and 0.03% land of Asia and the world, respectively (CBS, 2015). Geographically, the country has tremendous diversity and is closely related to its two giant neighbors India and China. Nepal has a total population of 26.5 million with an annual growth rate of 1.35% (CBS, 2015). Nepal lies in the temperate zone with an added advantage of having altitudes of 70–8848 m. Nepal is divided into three regions (northern mountain, mid hill, and southern *Terai*) comprising 7%, 46%, and 47% of the population and 35%, 42%, and 23% of the total land area, and it has seven provinces (CBS, 2016). The climatic condition ranges from tropical to arctic depending upon the altitude. The *Terai* region lies in the tropical southern part of the country and has a hot and humid climate. The mid hills and mountain region is pleasant almost all year around. The northern mountain region around with an altitude above 3353 m has an alpine climate with considerably lower temperature and thin air in winter. Nepal has four climatic seasons: spring (March–May), summer (June–August), autumn (September–November), and winter (December–February) (CBS, 2016).

The agricultural sectors contribute nearly 35% of Nepal's gross domestic products supporting the livelihood of more than 75% of the population (CBS, 2011). The diversified agroclimatic conditions provide a huge opportunity to grow, cultivate, process, and consume diverse agricultural and livestock products. Southern *Terai* is more fertile and has arable land compared to the mid-hill area, whereas mountains are nearly infertile in nature (MoAD, 2016). The main cereals cultivated in Nepal are paddy, maize, wheat, buckwheat, barley, and millet. The production of paddy, maize, and wheat is mainly concentrated in the *Terai* regions, while the production of buckwheat, millet, and barley is more concentrated in hills and some of the mountainous regions. The diverse climate of the country also supports the cultivation and production of a variety of fruits and vegetables. The major livestock of hills and *Terai* is cow, buffalo, goat, poultry, pig, duck, and sheep, while yak is domesticated only in mountain regions (MoAD, 2016).

2.3 History of fermentation and fermented food

Fermented foods have been used since humans arrived on earth after the existence of microbes and plants (Steinkraus, 1994). Historically, with the dawn of civilization, humans lived as hunter-gatherers, started agriculture, and learned ways of processing food. Fermentation after drying is the oldest food preservation method. It is believed that the first fermentation might have been developed accidentally when the storage of surplus food in ancient times was in practice and became popular with the dawn of civilization when they were accepted organoleptically. The science behind the fermentation was unknown even after the initiation of fermentation for 200 years and only flourished after 1700 CE along with the discovery of the microscope and Pasteur's discovery of fermentation (Mehta et al., 2012).

The art of fermentation seems to have originated in the Indian subcontinent in the settlement that predates the great Indus valley civilization. There are indications of highly developed systems of agriculture and animal husbandry during the Harappan spread or prevedic times. Artifacts from Egypt and the Middle East suggest that fermentation was known from ancient times in those regions. Fermented bread and beer were known in ancient Egypt and Babylonia in early 4000 and 3000 BCE (Farnworth, 2008; Hutkins, 2006). China was thought to initiate fermentation of vegetables and use of molds to make food around 300 BCE (Farnworth, 2008). Alcoholic fermentation involved in the making of wine and brewing is considered to have been developed during the period of 2000−4000 BCE by the Egyptians and Sumerians. It is documented that fermented drinks were being produced over 7000 years ago in Babylon (now Iraq), 5000 years ago in Egypt, 4000 years ago in Mexico, and 3500 years ago in Sudan (Dirar, 1993).

The culture of the South Asian countries has relatively few artifacts regarding the beginning of fermentation and fermented food. *Rig-Veda* (about 1500 BCE) has mentioned the "*Somras*," fermented juice and wine. In Hindu mythology, the use of *soma/somras*, as well as *sura*, by various groups in the society for anesthetic and calming effects has been mentioned around 2000 BCE (Farnworth, 2008; Prajapati and Nair, 2008). In Nepal, human existence had been reported before 9000 BCE. According to Nepalese history, animal husbandry and agriculture have been mentioned since ancient times by the Gopala dynasty (a cattle herder and buffalo herder from Ahira's dynasty) before *kirant* (from 1800 BCE to 300 CE) from Tibeto-Burman and Indo-aryan (*Licchavi*) ruled in Nepal (Bhattarai, 2008; Shrestha, 2002). The origin of fermented food in Nepal has been lost in antiquity. It perhaps originated in ancient times or has been introduced by different rulers who migrated from Indo regions and Tibeto-Burman regions along with their culture across the country (Tamang, 2010).

2.4 Ethnicity, origin, and distribution of ethnic groups

The ethnicity of Nepal can be grouped into three broad groups based on their ancestral origin, Indo-origin, and Tibeto origin and their pool of indigenous groups (Shrestha, 2002). Indo-Nepali groups mostly inhabit the fertile lower hills, rivers valley,

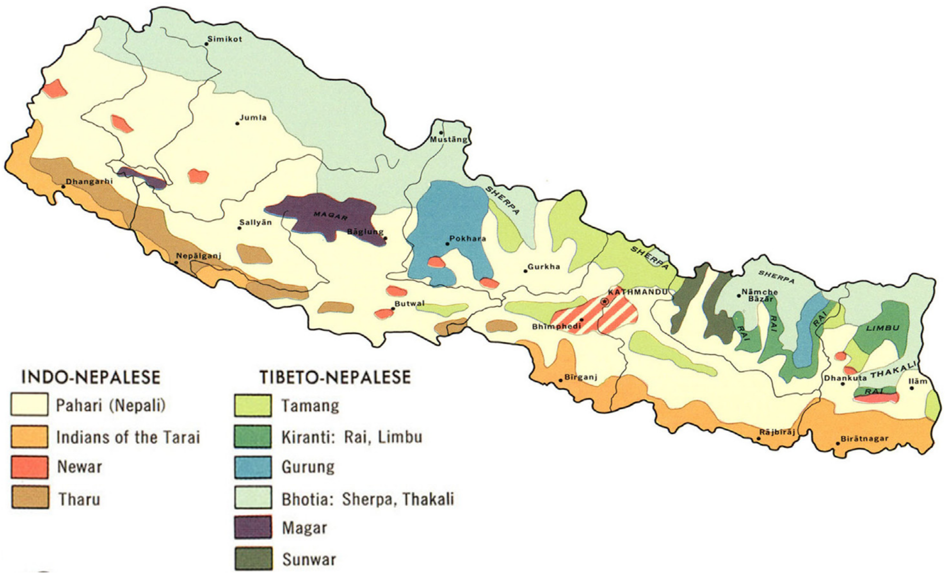

Figure 2.1 Ethnic groups and their distribution in Nepal.

and *Terai* plain. The Indo-Nepali groups include two distinct groups. The hill Indian origin group known as hill dwellers (*Pahari*) includes high caste Hindus, mostly of Brahmins and Kshatriya status. They have spread throughout Nepal. They usually constitute a significant portion of the local community. The second group of Indo-Nepal primarily includes the *Terai* habitants generally identified as *Madhesi*; they came to Nepal from northern India as shown in Fig. 2.1 (Bhattarai, 2008).

Tibeto-Nepali, coming from Tibet (*Bhot*) mostly occupy the higher hills (Fig. 2.1). The Tibeto-Nepali are generally found in higher altitudes, and they are mainly *Sherpas* (*Bhote*), *Gurung*, *Rai*, *Limbu*, *Thakali*, and *Tamang* tribes (Bhattarai, 2008; Shrestha, 2002). *Bhote* tribes are mainly found in the Trans-Himalayan zone. *Sherpa* tribes occupy northeast mainly around Everest (*khumbu*) regions and mainly practice Buddhism. Moving westward along the hills, there is a higher concentration of *Tamang* population, *Gurung* in west-central hills, while the *Magar* are found in the hills and further west. The *Thakali* are well known for Himalayan trade having settled along the upper reaches of *Kali Gandaki* river basin, which was a major trade route between Tibet and India in the past before 1950 (Bhattarai, 2008; Shrestha, 2002).

2.5 Food culture and traditions

Nepal is a multilanguage and multicultural country with various ethnic groups living together across the country. Altogether 125 castes/ethnic groups are residing in the country, and about 123 languages are being spoken. The 10 major caste and ethnic groups reported are *Chhetri*, *Brahman*, *Magar*, *Tharu*, *Tamang*, *Newar*, *Muslman*, *Kami*, *Yadav*, and *Rai*. Ten different religious groups *Hindu*, *Buddhist*, *Islam*, *Kiranti*, *Christian*, *Prakriti*, *Bon*, *Jain*, *Bahai*, and *Sikha* reside in Nepal (CBS, 2014).

Food culture and tradition often relate to ethnicity, religion, and tradition. Nepalese food culture reflects the diffusion and blending of the Hindu and the Tibetan cuisines, with modifications based on ethnic preferences and social philosophy over a period of time (Tamang, 2010). Himalayan ethnic foods have evolved because of traditional wisdom and experiences of generations over periods of time based on agroclimatic condition, available edible sources, ethnical preferences, and social and cultural acceptances (Tamang, 2010). *Bhat* (boiled rice) with *daal* (pulses soup), *tarkari* (vegetables curry), *dahi* (milk curd)/*mohi* (buttermilk), and *achar* (pickle) is the main meal of Nepalese. When there is a scarcity of rice in hilly areas, *dhinro* (bolied maize) with *mohi* is often consumed. Besides in the form of *tarkari*, various traditional foods, both fermented and nonfermented, are being consumed. Nepal is rich in traditional food culture and cuisines. More than 105 traditional foods are consumed in Nepal and about 24 different fermented foods are prepared and consumed since time immemorial (Subba, 2012). Based on seasonal and local substrate availability, different food groups—cereals (41), followed by legume and pulses (9), vegetable-based (12), milk-based (12), meat-based (5), fish-based (3), sugar-based (2) and others (7)—are used to prepare, store, and consume various dishes (Subba, 2012). Some fermented foods are unique to festivals such as *selroti* and are prepared and consumed mainly in religious and cultural festivals such as *Deepawali* or *Tihar* (Katawal, 2012). *Dahi* is often used in making *tika* and *achhata* for worshiping goddesses and applying on forehead for different ritual activities in *Hindu* culture. In *Newari* festivals, *Raksi* is important for guest hospitality and also in various ritual activities. *Jand* and alcoholic products are especially famous among *Matwalis* (*Rai* and *Limbu*) tradition and culture (Tamang, 2010). Some traditional foods are typically related to ethnic groups, and some are intercultural and interregional adaptations. Their different modes of consumption are presented in Table 2.1.

2.6 Traditional fermented food and types

Due to various ethnic tribes, cultural habitat, and availability of local substrates in Nepal, different fermented foods are prepared and consumed. Traditional fermented foods can be basically divided based upon the major substrate used for fermentation such as cereal-based fermented foods (*selroti*, *jand*, *tongba*, *nigar*), legume-based fermented foods (*kinema*, *masyaura*), fruits and vegetable-based fermented foods (*gundruk*, *sinki*, *khalpi*, *mesu*), milk-based fermented foods (*dahi*, *mohi*, *gheu*, *solar*, *somar)*, and meat- and fish-based fermented foods (*sidra*, *sukaako machha*, *sukuti*, *masular)*. Fermented foods can

Table 2.1 Traditional fermented food, their ethnic and regional origin and mode of consumption.

Basic foods groups	Fermented food	Preservation technique	Ethnical origin	Regional origin	Consumption pattern	References
Cereals	*Selroti*	Fermentation and frying	Intercultural	Interregional	Sweet confectionary, Snacks	Dahal et al. (2005), Subba (2012)
Pseudocereals	*Jand*	Fermentation	Intercultural	Eastern mountain	Beverage	Dahal et al. (2005), Subba (2012)
	Raksi	Fermentation and distillation	Intercultural	Interregional	Beverage	
	Nigar	Fermentation	Intercultural	Interregional	Beverage	
Legumes	*Masyaura*	Drying	Intercultural	Interregional	Curry, side dish	Dahal et al. (2005), Subba (2012)
	Kinema	Fermentation	*Limbu*	Eastern hill and mountain	Curry	
Vegetable	*Gundruk*	Fermentation and drying	Intercultural	Interregional	Side dish/appetizer	Dahal et al. (2005), Subba (2012)
	Sinki	Fermentation and drying	Intercultural	Interregional	Side dish/appetizer	
	Khalpi	Fermentation	Intercultural	Interregional	Appetizer	
	Mesu	Fermentation	*Limbu*	Eastern mountain	Side dish/appetizer	
Milk	*Dahi*	Fermentation	Intercultural	Interregional	Side dish, beverages	Dahal et al. (2005), Subba (2012)
	Mohi	Fermentation	Intercultural	Interregional	Beverages	
	Gheu	Dehydration	Intercultural	Highland Himalaya	Frying medium, as such for energy	
	Somar	Fermentation	*Bhotia*, *Sherpa*	Highland Himalaya	Soup	Rai et al. (2016)
	Chhurpi	Fermentation, and drying	Intercultural	Interregional	Curry, soup	
Fish	*Sidra*	Salting and drying	Intercultural	Interregional	Snacks	Subba (2012)
	Sukuti	Drying and smoking	Intercultural	Interregional	Snacks	Rai et al. (2016)
	Sukkako maachha	Drying	Intercultural	Interregional	Snacks	
	Masular	Drying	*Tharu*	East and west Tarai	Side dish/curry soup	Gartaula et al. (2014)

also be classified based on the fermentative organism involved and type of fermentation as alcoholic and nonalcoholic fermented food. *Jand*, *tongba*, and *nigar* belong to alcoholic fermented food. Vegetable-based fermented foods such as *gundruk*, *sinki*, *khalpi*, and *mesu* as well as milk-based *dahi*, *mohi*, *gheu*, etc. can be placed in the group of lactic acid fermented food. *Kinema* can be categorized as alkaline fermented food, while *masyaura* and *selroti* can be considered as mixed spontaneous fermented food.

2.7 Cereal, legume-based fermented food products

2.7.1 Selroti

Selroti is a ring-shaped fried bread/doughnut prepared by mixing rice flour paste [rice: water 1:1 (w/v)], banana (one small piece/kg paste), honey (5%), ghee (5%), and some spices. Sometimes banana and honey are replaced with sodium bicarbonate (0.25%) and sugar (10%). The well-mixed batter is allowed to ferment for either 4 h (during summer) or 24 h (during winter). The kneaded batter is filled in a small funnel and deposited as continuous rings into the hot oil. These rings are fried until brown and served while hot (Yonzan and Tamang, 2009).

2.7.2 Kinema

Kinema is a nonsalted and solid-state alkaline fermented soybean food product of the eastern hills of Nepal (Rai, 2012; Tamang, 2010). It is mainly consumed by non-Brahmin Nepalese inhabiting Nepal, Darjeeling and Sikkim of India, and in some parts of Bhutan. It has a pungent smell of ammonia, slimy texture, and short shelf life. It resembles the *Bacillus* fermented Japanese *natto*, Korean *chungkukjang*, *thuanao* of northern Thailand, *pepock* of northern Myanmar, and *seing* of Cambodia (Tamang, 2010). The preparation method of *Kinema* is lost in antiquity. In the traditional method, soybeans (*Glycine max* L.) are cleaned, washed, and soaked in water overnight at ambient temperature (10°C−25°C), and excess water is drained off. Soaked beans are cooked in an open cooker until they can be crushed easily between the fingertips. Then, the water is removed and crushed lightly by a wooden pestle to de-hull the seed. A small amount of firewood ash is often added. The soybean grits containing torn hulls are then wrapped with fresh fern (*Athyrium* sp.) or *Leucosceptrum canum* smith leaves, covered by a sackcloth and kept in a bamboo basket above an earthen oven in the kitchen to ferment for 1−3 days (maximum 1 week in winter) till formation of the typical flavor is dominated by ammonia. *Kinema* after fermentation has stringy threads when touched with fingers; the longer the threads, the better the quality of *kinema* (Sarkar et al., 1994). Fresh *kinema* is fried in edible oil along with salt, spices, and tomatoes and eaten as a side dish with rice. The predominant microflora of the *kinema* are

Bacillus subtilis and *Enterococcus faecium* bacteria and *Candida parapsilosis* and *Geotrichum candidum* as yeast (Sarkar et al., 1994).

2.7.3 Masyaura

Masyaura or maseura is an ethnic, fermented black gram or green gram product prepared by Nepalese living in the Himalayas. It is a cone-shaped hollow, brittle, and friable product mostly consumed by Newari communities of Nepal (Chetri and Tamang, 2008). *Masyaura* is a product similar to North Indian *wari* and South Indian *sandige*. They are brittle and spongy textured dried balls, 2−5 cm in diameter (Dahal et al., 2005). *Masyaura* is especially prepared from split black gram (*Phaseolus mungo*) and colocasia (*Colocasia esculenta*) or radish and ash gourd depending upon the availability of raw materials (Dahal et al., 2005). The dried balls are stored at ambient conditions. It is mixed with curry to make soup and served with rice as a side dish. Dried *masyaura* contains a final moisture content of 8%−10%. It is a cheap and rich source of protein (18%−20% on fresh weight), carbohydrates (67%−70% on fresh weight), and minerals. It is also known as meat for vegetarians (Dahal et al., 2005; Dahal et al., 2003). The major microflora identified are lactic acid bacteria (*Lactobacillus fermentum*, *Lactobacillus salivarius*, *Pediococcus pentosaceus*, and *Enterococcus durans*), spore former (*B. subtilis*, *Bacillus mycoides*, *Bacillus pumilus*, and *Bacillus laterosporus*), and yeast (*Saccharomyces cerevisiae*, *Pichia burtonii*, and *Candia castelli*) (Chetri and Tamang, 2008). During preparation of *masyaura*, seeds of black gram are cleaned, washed, and soaked overnight. Soaked seeds are dehulled by pressing through hands; hulls are removed and ground into a thick paste using mortar and pestle. Water is carefully added while grinding until the paste becomes sticky. Washed, peeled, and shredded colocasia tuber is mixed and hand-molded into small ball or cones. The mixture is placed on a bamboo mat and fermented in an open kitchen for 2−3 days and sun-dried for 3−5 days depending on weather conditions (Chetri and Tamang, 2008).

2.8 Nutritive value of cereal and legume-based nonalcoholic fermented products

Most of the cereals and legume-based fermented products are good sources of calories and proteins as shown in Table 2.2. Legume-based fermented products are easily digestible and enriched with vitamins, minerals, and amino acids. *Kinema* is rich in linoleic acid produced by microbial lipase during fermentation (Sarkar et al., 1996) and reported to contain all the essential amino acids (Sarkar et al., 1997). It has a higher content of riboflavin and niacin (Sarkar et al., 1998). *Masyaura* has high soluble proteins (74.8%−82.1% of total protein), amino nitrogen (1.0−2.02 mg/100 g, db), nonprotein nitrogen (0.83%−1.61%, db), and vitamin B-complex (vitamin B_1 from 116 to 246 mg/100 g, db and vitamin B_2 from 88 to 141 mg/100 g, db), and decreases

Table 2.2 Cereal- and legume-based fermented product and their nutritional composition (per 100 g dry basis).

Product	Substrate	Microflora	References
Selroti	Rice, wheat flour, and spices	Lactic acid bacteria (LAB): *Leuconostoc mesenteroides*, *Enterococcus faecium*, *Pediococcus pentosaceus*, *Lactobacillus curvatus* Yeast: *Saccharomyces cerevisiae*, *Saccharomyces kluyveri*, *Debaryomyces hansenii*, *Pichia burtonii*, *and Zygosaccharomyces*	Katawal (2012), Yonzon and Tamang (2010)

Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Fiber (%)	Ash (%)	Energy (kcal)	Ca (mg)	P (mg)	Mg (mg)	Na (mg)	K (mg)
11.4	4.7	26.5	68.4	0.12	0.3	532	6.4	12.7	24.9	17.4	46.7

Product	Substrate	Microflora	References
Kinema	Soybean	Bacteria: *Bacillus subtilis*, *Enterococcus faecium* Yeast: *Candida parapsilosis*, *Geotrichum candidum*	Sarkar et al. (1994)

Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Ash (%)	Energy (kcal)	pH	Acidity as lactic acid (%)
63.0	48.7	16.1	29.6	5.6	478	8.10	0.10

Product	Substrate	Microflora	References
Masyoura	Black gram, Colocasia tubers	Lactic acid bacteria (LAB): *L. fermentum*, *L. salivarius*, *Pediococcus pentosaceus*, *Enterococcus durans* Bacillus: *Bacillus subtilis*, *Bacillus mycoides*, *Bacillus pumilis*, and *Bacillus laterosporus* Yeast: *Saccharomyces cerevisiae*, *Pichia burtonii*, and *Candia castelli*	Chetri and Tamang (2008), Dahal et al. (2003), Lama (1988)

Moisture (%)	Protein (%)	Soluble protein as % of total protein	CHO (%)	Crude fiber (%)	Ash (%)	Vitamin B_1 (μg)	Vitamin B_2 (μg)
8–10	18–20	74.2–84	67–70	5.12	4.8	116–246	88–141

in pH (6.1–5.4), starch (57.7%–54.1%, db), free sugar (9.45%–4.61%, db), and reducing sugar (2.0%–0.75%, db) contents as compared with the raw ingredients (Dahal et al., 2003).

2.9 Cereal-based alcoholic fermented beverages

2.9.1 Jand

Jand (also spelled as *jandh/jaanr/jnar/jnard)* is a generic term that refers to a sweet-sour cereal beer made by solid substrate fermentation of cereals such as finger millets (*Eleusine coracana*), rice (*Oryzae sativa*), wheat (*Triticum* spp.), and maize (*Zea mays*) using *murcha* (Rai, 2006). It is an indigenous nondistilled alcoholic beverage of Nepal. Finger millet is a preferred substrate for *jand*, as it is believed to provide superior quality (Rai, 2012). It has found a very prominent place in *Limbu* and *Rai* culture in particular and other ethnic groups in general (Rai, 2006). *Murcha*, *an* amylolactic starter, contains saccharifying mold, lactic acid bacteria, and fermenting yeast (Rai, 2012). The basic steps of *jand* making include cooking of cereals, cooling to room temperature, mixing with *murcha* powder and leaving for a day or two to develop biomass, and fermenting in a tight close-necked earthen pot. The duration of fermentation is a week to several months.

Jand is consumed in different ways. It can be served after mixing with the requisite amount of water squeezed as strained *jand* and is also consumed as *tongba* or *tungba* by adding luke-warm water to loosely stuffed fermented millet in a cylindrical vessel. *Nigar* is more similar to cereal wine (Japanese *Sake*), while *jand* that contains live yeast and suspended particles has been categorized as cereal beer. If *jand* is pot distilled, it becomes *raksi*, a nonaged traditional spirit of varying alcohol content (15%–50%) (Rai, 2012).

2.10 Nutritive value of cereal-based alcoholic beverages

Cereal-based alcoholic products such as *jand*, *nigar*, and *raksi* have calorific values due to alcohol content (Table 2.3). Vitamin-like cyanocobalamine, which is not present in the finger millet, has reported to be synthesized by fermenting microorganisms (Basappa, 2002). Compared with unfermented mash, fermented finger millet has been reported to have an increment in protein content by twofold (7.62%–15.7% db) and ash content by 1.8-fold (2.76–4.62) along with a significant increase in phosphate, sodium, potassium, and zinc but no significant change in iron (Karki, 2013). The essential amino acids such as valine, threonine, leucine, and isoleucine are in higher concentrations in *koddoko jand* or *chyang* (Basappa et al., 1997). Because of high calorific values, both *bhaate Jand* and *koddoko jand* are consumed to regain strength by ailing persons and pregnant women (Tamang and Thapa, 2006; Thapa and Tamang, 2004).

Table 2.3 Cereal-based fermented alcoholic product and their nutritional composition (per 100 g dry basis).

<table>
<tr><th>Product</th><th colspan="2">Substrate</th><th colspan="3">Microflora</th><th>pH</th><th>Acidity[a]</th><th>Alcohol (%)</th><th colspan="2">References</th></tr>
<tr><td rowspan="2">Bhaate Jand</td><td colspan="2">Rice, wheat</td><td colspan="3">Mold: Mucor circinelloides, Rhizopus chinensis
Yeast: Saccharomyces fibuligera, Pichia anomala, Saccharomyces cerevisiae, Candida glabrata
Lactic acid bacteria (LAB): Pediococcus pentosaceus, Lactobacillus bifermentans</td><td>4.04</td><td>0.24</td><td>5.9</td><td colspan="2">Tamang et al. (2012), Tamang and Thapa (2006)</td></tr>
<tr><td>Moisture (%)
83.4</td><td>Protein (%)
9.5</td><td>Fat (%)
2.0</td><td>CHO (%)
86.9</td><td>Crude fiber (%)
1.5</td><td>Ash (%)
1.7</td><td>Energy (kcal)
405</td><td>Ca (mg)
12.8</td><td>Fe (mg)
7.7</td><td>Mg (mg)
50</td></tr>
<tr><th>Product</th><th colspan="2">Substrate</th><th colspan="3">Microflora</th><th>pH</th><th>Acidity[a]</th><th>Alcohol (%)</th><th colspan="2">References</th></tr>
<tr><td rowspan="2">Koddoko Jand</td><td colspan="2">Finger millet</td><td colspan="3">Mold: Mucor circinelloides, Rhizopus chinensis
Yeast: Saccharomyces fibuligera, Pichia anomala, Saccharomyces cerevisiae, Candida glabrata
Lactic acid bacteria (LAB): Pediococcus pentosaceus, Lactobacillus bifermentans</td><td>4.04</td><td>0.27</td><td>4.8</td><td colspan="2">Tamang et al. (2012), Tamang and Thapa (2006)</td></tr>
<tr><td>Moisture (%)
69.7</td><td>Protein (%)
9.3</td><td>Fat (%)
–</td><td>CHO (%)
83.7</td><td>Crude fiber (%)
4.7</td><td>Ash (%)
5.1</td><td>Energy (kcal)
394</td><td>Ca (mg)
281</td><td>Fe (mg)
24</td><td>Mg (mg)
118</td></tr>
</table>

[a]As % lactic acid.

2.11 Fruits and vegetable-based fermented food products

A number of fermented fruits and vegetable products have been prepared and consumed in different communities and regions of Nepal. *Gundruk*, *sinki*, and *sinnamani* are the fermented products obtained particularly from leafy vegetables and radish stem, with some variation in the substrate used and method of preparation. The words *gundruk* and *sinki* are derived from *Newari* words (Dahal et al., 2005; Kharel et al., 2007; Tamang, 2010).

2.11.1 Gundruk

Gundruk is prepared by spontaneous lactic acid fermentation of leafy vegetables and is commonly consumed by all the Nepalese and Gorkha tribes of northeastern states of India (Tamang, 2010). It is commonly prepared from mustard (*Brassica juncea*), radish (*Raphanus sativus*), *rayo sag* (*Brasicca rapa*), and cabbage (*Brassica oleracea*) and some other locally grown vegetable leaves (Tamang and Tamang, 2010; Tamang et al., 2009). *Gundruk* is usually prepared from December to February when the weather is less humid.

During the preparation, the leaves are withered in the sun for 1−2 days. The withered leaves, after a mild crushing, are hand pressed in a perforated tin or earthen jar with a heavy article such as a large stone to remove surplus water. They are then left to ferment in a warm and dry place for 15−22 days. In the village setup, a hole of diameter and depth of about 1 m is dug in the ground and dried by fire. A 30 cm layer of banana or bamboo leaves are placed in the bottom; the dried crushed leaves of the vegetables to be fermented are placed above this layer and covered with a layer of banana or bamboo leaves. A heavy stone is kept to compress the substrate, which is allowed to ferment in situ until a fermentation odor develops (15−22 days). The fermented *gundruk* is then taken out and sun-dried (Dahal et al., 2005). The dominant floras identified in *gundruk* fermentation were *Lactobacillus plantarum*, *Pediococcus pentosaceous*, and *Lactobacillus cellubiosus*. Lactic acid and acetic acid were the major organic acids in *gundruk* and *sinki* (Karki, 1986).

2.11.2 Sinki and Sinnamani

Sinki and *sinnamani* are prepared from the whole radish stem. *Sinnamani* is similar to *sinki*, but drying after fermentation is usually not done in the case of *sinnamani*. *Sinnamani* is used as a pickle in the fresh and soft stage, and it is sourer than *sinki* (Dahal et al., 2005). The method of preparation of *sinki* is also similar to that of *gundruk*, except that the substrate is radish root (*R. sativus*) and the fermentation takes 30−40 days. *Sinki* fermentation is initiated by heterofermentative *L. fermentum* followed by another heterofermentative *Lactobacillus brevis* and succeeded by homofermentative *L. plantarum* (Tamang and Sarkar, 1993). The preparation and shelf life of *sinki* are similar to those of *gundruk*, and *sinki* is mainly consumed as an appetizer or pickle with the main dish (Karki, 1986).

2.11.3 Khalpi

Khalpi is a well-known lactic acid fermented pickle of Nepal, prepared in almost every home. *Khalpi* is prepared with ripe cucumber, spices, and salt. The cucumber is washed, sliced lengthwise, and the inner soft portion is removed, and it is cut into pieces (5−8 cm), mixed with rapeseed powder, red chili powder, turmeric powder, and salt, and heated with mustard oil. The mixture is transferred to an earthen or glass pot, covered with cloth or lid and allowed to ferment for 3 days (Dahal et al., 2005). In *Khalpi* fermentation, initially, *Leuconostoc fallax*, *L. brevis*, and *Pediococcus pentosaceus* are active and later dominated by *L. plantarum* (Tamang and Tamang, 2010).

2.11.4 Taama/Mesu

Mesu (*Me* means young bamboo shoot and *su* means sour in *Limbu* language) is a pickle, similar to *naw-mai-dong* of Thailand. It is prepared from the tender edible bamboo shoot of common variety of bamboo such as *choya bans* (*Dendrocalamus hamiltonii* also known locally as *tama bans*), *mal bans* (*Bambusa nutans*), *bhalu bans* (*Dendrocalamus sikkimensis*), *dhungre bans* (*Dendrocalamus gigantea*), and *Karati bans* (*Bambusa tulda Roxb.*) depending on their availability and seasons (Kharel et al., 2007; Tamang, 2010; Tamang and Sarkar, 1996).

The shoots (*taama*) are finely chopped (1−2 cm) and transferred into bamboo vessels or a glass bottle, tightly packed, and capped to provide an airtight environment. The material is allowed to ferment at ambient temperature (20°C−25°C) for 7−8 days. Lactic acid bacteria seem to be the dominant organism in *Mesu* fermentation (Tamang and Sarkar, 1996). *Mesu* fermentation is initiated by *Pediococcus pentosaceus* followed by *L. brevis* and dominated by *L. plantarum* presented naturally in fresh shoots (Tamang and Sarkar, 1996). *Mesu* is usually prepared from June to September. It has a sour taste and strong ammonia odor. The curry called *allu-taama-bodi* (potato-*mesu*-white beans) is one of the more popular items in the *Newari* community of Nepal (Dahal et al., 2005). A very common pickle by mixing *mesu* with salt and green chilies is also prepared. It is also used in the preparation of meat curry after frying (Tamang and Sarkar, 1996).

2.12 Nutritive value of vegetable-based fermented product

The nutritive value of *gundruk*, *sinki*, *khalpi*, and *mesu* is presented in Table 2.4. *Gundruk* is a good source of B-vitamins and minerals along with essential amino acids (Karki, 1986; Karki et al., 2016). The level of palmitic acid, oleic acid, and linoleic

Table 2.4 Vegetable-based fermented product and their nutritional composition (per 100 g dry basis).

Product	Substrate	Microflora	pH	Acidity[a]	References
Gundruk	Leafy vegetables	*Lactobacillus plantarum* *Pediococcus pentosaceous*, *Lactobacillus cellubiosus*	4.40	0.8–0.9	Karki (1986), Karki et al. (2016)

Protein (%)	Fat (%)	CHO (%)	Energy (kcal)	Ca (mg)	Na (mg)	K (mg)
35.9	2.1	48.9	321	92.2	6.7	678

Product	Substrate	Microflora	pH	Acidity[a]	References
Sinki fresh	Radish tap root	*Lactobacillus plantarum*, *Lactobacillus brevis*, *Lactobacillus fermentum*	3.30	1.2	Tamang and Sarkar (1993)

Moisture (%)	Protein (%)	Fat (%)	Ash (%)	–	–
93.5	14.6	2.5	11.3	–	–

Product	Substrate	Microflora	pH	Acidity[a]	References
Sinki dried	Radish trap root	*Lactobacillus fermentum*, *Lactobacillus plantarum*, *Lactobacillus brevis*	4.40	0.72	Tamang and Sarkar (1993)

Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Ca (mg)	K (mg)	Fe (mg)
21.3	14.6	2.5	11.5	121	443	18.0

Product	Substrate	Microflora	pH	Acidity[a]	References
Khalpi	Cucumber	*Lactobacillus plantarum*, *Lactobacillus brevis*, *Leuconostoc fallax*	3.9	0.95	Tamang and Tamang (2010), Tamang (2010)

Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Energy (kcal)	Ash (%)	Ca (mg)	Na (mg)	K (mg)
91.4	12.3	2.6	70.9	356	14.2	6.4	2.3	125

Product	Substrate	Microflora	References
Mesu	Tender and young bamboo shoots	*Lactobacillus plantarum*, *Lactobacillus brevis*, *Lactobacillus curvatus*, *Leuconostoc citreum*, *Pediococcus pentosaceus*	Tamang and Sarkar (1996), Tamang et al. (2012)

Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Energy (kcal)	Ca (mg)	Na (mg)	K (mg)
89.0	27.0	2.6	55.6	352.4	7.9	2.8	282

[a]As % lactic acid.

acid is much higher in mustard leaf *gundruk* as compared with the unfermented vegetables (Karki et al., 1983b; Karki et al., 2016). In mustard leaf *gundruk*, free amino acids such as glutamic acid, alanine, lysine, and threonine increased with a decrease in asparagine, glutamine, histidine, and arginine (Karki et al., 1983a; Karki et al., 2016). The level of iron and calcium is high, but carotenoids are reduced (>90%) probably due to sun drying (Dietz, 1984). *Gundruk* contains cyanate and isothiocyanate as the main flavor compounds followed by alcohols, esters, and phenylacetaldehyde (Karki et al., 1983c). *Gundruk* is considered as a good appetizer (Tamang and Tamang, 2010).

The *sinki* collected from different regions has been reported to vary in its proximate composition (Tamang and Tamang, 2010). The protein, fat, carbohydrate, and the calorific value of *sinki* are almost the same as its substrate (radish). Dried *sinki* is a rich source of organic acid, and minerals such as calcium, iron, and potassium (Table 2.4). The mean protein, fat, and ash content of dried *sinki* has been reported to be 14.6%, 2.5%, and 11.5%, respectively (Tamang and Tamang, 2010).

2.13 Milk-based fermented food products

Milk is a highly nutritious and versatile food for infants to old age people. Nepalese people enjoy drinking milk in its natural form or use it to make a wide range of fermented and nonfermented products (Kharel et al., 2007). The major fermented milk products, such as *dahi*, *mohi*, *gheu*, and *chhurpi*, are famous in all regions of Nepal.

2.13.1 Dahi

Dahi is the main naturally fermented traditional milk product of Nepal, Darjeeling hills, and *Sikkim*. It is also used for the preparation of several other milk products such as *mohi* (butter milk), *nauni ghee* (butter like), *gheu* (ghee), soft *churpi*, and hard *chhurpi* (Rai et al., 2016). Different types of *dahi* are prepared in Nepal. A special *dahi* mainly prepared in the Bhaktapur and Kathmandu valley called as *juju-dhau* is very famous because of its texture, taste, and flavor (Dahal et al., 2005).

Traditionally, *dahi* is prepared from cow or buffalo milk by adding starter culture from previously made *dahi* locally known as *jordan* for fermentation. Milk is boiled and cooled to room temperature. *Jordan* is added and fermented in specially designed cylindrical wooden vessels (locally known as *Theki*) or in earthen pots (mainly in local shops) for 1−2 days (Kharel et al., 2007). *Dahi* is consumed directly as a beverage in Nepal, Darjeeling and Sikkim, and Bhutan. It is also consumed by mixing with *chiura* (beaten rice) or rice (Rai et al., 2016).

2.13.2 Mohi, Nauni-gheu, and Gheu

Nauni-gheu is a butter-like product achieved by traditional, manual churning of the *Dahi*. It contains 77%–78% fat, which is slightly less than butter (80%–82%). In the villages, it is customary to consume *nauni-gheu* with rice, which is considered as the staple food of most Nepalese. Churning is carried out in *Theki* manually with the help of a wooden churner locally known as *Madani*. The separated *nauni-gheu* is melted and boiled in an open pan until water evaporates. When it is cooled, a clear upper layer (known as *gheu*) separates from *bilauni* (precipitated material collected at the bottom of the pan). *Gheu* is filtered and stored for future use (Kharel et al., 2007). The liquid portion called *mohi* (resembles buttermilk) contains almost all proteins, lactose, and vitamins found in milk and appreciable amounts of fat (residual) and hence is widely consumed as a nutritious beverage.

If *mohi* is too sour, it is commonly used to prepare a spicy soup called *sollar*. *Sollar* is prepared by adding sour *mohi* to already fried spices (fenugreek, chopped onion, cumin seed, and turmeric powder) having a golden brown color. *Solar* is consumed by all, although it is believed to be more beneficial for people suffering from cold, fever, and sore throat (Kharel et al., 2007). *Gheu* is consumed with rice, mixed with *daal* (lentil soup) and used in traditional sweets or as frying medium in the preparation of a number of cereal snacks and in cooking. *Mohi* is often consumed as a cool beverage during summer or to overcome tiredness (Rai et al., 2016).

2.13.3 Chhurpi and Somar

Chhurpi is a *chhana* (curd)-based milk product indigenous to Nepal, Sikkim, and Bhutan (Rai et al., 2016). Traditionally, soft *chhurpi* is obtained when *mohi* (butter milk) is boiled for about 15 min and curd is collected by separation using a muslin cloth, which is hung tightly by a string to drain out remaining whey. If it is kept in a tight container for 10–15 days, the product is known as *somar* (Rai et al., 2016). If soft *chhurpi* is overpressed by stone for 2 days and sun-dried, it can be converted into hard *chhurpi* (Rai et al., 2016). This hard variety of *chhurpi* prepared from yak milk is also known as *dudh Chhurpi*.

However, the *chhurpi* making process varies from region to region. *Chhurpi* is also prepared from cream-separated skim milk. The milk either raw or boiled is kept on a wooden vat at room temperature for 1 day, and the cream is separated. The cream-separated milk (skim milk) is then boiled for 30 min to make the curd. Curdling of skim milk by using alum or citrus fruit juices (citric acid) is also widely practiced in Nepal (Kharel et al., 2007). The remaining process is similar to the traditional method of making soft and hard *chhurpi* (Kharel et al., 2007; Rai et al., 2016).

2.14 Nutritive value of milk-based fermented food

The nutritional composition of *dahi*, *mohi*, *gheu*, and soft and hard *chhurpi* is presented in Table 2.5. Milk-based fermented food products have the high calorie content. They are good sources of milk proteins except for *Gheu*. *Gheu* has the highest calorie content because of very high fat content. Among minerals, calcium is present in higher concentrations. The nutritive value of products solely depends on the type of milk used for preparation. The protein and fat content in *chhurpi* made from yak milk has been reported to be higher than those made from cow's milk (Dewan, 2002; Tamang, 2010).

2.15 Fermented fish products

People from Nepal prepare and consume different types of traditionally prepared smoked dried fermented salted fish products. Dried (*sidra*), dried salted (*sukuti*), dried smoked (*sukako maachha*), and *masular* (sun-dried mix of *sidra* and bottle guard leaf) are widely prepared and consumed in Nepal and some parts of Northeast India (Gartaula et al., 2014; Thapa, 2016). The microorganism reported in *sidra*, *sukako maccha*, and *sukuti* are almost the same and are mainly lactic acid bacteria (*Lactococcus lactis* subsp. *cremoris*, *L. Lactis* subspp. *lactis*, *L. plantarum*, *Leuconostoc mesenteroides*, *Enterococcus faeciem*, *Enterococcus faecalis*, *P. pentosaceous*, and *Weissella confusa*) and yeast (*Candida chiropetrorum*, *Candida bombicola*, and *Saccharomycopsis* spp.) (Thapa, 2016).

2.15.1 Sidra

Sidra is an ethnic sun-dried product commonly consumed in Nepal, Northeast India, and Bhutan. Small types of fish (*Puntis sarana Hamilton*) are generally used in *sidra* making. Collected fish are washed, dried in sun for 4–7 days, and stored at room temperature for 3–4 months. It is generally consumed by making chutney or pickling.

2.15.2 Sukako Maachha

Sukako Maachha is a dried, salted, and smoked fish product. Hill river fish such as *dothay asala* (*Schizothorax richardsoni Gray*) and *chuchay asala* (*Schizothorax progastus McClelland*) are generally collected in bamboo baskets from rivers or streams, washed and mixed with salt and turmeric powder, hooked in a bamboo-made string, and hung over an earthen oven in the kitchen. It can be kept for 4–6 months and usually eaten as a curry with or without soup (Thapa, 2016).

2.15.3 Sukuti

Sukuti is another popular traditional fermented fish cuisine of Nepal, Bhutan, Darjeeling hills, and Sikkim. Fish (*Harpodon* nehereus *Hamilton*) are collected, washed,

Table 2.5 Milk-based fermented product, and their nutritional composition (per 100 g dry basis).

Product	Substrate	Microflora	pH	Acidity[a]	References
Dahi	Cow's milk, Buffalo milk, Yak milk	LAB: *L. bifermentans*, *L. alimentarius*, *L. paracasei* subspp. *pseudoplantarum*, *Lactococcus lactis* subspp. *Lactis*, *Lactococcus lactis* subspp *cremoris* Yeast: *Saccharomycopsis* and *Candida*	4.2	0.73	Dewan and Tamang (2007), Tamang (2010)

Product	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	CHO (%)	Energy (kcal)	–
Dahi	84.8	22.5	24.5	4.7	48.2	503	–

Product	Substrate	Microflora	pH	Acidity[a]	References
Mohi	Cow's milk or yak milk	*LAB: L. alimentarius*, *Lactococcus lactis* subspp. *lactis*, and *Lactococcus lactis* subspp. *cremoris* Yeast: *Saccharomycopsis* and *Candida*	3.9	0.73	Dewan (2002), Dewan and Tamang (2007), Tamang (2010)

Product	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	CHO (%)	Energy (kcal)	–
Mohi	92.6	44.7	12.4	2.7	40.2	451	–

Product	Substrate	Microflora	pH	Acidity[a]	References
Gheu	Cow or yak milk	Lactic acid bacteria (LAB): *Lactococcus lactis* subsp. *lactis*, *Lactococcus lactis* subsp. *cremoris*	5.9	0.28	Dewan (2002), Tamang (2010)

Product	Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Energy (kcal)	Ca (mg)	Fe (mg)	Mg (mg)	Mn (mg)	Zn (mg)
Gheu	12.6	1.6	96.1	1.2	876	81.2	1.0	32.4	1.8	43.9

Product	Substrate	Microflora	pH	Acidity[a]	References
Somar	Cow or yak milk	Lactic acid bacteria (LAB): *L. paracasei* subsp. *Pseudoplantarum*, *Lactococcus lactis* subspp. *cremoris*	6.0	0.04	Dewan (2002), Tamang (2010)

Product	Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Energy (kcal)	Ca (mg)	Fe (mg)	Mg (mg)	Mn (mg)	Zn (mg)
Somar	36.5	35	15.4	46.9	466	31.2	0.4	13.7	0.5	5.2

Product	Substrate	Microflora	pH	Acidity[a]	References
Chhurpi hard/ Dudh chhurpi	Yak milk or cow's milk	Lactic acid bacteria (LAB): *L. farciminis*, *L. paracasei*, *Weissella confusa*, and *L. bifermentans*	6.0	0.29	Dewan (2002), Tamang (2010)

Product	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	CHO (%)	Energy (kcal)	Ca (mg)	Fe (mg)	Mg (mg)	Mn (mg)	Zn (mg)
Chhurpi hard/ Dudh chhurpi	16.8	57.2	6.1	5.2	31.6	409	19.8	0.5	6.3	0.4	10.0

Product	Substrate	Microflora	pH	Acidity[a]	References
Chhurpi soft	Cow's milk or yak milk	Lactic acid bacteria (LAB): *L. plantarum*, *L. curvatus*, *L. paracasei* subsp. *Pseudoplantarum*, *L. kefir*, *L. fermentum*, *L. alimentarius*, *L. hilgardii*, *Enterococcus faecium*, and *Leuconostoc mesenteroides*	4.3	0.61	Dewan (2002), Tamang (2010)

Product	Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Ash (%)	Ca (mg)	Fe (mg)	Mg (mg)	Mn (mg)	Zn (mg)
Chhurpi soft	73.8	65.3	11.8	16.3	6.6	44.1	1.2	16.7	0.6	25.1

[a]As percent lactic acid.

rubbed with salt, and sun-dried for 7–8 days and stored for 3–4 months. It is commonly consumed as pickle, curry, and soup, and is commonly sold in the marketplaces (Thapa, 2016).

2.15.4 Masular

Masular (*Masu* means fish and *Lar* means syrup or soup in *Tharu* language) is a dried food prepared from *sidra* and young tender bottle-gourd leaves (*Lagenaria siceraria Standl.*), mashing them together in *okhalli/dhikki* and finally providing the shape similar to pancake followed by sun drying. It is the traditional food of the *Tharu* communities of the *Terai* regions of Nepal. The preparation is limited to the household level; the final product has characteristics of dry fish. It is mainly prepared and consumed in the *Deepawali* festival by *Tharus* living in *Terai* areas, but can also be prepared in any season over the years. It is mainly consumed by making paste or syrup after cooking with tomatoes and other spices and salt (Gartaula et al., 2014).

2.16 Nutritive value of fermented fish products

All the fish products are sun-dried and hence have a low moisture content. They are slightly acidic as pH ranges from 6.4 to 6.5. Fermented fish products *sidra*, *sukako machha*, and *masular* are fair sources of calories and good sources of proteins (Thapa and Pal, 2007). Because of low moisture content and acidic nature, they can be stored for a longer time and are important for protein supplementation of local diets during off-seasons. They are also good sources of calcium and phosphorous (Tamang, 2010). The fermented fish products and their nutritive values are presented in Table 2.6.

2.17 Nutraceutical potential and health benefit of traditional fermented food

Fermented foods are transformed food products produced by the action of microbial growth and enzymatic conversions of major and minor food components. Traditional fermented foods contain both functional and nonfunctional microorganisms (Tamang et al., 2016c). The functional microorganisms that are present in traditionally fermented foods are responsible for the enrichment of nutraceutical values and health beneficial functional properties and reduction of antinutritional factors and allergens (Marco et al., 2017; Pervez et al., 2006). A summary of possible nutraceuticals and the health benefits of traditionally fermented food is compiled in Table 2.7, and a brief discussion follows.

2.17.1 Probiotics properties

Lactobacillus strains belong to the *L. acidophilus* group. *L. paracasei*, *L. plantarum*, *L. reuteri*, and *L. salivarius*, which represent the respective phylogenetic group, are known to

Table 2.6 Fermented fish products and their nutritional composition (per 100 g dry basis).

Product	Substrate	Microflora	pH	References
Sukako Machha	Dothay Asala Chuchay Asala (hill river fish)	Lactic acid bacteria (LAB): *Lactococcus lactics* subspp. *cremoris*, *Lactococcus lactis* subspp. *lactis*, *Lactococcus plantarum*, *Leuconostoc mesenteroides*, *Enterococcus faecium*, *Enterococcus faecalis*, *Pediococcus pentosaceus* Yeast: *Candida chiropetrorum*, *Candida bombicola*, *Saccharomyces* spp.	6.4	Thapa (2016), Thapa and Pal (2007)

Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Ash (%)	Energy (kcal)	Ca (mg)	Fe (mg)	Mg (mg)	Mn (mg)	Zn (mg)
10.4	35.0	12.0	36.8	16.2	395.2	38.7	0.8	5.0	1.0	5.2

Product	Substrate	Microflora	pH	References
Sidra	*Puntius sarana* (small fishes of freshwater and lake)	Lactic acid bacteria (LAB): *Lactococcus lactics* subspp. *cremoris*, *Lactococcus lactis* subspp. *lactis*, *Lactococcus plantarum*, *Leuconostoc mesenteroides*, *Enterococcus faecium*, *Enterococcus faecalis*, *Pediococcus pentosaceus* Yeast: *Candida chiropetrorum*, *Candida bombicola*, *Saccaharomyces* spp.	6.5	Thapa (2016), Thapa and Pal (2007)

Moisture (%)	Protein (%)	Fat (%)	CHO (%)	Ash (%)	Energy (kcal)	Ca (mg)	Fe (mg)	Mg (mg)	Mn (mg)	Zn (mg)
15.3	25.5	12.5	36.8	16.6	395	25.8	0.9	1.6	0.8	2.4

Product	Substrate	Microflora	pH	References
Masular	*Puntius sarana* (*Sidra*) + Bottle gourd leaves	Not available	–	Gartaula et al. (2014)

Moisture (%)	Protein (%)	Fat (%)	Crude fiber (%)	Ash (%)	
10.1	41.5	13.97	4.77	20.11	–

Table 2.7 Nutraceutical potential and health benefits of fermented food products.

Food	Nutraceuticals and functional components	Possible health benefits	References
Selroti	Bacteriocins, soluble nitrogen, and trichloroacetic acid (TCA) soluble nitrogen	Antimicrobial activity, enhancement in protein digestibility.	Anal (2019), Yonzon and Tamang (2010)
Kinema	Polyphenolic compounds, Isoflavon Glycon, Group B Saponin and derivatives	Antioxidant, estrogenic, antiosteoporotic, and anticarcinogenic activity	Moktan et al. (2008), Omizu et al. (2011), Samruan et al. (2012), Tamang et al. (2016b)
Masyaura	Omega fatty acids, soluble nitrogen (bioactive peptides)	Antioxidant activity	Dahal et al. (2005)
Kooddoko Jand	Soluble protein, protein hydrolyzed, fiber	Helps in digestion and absorption, consumed to regain strength by an ailing person and pregnant women, antioxidant activity	Karki (2013), Thapa and Tamang (2004)
Bhaate Jand	Maltooligosaccharides, pyranose derivatives, polyphenolics	Inhibits the intestinal pathogens antioxidants, antimutagenics, free radical scavenging and immune-stimulatory activities consumed to regain strength by an ailing person and pregnant women	Das and Deka (2012), Ghosh et al. (2015), Phutthaphadoong et al. (2010), Ray et al. (2016)
Gundruk	Organic acids, probiotics, fiber, bacteriocins	Increases digestion and absorption good appetizer, antimicrobial, beneficial in diarrhea and constipation	Gautam and Sharma (2015), Karki (1986), Karki et al. (1983a,b), Tamang et al. (2009)
Khalpi *Mesu* *Sinki*	Organic acids, probiotics, fiber, bacteriocins	Increases digestion and absorption good appetizer, antimicrobial, beneficial in diarrhea and constipation	Tamang et al. (2009)
Dahi	Probiotics, antimicrobials, functional enzymes, bioactive peptides	Effective against infectious diseases including viral, bacterial, or antibiotic-associated diarrhea, relief of chronic bowel inflammatory diseases, immunomodulation, lowering of serum cholesterol, decreased the risk of colon cancer, improves lactose digestion, reduces allergies, and has an effect on intestinal microbiota	Saad et al. (2013) Balamurugan et al. (2014), Khatri and Khadka (2018)
Gheu	Conjugated linolenic acid (CLA), phospholipids, Shingolipid	Antioxidant, anticarcinogenic, antidiabetic, antiobesity, antiatherogenic, osteosynthetic, and immunomodulatory effects	Kwak et al. (2013)

contain probiotic strains. Probiotics are the live organisms having the ability to resist gastric pH and exposure to bile and are able to grow and colonize in the gastric tract, conferring a health benefit to host (Hill et al., 2014; Saad et al., 2013). These probiotic organisms have wide applications in the treatment of infectious diseases including viral, bacterial, or antibiotic-associated diarrhea, relief of chronic bowel inflammatory diseases, immunomodulation, lowering of serum cholesterol, decreased risk of colon cancer, improved lactose digestion, and reduced allergies and adverse effect on intestinal microbiota (Saad et al., 2013). Some strains (out of 94 strain isolated) of lactic acid bacteria from fermented vegetables of Himalayan regions have shown to have the adhesion potential in gut epithelial cells indicating chances of being probiotic in nature (Tamang et al., 2009). *Lactobacillus sphicheri* G_2, a *gundruk* isolated strain has shown to have probiotic properties (Gautam and Sharma, 2015). Similarly, some strains of lactic acid bacteria (*Lactobacillus*, *Lactococcus*, and *Leuconostoc*) from homemade milk curd (Balamurugan et al., 2014) and some strains of *Lactobacillus* from traditionally prepared *dahi* have been reported to possess probiotic potential (Khatri and Khadka, 2018).

2.17.2 Antimicrobial properties

Many lactic acid bacteria present in fermented milk and vegetable products can produce antimicrobial components such as bacteriocin and nisin. Several strains of lactic acid bacteria isolated from fermented vegetables (*gundruck*, *khalpi*, *mesu*) have shown the ability to have antimicrobial properties (Tamang et al., 2009). *L. lactis* isolated from *dahi* has shown to produce nisin Z that inhibits *Listeria monocytogenes*, *Escherichia coli*, *Salmonella*, and *Bacillus* (Mitra et al., 2010). Isolated lactic acid bacteria from *Selroti* are reported to possess antimicrobial activity (Yonzon and Tamang, 2010). The antimicrobial properties and their compounds can have important applications for biopreservation and maintaining food safety (Gaggia et al., 2011). They can also be important for maintaining gut health and acute diarrhea (Balamurugan et al., 2014) and for immunomodulatory effects (Granier et al., 2013). Lactic acid fermented vegetables such as *gundruk* and *sinki* are believed to be consumed by local people as remedies against diarrhea and stomach disorder (Tamang and Tamang, 2010).

2.17.3 Antioxidant properties

The antioxidant activity of *Bacillus* fermented soybean-based Asian foods, for example, Japanese *natto* (Ping and Shih, 2012), Korean *chunkokjang* and *doenjang* (Shin and Jeong, 2015), Chinese *douchi* (Shon et al., 2011), and Thai *Thuanao* (Samruan et al., 2012), are well documented. Nepalese *kinema* largely resembles these food products. Extracts of *kinema* have a higher antioxidant activity than soybean extracts (Moktan et al., 2008). In soybean fermentation, an increase in polyphenolic compounds with increased antioxidant properties has been reported (Hong et al., 2012). Glycosidic isoflavones are hydrolyzed in soya bean fermentation to aglycon and isoflavin that increases antioxidant activity along with estrogenic, antiosteoporotic, and anticarcinogenic activity (Samruan et al., 2012; Tamang et al., 2016b). In soybean fermented products such as *kinema*, Group B saponin (DDMP-2,3-dihydro-2,5-dihydroxy-6-metyl-4*H*-pyran-4-one) and its derivatives that have a preventive role against hypercholesterolemia, colon cancer, and lipid peroxidation were reported to be increased (Omizu et al., 2011; Tamang et al., 2016a). An increase in antioxidant activity along with soluble protein and volatile acid has also been reported in finger millet fermented *jand* (Karki, 2013). *Koodoko jand* are rich in crude fiber (Thapa and Tamang, 2004) and soluble proteins (Karki, 2013) that are beneficial for food digestion and absorption. Fermented rice bran has been reported to have anticancer properties against various types of cancers including colon, stomach, and bladder cancer (Phutthaphadoong et al., 2010). The fermented rice beer contains maltooligosaccharides (maltotetrose, maltotriose, and maltose), which inhibits the intestinal pathogens and is very nutritious for infants and the elderly. Beside these, it also contains a number of pyranose derivatives (1,2,3,4-tetra-*O*-acetyl-4-*O*-formyl-D-glucopyranose, B-D-galactopyranose pentacetate) and polyphenolics and flavanol compounds that provide elevated antioxidants, antimutagenics, free radical scavenging activities, and immune-stimulatory activities (Das and Deka, 2012; Ghosh et al., 2015; Ray et al., 2016).

2.17.4 Bioactive peptides

Bioactive peptides produced in fermented products have been reported to have various health effects such as antioxidants, antihypertensive, ACE inhibition activity, immunomodulatory effect, and antimutagenic and anticarcinogenic (Martinenz-Villaluenga et al., 2017; Qian et al., 2011). Bioactive peptides are formed by proteolysis organisms by acting on the substrate proteins (Tamang et al., 2016b). *Dahi* has been reported to contain bioactive peptides and shown to have antihypertensive properties (Ashar and Chand, 2004). Studies on bioactive peptides in other Nepalese fermented foods are rarely available. However, the increase in soluble nitrogen level in *selroti* (Anal, 2019; Yonzon and Tamang, 2010), *kinema* (Sarkar et al., 1997), *masyaura* (Dahal et al., 2003), and *jand* (Karki, 2013) may reflect sign of profound proteolysis, indicating some possibilities of bioactive peptides formation in those food during fermentation and further storage.

2.17.5 Conjugated linoleic acid

Fermentation can change free fatty acids into conjugated linoleic acid (CLA) that has a number of health benefits (Paszczyk et al., 2016). *Ghee* or *Gheu* is a concentrated source of fat and is a good source of CLA, phospholipids, and sphingolipids. These components have been reported to have various health benefits including antioxidant, anticarcinogenic, antidiabetic, antiobesity, antiatherogenic, osteosynthetic, and immunomodulatory effects (Kwak et al., 2013).

2.18 Conclusion

Traditionally fermented food has been consumed since historical times, and they are physically, socially, and culturally accepted food in most of the communities in Nepal. Fermentation alone or in combination with other methods such as drying and frying are basic methods of food preservation in many households or communities, as well as sources of income generation and livelihood of people. Fermentation also brings a reduction in antinutrient factors; improves utilization of the nutrients, and can be a vital supplement of diverse nutrients that would not be present otherwise in the natural substrate. Traditionally, fermented foods can be a nutritionally important part of a regular diet and fulfill the non-seasonal food shortages. Similarly, fermentation also enhances the nutraceutical and health beneficial properties. Fermented foods possess a number of beneficial compounds depending upon the functional organisms and possible transformation of substrate components to health-related nutraceuticals, ranging from good appetizers to antioxidants, antiatherogenic, antiinflammatory, cholesterol-lowering to anticarcinogenicity. Hence, traditional fermented foods are not only nutritionally important but also have exploitation potential for health benefits. However, future studies with clinical trials and animal models are required to substantiate the claims of functional foods and the functionality of fermentative organisms to safeguard their holistic use and applications.

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