EFFECT OF SALT, DRYING TEMPERATURE AND PACKAGING MATERIALS ON THE QUALITY OF FERMENTED AND DEHYDRATED BAMBOO SHOOTS *(Dendrocalamus hamiltonii)*

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Approval Letter

This ***dissertation*** entitled ***Effect of Salt, Drying Temperature and Packaging Materials on the Quality of Fermented and Dehydrated Bamboo Shoots (Dendrocalamus hamiltonii)*** by **Sangita Rijal** has been accepted as the partial fulfillment of the requirement for the **B.Tech degree in Food Technology**.

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(Sangita Rijal)

Abstract

The present study focused on the effect of salt concentration (0%, 1.5%, 3%, 4.5% and 6%), drying temperature (50°C, 60°C,70°C), and packaging materials (high density polypropylene, low density polypropylene) on the sensory (color, smell, taste, texture and overall acceptability), chemical (moisture, acidity) and microbial quality (total plate count) of fermented and dehydrated bamboo shoots. The young and tender bamboo shoots (*Dendrocalamus hamiltonii)* were fermented for 18 days when the acidity development remained constant (0.72 g/100ml of lactic acid). The optimum 3% salt concentration was selected by sensory analysis. The selected bamboo shoots were dried at different temperature up to the moisture content (below 10%) and the effect of temperature on the sensory qualities was assessed. The final product was packed in high density polypropylene and low-density polypropylene in a range of 100gm and stored at room temperature (27°C-29°C). The changes in acidity, moisture and total plate count were studied in interval of 15 days for 90 days of storage period and the data were analyzed by one-way ANOVA using Genstat release 12.1(2013) and the means were compared using LSD at 5% level of significance.

After the completion of experiment, 3% salt concentration, 70^{O}C drying temperature and HDPE packaging material was found to be preferred by the panelist. On further analysis of packaged product inside HDPE and LDPE, changes in acidity was seen from 1.1 to 1.6 and 1.8 g/100ml as lactic acid, moisture increased from 8.1% to 14.2 % and 16.05% and total plate count rose to 21 cfu/g and 31 cfu/g from 1 cfu/g respectively.

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List of Abbreviation

Abbreviation	Full form
DOE	Design of experiment
HDPE	High density polyethylene
LAB	Lactic acid bacteria
LDPE	Low density polyethylene

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Part I

Introduction

1.1 General introduction

Bamboo (Choya Bans) is a group of perennial evergreen in the order of poales, true grass family Poaceae, subfamily Bambusoideae, tribe Bambuseae, genus dendrocalamus, species hamiltonii (Cusack, 1999). It is a multipurpose plant which can be substituted for timber in many respects due to its lignified culms, and because of its fast growth, intricate rhizome system, and sustainability, it has become a plant with conservation value. Bamboo plants have some useful properties and having lot of beneficiary uses; as pillar, fencing, housing, household products etc. (Santosh *et al.*, 2010).

Bamboo shoots are the young and tender culms of bamboo that are consumed as various food items after harvesting in fresh or processed forms. The freshly harvested bamboo shoots are cream yellow in color, strong smell and sweet in taste. Bamboo shoots are very seasonal, short-lived and perishable in nature. All the species of bamboo shoots are not edible in nature. In most of the countries people consumed bamboo shoots in forms of raw, dried, canned, boiled, fermented or medicinal (Pokharel, 2012).

Bamboo shoot is an ideal vegetable being low in fat, high in protein, edible fiber, minerals elements and free of toxicants. Bamboo shoots have almost every vitamin mainly including calcium, sodium, potassium. The fact that it has zero amount of cholesterol and are also low in calorie added its importance in healthy food (Pokharel, 2012). In Nepal, Bamboo shoots is used for the preparation of different indigenous food (Das, 1998).

Bamboo shoots are generally 20-30 cm long, taper to one end, grow extraordinarily, at about 121 cm a day and weight almost to pound depending upon the location, depth and nutrient of the soil, pH, water and drainage condition, temperature, rainfall and fertility of soil. The edible bamboo shoots are harvested just at a point of attachment of rhizome upon the indication of tips budding from the rhizome. If they are allowed to grow for longer period of time they become tough, woody and lose their delicate taste and aroma (Farrely, 1984).

The harvesting of young and tender bamboo shoots should be done during the growing season. When young shots attain suitable height and development it should be harvested properly. After harvesting, it can be used in different forms mostly fresh or fermented. Mostly traditional method of fermentation is followed by different ethnic communities. Some of the local names of fermented bamboo shoots in different community are soibum, soidon, soijim, mesu, eup and so forth (Phithakpol *et al.*, 1995).

People usually chopped bamboo shoots (1-2cm) and transferred it to a vessel, tightly packed to provide air tight condition. The material is allowed to ferment at ambient temperature (20-25°C) for 7-8 days. The completion of fermentation is indicated by the typical fermented flavors or taste (Tamang and Sarkar, 1996). Lactic acid bacteria (LAB) can also produce various aromatic component, bacteriocins and expolysaccharides which contribute to the development of flavor, taste, aroma, smell, texture, shelf life and safety. LAB that are important for the fermentation of bamboo shoots are *Lactobacillus plantarum, L. brevis, L. pentosaceus L. brevis, L. planetarium* (Tamang and Sarkar, 1996).

1.2 Statement of the problem

Nepal is an agricultural country along with diversity in its culture, land, lifestyle, religion and many others. People generally depends on farming for survival. The growth of bamboo is very old in context of Nepal. In every household people consume it as a curry as well as by making pickle. One of the products prepared in Nepalese community is voyen which is a sliced bamboo shoot prepared by *Dendrocalamus hamiltonii*, has a shelf life of 2-3 days (Kithan *et al.*, 2015). Although, it has many benefits but its marketing system in rural areas is inefficient that results in high market price. Many people are still unaware of modern tools and technology and poor market condition. Bamboo shoots can be consumed by consumers and provided to the consumers in a variety of ways, including; raw, canned, boiled, marinated, fermented, frozen, liquid and medicinal form (Desrosier, 1987). People generally prefer fresh, tender bamboo shoots but because of inappropriate packaging and storage its quality get effected. (Bharat, 2019).

1.3 Objectives

1.3.1 General objective

The general objective of the work is to study the effect of salt concentration, drying temperature and packaging materials during the fermentation and dehydration of bamboo shoots (*Dendrocalamus hamiltonii*).

1.3.2 Specific objectives

1. To study the effect of different salt concentration (0%, 1.5%, 3%, 4.5% & 6%) during fermentation on the sensory (color, smell, taste, texture and overall acceptability) and chemical (acidity) quality of fermented bamboo shoots.

2. To study the effect of drying temperature (50^{O}C, 60^{O}C & 70^{O}C) on the sensory quality (color, smell, taste, texture and overall acceptability) of fermented and dehydrated bamboo shoots.

3. To study the chemical changes (moisture, acidity) and microbial quality (total plate count) of fermented and dehydrated bamboo shoots on different packaging material (Low density polypropylene, High density polypropylene).

1.4 Significance of the work

Bamboo shoots are seasonal. Seasonal type of foods is very important if they are preserved properly. Fermentation and drying are those technique that can be followed by people as it will be beneficial in offseason. Fermentation of shoots is done since many years in Nepalese society as it is a traditional method whereas drying is one of the modern techniques. People are still lacking proper method of fermentation and drying so this study helps in providing proper knowledge for production of bamboo shoots for all seasons using both methods.

In, the current context of the world people is being more focused on their diet and health so the production of bamboo shoots at commercial level may result a great advantage on the economy of nation. In order to get rid of such problems, different provisions should be made by NGOs, local bodies and INGOs to improve economic potential and marketing trend of bamboo study area. As, the young clumps are less consumed in comparison to middle aged and matured ones there is a need of treatment like drying for its sustained production. Since, it is perishable in nature there is a need of proper processing for its long-term storage including fermentation and drying. Trainings on the new improved method of bamboo plantation and management of bamboo clumps should be provided to the bamboo producers. Nowadays, people generally focus on their health, so consumption of bamboo shoots will be very beneficial as it is a source of protein, carbohydrate, fiber and minerals. The presence of fiber in large quantities helps in dealing gut issues. Bamboo shoots contains reasonable number of proteins, carbohydrate, fiber, and minerals. These shoots are cardiac patient friendly as they contain unsaturated fat that help in fighting against bad cholesterol (Hussain *et al.*, 2016). After the completion this study will be more beneficial in production of bamboo shoots which encourage more farmers for the cultivation of bamboo. Fermented bamboo shoots are an indigenous product which is also known as *tama*. As, a result this process can also be easily followed by farmer and industrialist and can also be a great source of income for famers as well. Study on the changes on acidity, moisture of the product can be done. The best product given by optimization can be made further for the industrialization.

1.5 Limitations of the work

1. Storage stability analysis was carried out for 90 days due to time constraint.
2. Effect of temperature variation during fermentation could not be studied due to lack of available instrument.

Part II

Literature review

2.1 Bamboo

In search for the new source of food for humans and animals, many wild plants are being investigated as a food source. Bamboo is one of the foods which came across during investigation. It is one of the most diverse group of plants in the grass family, and the most primitive family. They are generally identified as a plant having woody culms and a series of complex branching including a complex and generally robust rhizome system, and infrequent flowering (Pokharel, 2012) Bamboo plants have some useful properties and having lot of beneficiary uses; as pillar, fencing, housing, household products and others (Santosh *et al.*, 2010).

2.1.1 Geographical distribution of bamboo

Bamboo is one of the fastest growing plants, with reported higher growth in tropical and subtropical climates compared to timber (Akinlabi *et al.*, 2017). In context of Asia, it is extensively cultivated and utilized throughout whereas lesser degree in South America. Bamboo grows naturally in all continents except Antarctica and Europe (Maoyi and Jianghua, 1996). The majority of species are native to Asia: however others including Africa, Australia, North America, South America and Central America all have endemic species (Crawford, 1997)

The area of bamboo resources in the world is still not properly discovered but according to Maoyi and Jianghua (1996), an excess of 14 million hectares of bamboo could be found in the tropical, subtropical and temperate zones of Asia, Africa and Latin America. The majority of commercial production of bamboo takes place in India, Japan, China, Indonesia, Thailand, Burma, Vietnam and the Philippines. Although most species of bamboo produce edible shoots, of more than 1500 species less than 100 are grown specifically for shoots. In, Asia bamboo with approximately 65 genera of which 14 are endemic to the region. The number of species is around 900 spreads over the range of 51^{o} N to 47^{o} S latitude and 140 W to 70 E longitude. Out of all 900 species about 100 species are of woody nature. Bamboo is identified as a potential species for the poverty reduction in many countries including Nepal(Anonymous, 2014).

2.1.2 Bamboo taxonomy

Bamboos are the member of the Poaceae (or Gramineae) family, which is divided into between six and ten subfamily groups. The subfamily Bambusoideae comprises both woody and herbaceous bamboos. It is divided into six tribes, one of the woody bamboos (Bambuseae) and five of herbaceous bamboos. Bambuseae can be divided into ten subtribes, 101 genera and in excess of 1500 species (Ohrnberger, 1999).The hierarchy of bamboo plant has been illustrated below (Chau *et al.*, 1997).

The hierarchy:

Kingdom:	Plantae (plants)
Phylum (Division):	Magnoliophyta (Flowering plants)
Class:	Liliopsida (Monocotyledons)
Subclass:	Commelinidae (Non-Petaloid Monocots)
Order:	Poales (Grasses and related species)
Family:	Gramineae (Poaceae) (grasses)
Subfamily:	Bambusoideae
Tribe:	Bambuseae (Woody Bamboos)
Genus:	*Dendrocalamus*
Species:	*Hamiltonii*

A formal and overall classification of the woody bamboos has not yet been properly identified as pointed out by Rao and Rao (1995). About 60-90 genera seems generally been accepted and a list of 192 species of bamboo were obtained from Asia- Pacific region, which includes both native and cultivated species. Out of the estimated species 180 species of bamboo are found in Southeast Asia, 100 species are indigenous to the region and have limited distribution. About 30 species are found during cultivation and were probably brought in from others part of Asia while other 125 species are growing wild in their natural habitat but have been brought into cultivation into others regions (Rao and Rao, 1995).

2.2 Bamboo shoots

A bamboo shoot is a young culm of certain bamboo species that is harvested at the time it appears above the soil surface (Pokharel, 2012). It contains short vertical nodes and internodes tightly clasped with overlapping sheaths that have to be removed to extract edible part (Karanja, 2017). This shoot is about 8-12 inches long and is encased in a thin, hard, protective sheath (Pokharel, 2012). The sheaths covering the bamboo shoots are black, brown, yellow or purple and in some species it is covered with tiny hairs (D. Choudhury *et al.*, 2012a).During, the growth of bamboo shoots certain critical biochemical reactions takes place which leads to the rapid growth and hardening of culms. Shoots should be harvested during fresh and tender conditions before it turn hard, woody and inedible in nature. Mostly rainy seasons are preferable for the harvesting of shoots. It is generally a young, immature, expanding culms that emerges from nodes of rhizomes of plants. During, harvesting it is cut just above the surface of soil with the help of spade (Pokharel, 2012).

Bamboo shoots are harvested when they reach a height of 30cm. They are generally crispy, soft, tender, and ivory yellow in color. When the white part is revealed, once the culm sheath is peeled off it turns yellowish when cooked (Chauhan *et al.*, 2016). When a newly harvested bamboo shoot is peeled, it gives a strong smell and bitter taste. The bitter taste in bamboo shoots is due to the presence of cyanogenic glycoside taxiphyllin, which is toxic in nature. All species of bamboo shoots available in the world are not edible (Choudhury *et al.*, 2012b). The shooting of bamboo varies from species to species, their size and weight depend upon location, depth and nutrition of the soil, temperature, pH, soil fertility and drainage conditions (Choudhury *et al.*, 2012b).

2.3 Edible bamboo shoots

There are number of bamboo species of used for edible purpose and are mainly found in Central India. *Bambusa bambos and Dendrocalamus strictus* are the commonly occurring species. There are others species like *B. nutans, B. tulda, D. giganteus* and *D. hamiltonii*. In case of Central India, people harvest bamboo shoots from nearby forest as bamboos are not commercially cultivated for its edible shoot production (Fu *et al.*, 2011). Bhalu Bans (*Dendrocalamus sikkimensis*), Mal Bans *(Bambusa nutans*) and Choya Bans (*Dendrocalamus Hamiltonii)* are the common species of bamboo which are used as a source of food in Nepal. Among these species of Bamboo, Choya Bans (Dendrocalamus *Hamiltonii*) is used for the study here (Poudyal, 2006).

This species is the native of North-eastern Himalayas. In Nepal, it is distributed from Terai to the hills. Its local name is Guliyo bans and Choya bans in Nepali. This species lies in tribe Dendrocalameae and Bambusatae and its rhizome system is Pachymorh or sympodial or clumping. It is 12–15 cm in diameter and growing up to 15–18 m in height. It is available during the month of mid- June to mid- September. It is edible and sweeter in nature as well. Their culm height is 20-25 m and color of the culm is light green. Its shooting period is 1 to 3 months (Poudyal, 2006). This species is also found in India, Bhutan, Pakistan, Nepal, Sri Lanka and including far- eastern China (Anonymous, 2021). There are two types of tama in these species i.e., *Mithi tama and Tite tama*. Out, of both types *tite tama* is used in the study here(Poudyal, 2006)..

2.4 Harvesting of Shoots

Proper harvesting practices determines to a large extent the quality of the product. While the harvesting itself cannot improve the quality of product, people should also focus on good harvesting practices which include correct time of the harvesting (Rai, 2007).

The shoots should be harvested after it gains its maturity stage i.e. the stage at which the shoots become more acceptable by the consumer. If the shoots are harvested too early then it may provide bitter taste due to the presence of high cyanogen content which is unfit for consumption. It may also provide small size shoots. If the shoots are harvested late then it becomes woody and tough in nature. Shoots should also be harvested during morning and evening to avoid greater field heat (Rai, 2007). Shoots are generally grown beneath the soil surface, finally breaking through into the light. The exposure of shoots to sunlight cause the production of chemical that are bitter in taste and hastens shoots elongation by stimulating the development of a very woody base. The bamboo shoots grow between 10 cm to 20 cm under the soil surface. A crack on the soil usually reveals the new shoot’s location. As, new shoots arise from the rhizomes which more or less radiate outwards from the clump can be harvested without much disturbance from the surrounding (Anonymous, 2004).

In the case of harvesting of shoot by digging it out, digging should be done with care so that the shoot is not bruised. Shoot should be dug when the tips are just emerging from the surface of the soil or very soon after that stage. The soil should be properly removed from the base of the emerging shoot, exposing the lower part of the rhizome neck. The last third of the shoots should be properly cut with the help of narrow axe, machete or sharpened narrow bladed spade. During the cutting, the remains necks in the soils have viable buds some of them will produce a shoot in following season (Anonymous, 2004).

In the other case, harvesting is done when the shoot tips emerge above the soil. The shoot is cut free from the soil and near the base of rhizome. Shoots are cut with sharp flat blade, wide enough for the diameter of the shoot. The soft tender texture of the shoot’s cuts easily. Care is needed to cut through the base of the shoots not the rhizome neck. After extraction of the shoots, dugout parts should be covered with soil (Pokharel, 2012).

2.4.1 Harvesting season

Bamboo shoot is to be harvested during the season of sprouting from the ground for edible purpose. Most of the species gives rise to the new shoot during or soon after the monsoon.

2.4.2 Harvesting size and time

The most recommended size for harvesting of young bamboo shoots is that it should be about 37.5 cm (15”) to 45 cm (18”) above the ground i.e., 4-9 days of the growth. The shoots will reach its harvesting size within a couple a day by breaking its soil crust. Proper checking of the shoots and its clumps should be monitored properly for their growth. The ideal time for harvesting of the shoots is late evening or early morning. During exposure to sunlight chemical reaction may occurs which causes bitter taste due to cyanogen content. The harvested shoot should be properly cared and handle so that it does not get damaged and becomes unhealthy for consumption. The outer culm sheath of the should not be tear or damaged as it helps to retain the freshness of the bamboo shoot (Anonymous, 2004).

2.5 Nutritional value of bamboo shoots

The nutrients content in bamboo shoots has been reported to be higher in the shoots than in leaves and stems, and is also found to vary between different parts of the shoots (Karanja, 2017). Bamboo shoots contain several nutritional components like protein, carbohydrates, fat, vitamins, minerals, etc. Bamboo shoot is rich in fiber and low in fat (Chongtham *et al.*, 2011).The shoots have a good profile of minerals consisting of potassium (K), calcium (Ca), manganese, zinc, chromium, copper, iron(Fe), plus low amount of phosphorous (P), and selenium (Chongtham *et al.*, 2011). Fresh shoots are a good source of thiamine, niacin, vitamin A, vitamin B_{6}, and vitamin E. They contain 17 amino acids, 8 of which are essential for the human body. They contain protein between 1.49 to 4.04 (average 2.65g) per 100g of fresh bamboo shoots. Fat contains is comparatively low (0.26 to 0.94%) and the shoots contains important fatty acids. The water content is 905 or more. The sugar content is less in compared to other vegetables. Based on nutritional analysis, it has been determined that bamboo shoots are good source of food energy and is considered as new health food.

The proximate composition and mineral content of the bamboo shoots (*Dendrocalamus hamiltonii*) is described in Table 2.1. and 2.2 respectively.

Table 2.1 Proximate composition of bamboo shoots (Dendrocalamus *hamiltonii*)

Parameters	Value (%)
Moisture	92.51±0.51
Protein	3.72±0.12
Fat	0.41±0.02
Dietary Fiber	3.90±0.03
Ash	0.86±0.12
Carbohydrate	5.50±0.08

Source: Chongtham *et al.* (2011)

Table 2.2 Mineral content of bamboo shoot *(Dendrocalamus hamiltonii)*

Minerals and vitamins	Values(mg/100g)
Potasssium	416
Calcium	3

Sodium	9.32
Magnesium	6.09
Phosphorus	28,12
Iron	2,69
Zinc	0.70
Manganese	0.16
Copper	0.29
Selenium	0.8 μg
Vitamin C	2.45
Vitamin E	0.71

Source: Chongtham *et al.* (2011)

2.6 Uses of bamboo shoots

Bamboo shoots is consumed as either fresh or processed forms. People have been using fermented bamboo shoots since centuries in Asian dishes as it provides unique flavors and crunchy texture. It is generally mixed with other ingredients like ginger, garlic, red chili, pepper, bell pepper and stir with poultry, stock. Anise and others to make soup (Pandey and Ojha, 2011). In Manipur, a state in India bamboo shoots is consumed as fresh or fermented. Fermented form is locally known as *Soibum*, which is highly prized. They are mainly used as fresh, dried, shredded, fermented, canned and pickled. It is used extensively as a pickle, snacks, papads, and other stuff to curries, bhaajis, and other preparation with rice. Bamboo shoots are generally available in three forms:

- Fresh shoots
- Fermented shoots
- Canned shoots (Rai, 2007)

2.7 Health benefits of bamboo shoots

2.7.1 Weight loss

Bamboo shoots are ideal for healthy weight loss as they are low in calories (Karanja, 2017). Dietary fibers have markedly increased volume after swelling and can cause satiety. Besides, the presence of dietary fiber affects the digestion and absorption of other food components and delays the feeling of hunger (Wang *et al.*, 2012).

2.7.2 Appetizer

The high cellulosic content of bamboo shoots stimulates appetite. Being crisp, crunchy, and tender with a sweet flavor, shoots have a unique and delicious taste that function as an appetizer (Padhan, 2015).

2.7.3 Controls cholesterol

Consumption of bamboo shoots is also helpful in decreasing LDL (low density lipoprotein) levels of cholesterol, with stable glucose levels. This is due to the fact that bamboo shoots contain negligible amounts of fat and very low calories (Padhan, 2015). Also, soluble dietary fiber is primarily responsible for decreased cholesterol absorption by several mechanisms including interference with micelle formation and influence with enzyme substrate interaction. Insoluble dietary fiber may assist in reducing cholesterol absorption by reducing transit time and total time available for absorption (Rana, 2009). Furthermore, phytosterols are ideal for dissolving harmful LDL (low density lipoprotein) cholesterol in the body (Padhan, 2015). Vitamin C also reduces the plasma cholesterol level (Chongtham *et al.*, 2011).

2.7.4 Anticancer

Dietary fiber appears to play a contributing role in reducing colon cancer risk. The beneficial involvement of dietary fiber in colon cancer prevention includes increasing faecal bulk and thereby decreasing the concentration of carcinogens, co-carcinogens and decreasing transit time to minimize exposure of intestinal cells to these compounds (Rana, 2009). Phytosterol-rich diets help in reduction of colon, breast, and prostate cancer (Nongdam and Tikendra, 2014).

2.7.5 Anti-inflammatory properties

Phenols have anti-inflammatory properties (Nongdam and Tikendra, 2014).

2.7.6 Helps in digestion

Various enzymes such as nuclease, deaminase, proteolytic enzymes, amylase, amigdalin splitting enzyme and silicon splitting enzyme are present in tender bamboo shoot. The juice of pressed bamboo shoot help in digestion of proteins (Vanitha *et al.*, 2017).

2.7.7 Other benefits

Decoctions of tender shoots is also used for cleaning wounds and maggot infected sores, ulcers etc (Rana, 2009). For women's it is helpful in stimulating the menstrual cycle and induce labour pain during the last month of the pregnancy (Vanitha *et al.*, 2017). Besides, the shoots of few bamboo species such as Bambusa bambos are used in treating thread worm, cough and diarrhea due to the presence of glucosides, betain, urease, cynogens, nuclease and cholin (Basumatary *et al.*, 2017). Germaclinium in shoots has been reported to carry anti-aging properties (D Choudhury *et al.*, 2012b).

2.8 Medicinal importance of bamboo shoots

Bamboo shoot has been in use for medicinal purpose, since time immemorial by the tribal people of various regions. Presence of different flavones, glycosides, bamboo shoots have good anti-oxidant, anti-free-radical and anti-aging agents, and can be extracted to make capsules and tablets. In the traditional system of Ayurveda, the silicious concretions found in the bamboo shoots is called banslochan and in the Indo-Persian and Tibettan system of medicine, it is called as bamboo manna and is known to be a good tonic for respiratory disorders. Bambusa arundinacea speciesis considered as the excellent source of bamboo manna. In China, bamboo shoots are used for treating infections. The juice of pressed bamboo shoots possesses protease activity that helps in digestion of protein. The boiled bamboo shoots are used as appetizers. Decoction of the shoots are used for cleaning wounds and maggot infected sores, ulcers etc. Bamboo shoots, mixed with palm-jaggery, are known to induce parturition or abortion (D Choudhury *et al.*, 2012b)

2.9 Functional components of bamboo shoots

Bamboo shoots contain a number of phenols and phytosterols. It generally has an adverse effect on human health. There is also a presence of alkanes, alkenes, aromatic compounds, primary amines and esters in shoots. (Wróblewska *et al.*, 2018)

2.10 Bamboo shoots as food

In many parts of the world, bamboo shoots form a part of the conventional cuisine and are consumed in various forms (D Choudhury *et al.*, 2012b).

2.10.1 Fresh bamboo shoot

People consume fresh bamboo shoots in various forms. Bamboo shoot can be eaten fresh after boiling. In Indonesia, bamboo shoots are eaten with thick coconut milk and spices, which are called gulei rebung; sometimes also mixed with other vegetables, called sayur lade. In Manipur, the fresh bamboo shoots are taken with dry fish. The edible bamboo species in Western Ghats of India are extensively used as snacks, fried food stuffs, and curries. Tama, a non-fermented bamboo shoot curry is very familiar among the people of Sikkim (D Choudhury *et al.*, 2012b). Steam ground pork with finely diced bamboo shoots sprinkled with soy sauce as a very popular dish in China. Vietnamese broth called sup bunmang, is a noodle soup made with chicken and fresh bamboo shoots and taken as 57 breakfast (Karanja, 2017). The bamboo shoot pieces after boiling are salted slightly for 8–10 minutes and consumed in Australia and New Zealand (Nongdam and Tikendra, 2014).

2.10.2 Fermented bamboo shoots (Mesu)

Traditionally, various fermented bamboo shoot products are consumed in the world. A traditional fermented bamboo shoot product of the eastern hills of Nepal and Bhutan is *mesu.* Use of *mesu* as a pickle and as a base in curries is a conventional dish among the Nepalese, Bhutias and the Lepchas of the Darjeeling hills and Sikkim. In Nepal, bamboo shoots are fermented with turmeric and oil, and cooked with potatoes to prepare an item called alu tama(D Choudhury *et al.*, 2012b). *Soibum*, a fermented bamboo shoot, is an exceptional delicacy of the Meities of Manipur, eaten as pickle and curry mixed with fermented fish. Similar fermented bamboo 58 shoot product called naw-mai-dong or nor-mai-dorng is consumed in Thailand. Soidon is another fermented bamboo shoot product in Manipur, prepared from the tip of matured bamboo shoots and consumed both as a curry and pickle. Soijim is another type of fermented bamboo shoot product developed by submerged fermentation in Manipur. Iromba is a fermented or boiled bamboo shoot taken with fish and other vegetables by Khasi tribes in Meghalaya. In central India, the young shoots are grated and fermented to prepare kardi oramil, a sour vegetable soup (D Choudhury *et al.*, 2012b).

2.10.3 Dried bamboo shoot

Drying is the one of the oldest and simplest food processing technology in the food industries. Vary research have been carried out on the drying technology but a little work has been reported on drying of bamboo shoot. Water content of fresh bamboo shoots is about 92.6/100 g of fresh weight compared to 4.6/100g in dried bamboo shoots. However, it has been discussed that moisture content of dried bamboo shoots decreases up to 95.1%. Quality attributes of end product using multi-stage drying technologies, such as solar-assisted heat pump drying, solar drying with thermal energy storage, microwave assisted vacuum drying, refractive drying and supper heated steam drying may be explored for drying bamboo shoots Since fresh bamboo shoots are perishable in nature, drying can be considered as an efficient method for its preservation along with the increase in their shelf life. The dried bamboo shoots can be packaged easily and can be used in different soups and vegetables (Choudhury *et al.*, 2012b).

2.11 Fermentation

2.11.1 Introduction

Fermentation is one of the oldest food preservation techniques in the world(Rhee *et al.*, 2011). Campbell-platt (1987) defined fermented foods as those foods which have been subjected to the action of micro-organisms so that the biochemical changes cause significant modification to the food. Foods subjected to the influence of lactic acid producing micro-organisms is considered as a fermented food (Sahlin, 1999). The indigenous food products such as bread, wine and cheese have been prepared and consumed for several years and is strongly linked to culture and tradition especially in rural household and village communities. It is relatively efficient, low energy preservation process which increase shelf life and decrease the need for refrigeration or other form of food preservation technique. It is therefore useful to use in those area where access to sophisticated equipment is limited (Battcock and Ali, 1998).

Fermentation of fruits and vegetables can occur spontaneously by the natural lactic bacterial surface microflora, such as *Lactobacillus spp.*, *Leuconostoc spp.*, and *Pediococcus spp.*, however the use of starter culture such as *L. plantarum*, *L. gasseri*, and *L. acidophilus* provides consistency and reliability of performance. Fermented fuits and vegetables play important role in preservation, production of wholesome nutritious foods in wide variety of flavors, aroma, and texture which enrich human diet and remove anti nutritional factors to make food safe to eat. Vegetable have low sugar content but are rich in minerals and vitamins, have neutral pH and provide natural medium for LA fermentation (Montet *et al.*, 2014). The most significant role of fermentation is it helps to make nutrients naturally present in the starting food materials, more palatable and widely available than would be possible without fermentation. The fermentation process can have direct effects on the nutritive qualities if foods. The preservation of food is generally based on reducing or eliminating microorganisms and focus on controlling their growth. To prevent or reduce microbial spoilage of food four basic principle can be applied: minimize level of microbial contamination, inhibit the growth of contaminating microflora, killing the contaminated microorganisms, remove the contaminated microorganisms. It can also be achieved by creating the environment for growth of specific microorganisms the gives desirable taste, flavor, aroma or appearance to foods (Guizani., 2010).

2.11.2 Lactic acid bacteria (LAB)

Lactic acid bacteria are the most important group of microorganisms used in the fermentation of vegetables to produce stable products. The microorganisms itself create an environment which become inhibitory or lethal to other organism, while stimulating their own growth and this selection is basis for preservation by fermentation. Lactic acid bacteria produce both antimicrobial components with relatively board inhibition spectrum as well as compound with narrow antimicrobial spectrum (bacteriocins). Fermentation will cause desirable changes on the sensory and functional properties of food that is desirable to consumer (Guizani., 2010).

Lactic acid fermentation of vegetables into pickle plays a crucial role in the food and nutritional security of the people of Asia (Steinkraus, 2002). When there is a surplus production, pickle can be consumed in the off season which are made by vegetables**.** As, vegetables has low sugar content, rich in minerals, vitamins, and neutral pH, and they are the natural medium for the lactic acid fermentation. It inhibits the growth the undesirable microorganisms and also improve sensory quality of fermented vegetables (Buckenhüskes, 1997). LA fermentation of vegetables is popular in several African, Asian, European and Latin American countries (Sethuraman *et al.*, 2010). Lacto fermentation is generally the most common type used to convert foods into their cultural variations. During this procedure, the sugars are converted into lactic acid, which in turn gives birth to different genus of lactic acid bacteria. Various proportions of these microorganisms are produced at various stage of fermentation process, supplying different taste and texture qualities. Lacto fermentation is created in an oxygen free environment that support growth of desirable bacteria and eliminates pathogenic varieties when kept at appropriate temperature designed for each particulate food and beverages (Rai, 2009).

2.11.3 Beneficial effects claimed for lactic acid bacteria

It has been acknowledge that lactic acid fermented food products have several advantages, some of the important are as follows (Upadhaya, 2002):

1. It focuses on the nutritional improvement of food.
2. Elimination of pathogens.
3. It has anticancer activity.
4. It helps in stimulation of immune system.

2.11.4 Factors affecting fermentation

The complex nature of fermentation involves several physical, chemical and microbiological factors that can influence the final product quality. The two essential factors that influence the growth of the two main LAB species during fermentation of product are salt concentration and temperature (Fleming 1991).

2.11.4.1 Temperature

The growth of heterofermentative species in bamboo shoots, such as *L. mesenteroides,* is initiated at low temperatures (~18°C), whereas the growth of the homo fermenter *L. plantarum,* is favored at higher temperatures (~32°C). As previously mentioned, these two bacteria can alter product quality (Pederson and Albury, 1969). Fermentation at higher temperatures (above 32°C) often leads to a low concentration of acetic acid and will not attain as high a total acidity level even though the pH is lower due to limited growth of heterofermentative LAB species. The off-flavor developed from fermented product is due to altered acidity profiles. Also, products fermented at higher temperatures will be more susceptible to yeast spoilage and will darken readily. However, products fermented at temperatures between 18°C to 22°C results in a quality product compared to products fermented at 26°C and above, as the heterofermentative lactic acid bacteria grow better at these lower temperatures. In general, products fermented at relatively lower fermentation temperatures has better or more consistent color, flavor and quality compared to products fermented at higher temperatures(Fleming *et al.*, 1985).

2.11.4.2 Salt concentration

The production of high-quality products is also dependent on the addition and even distribution of salt. Salt is an important addition to good product production to encourage LAB growth which outcompete spoilage and pathogenic microorganisms and helps to further govern the desired sensory qualities of the final product (Holzapfel *et al.*, 2008). Salt withdraws water and nutrients from the tissues, and the absorbed nutrients serve as substrates for the growth of lactic acid bacteria. Salt, in combination with acid produced, is responsible for restricting the growth of undesirable microorganisms and delaying the enzymatic softening of the tissues. Therefore, it is common to observe undesirable flavors and softening of tissues due to insufficient salt. The typical salt concentrations added to products for its can range between 2 to 10% (w/w) (Fu *et al.*, 2011). The concentration of salt added to product for fermentation also helps to determine the growth of LAB species. Since *L. mesenteroides* is more salt sensitive than other LAB, lower salt concentration (1–2.5%) are more advantageous for its growth, whereas higher salt concentrations (3.5% or more) favor the growth of homofermentative LAB that produce little carbon dioxide essential for flushing out entrapped air among the products (Pederson and Albury, 1969). In addition, yeast 16 growth (most commonly pink yeast) becomes more prevalent at higher salt concentrations due to the inhibition of heterofermentative bacteria, thus negatively affecting the product quality. Moreover, higher salt concentrations favor the growth of homofermentative LAB which results in higher lactic acid levels in relation to other end products such as acetic acid, carbon dioxide and alcohol. Pederson and Albury (1954) demonstrated that lower ratios of heterofermentative bacteria to homofermentative bacteria during fermentation resulted in a lower total acidity produced in the final product which contributes toward the flavor and aroma of the final product (Breidt, 2013). The unique flavors of product are often derived from the salt concentration and the ratio of organic acids after a complete and adequate fermentation process. Other factors such as adequate salt concentration and fermentation temperatures, are also important to promote the proper ratios of heterofermentative to homofermentative LAB and organic acids, which contribute to the desirable flavors, textures and qualities of obtained products.

2.12 Drying of vegetables products

Drying is the unit operation in which all the free moisture in food stuff is removed by evaporation or sublimation as an application of heat at controlled condition. This definition does not include alternate method of moisture removal like filtration, membrane separation, centrifugation, distillation etc. (Greensmith, 1998). Fruits and vegetables are important sources of essential dietary nutrients such as vitamins, minerals, and fiber. Since the moisture content of fresh fruits and vegetables is more than 80%, they are classified as perishable foods. Keeping the products fresh is difficult to maintain throughout the distribution chain. One of the methods followed for the preservation is drying. It is suitable alternative for postharvest management. Over 20% of the world perishable foods are dried to increase shelf life and promote food security. Fruits, vegetables and their products are dried to enhance storage stability, minimize packaging requirement and reduce transport weight (Sagar and Suresh, 2010). During the drying there are changes in the quality parameters of dried products (Sablani, 2006).

Dehydration is one of the most effective means to extend the shelf life of perishable foods. The main purpose of dehydration in preserving foods is to remove moisture so that the water activity of the dehydrated product is low enough (e.g., $a_w < 0.6$) to stop spoilage and the growth of pathogenic microorganisms and to reduce other deteriorative reactions. Dehydration is also used in combination with other hurdles, such as low pH and use of preservatives, to extend the shelf life of foods. Dehydration significantly reduces the costs of transportation and storage, because of the significantly reduced weight and volume of the dehydrated products and because the products do not require refrigeration. In addition, dehydration is an effective method to prepare convenient food ingredients for use in products such as dry soup mixes, frozen entrees, baby foods, and dairy products, or directly as seasoning blends (Somogyi and Luh, 1988). Dehydration, being one of the oldest methods of food preservation, represents a very important aspect of food processing (Lin *et al.*, 1998). Longer shelf life, product diversity and volume reduction are the reasons for the popularity of dried fruits and vegetables (Prakasha *et al.*, 2004). Dehydration removes water from foods to a final concentration, which assures microbial stability of the product and minimizes chemical and physical changes of the material during storage. In most 27 drying processes water is removed by convective evaporation, in which heat is supplied by hot air(Lewicki and Jakubczyk, 2004).

2.12.1 Different methods of drying

2.12.1.1 Sun drying

It is the natural method of drying, which makes use of sunlight, requires time, and efforts by man to collect and spread the product (Hall, 1970). It has little or no moisture drying which might enhance mold growth. It is the oldest method of food drying in developing countries. This technique is totally weather dependent and has a problem with contamination with dusts, soil, sand and insects. It is the most labor-intensive method of food drying. Sun drying temperature varies with the geographical regions. In tropics region, a product spread on matting in a layer not thicker than about 5 cm receives a drying temperature of about 30°C on an average (Desrosier, 1987). The time of sun drying depends upon the product characteristics and drying condition and typically range from 3 to 4 days but can be longer.(Desrosier, 1987).

2.12.1.2 Solar drying

Sun drying is not as sanitary as other methods of drying. An improved indirect solar dryer, a natural draft dryer is used recently which consists of a rectangular box dryer with two chambers for heating and drying respectively. This method uses sun's energy for drying but excludes open air sun drying. Solar drying is more effective than sun drying and has low operating cost than the other mechanical dryers. A simple principle involved in solar dryer is that, air is drawn through the dryer by natural convection. The air is heated as it passes through the collector and then partially cooled as it picks up moisture from the produce. The produce is heated both by the hot air and sun (Olivia, 2009).

2.12.1.3 Cabinet drying

Cabinet drier consist of an insulated cabinet fitted with shallow mesh or perforated trays, each of which carries a thin layer of food. Hot air is circulated through the cabinet tray. A system of duct and baffles is used to direct air, over and/ or through each tray, to promote uniform air distribution either horizontally between the trays of food materials or vertically through the trays and food. Air heaters may be direct gas burners, steam coil exchangers or 30 electrical resistance heaters. The air is blown past the heaters and thus heated air is used for dying. It is relatively cheap to build and maintain, flexible in design, and produces variable product quality due to relatively poor control. It is used singly or in groups, mainly for small- scale production (1-20 ton/day) of dried fruits and vegetables (Fellows, 2000).

2.13 Preservation of food by drying

Drying helps to remove moisture from the food so bacteria, yeast and mold cannot grow and spoil the food. It slows down the action of enzyme but does not inactivate them. As, drying removes the moisture it makes food smaller and lighter in weight. When the food is ready to use, water is added back and the food returns to its original shape. Foods can be dried in the sun, in oven or in a food dehydrator by using the right combination of warm temperatures, low humidity and air current. In drying warm temperature causes the moisture to evaporate. Low humidity allows moisture to move quickly from the food to the air. Air current speeds up drying by moving the surrounding moist air away from the food (Harrison and Andress, 2012).

2.14 Nutritional values of dried food

Dehydrated foods are usually dried with low heat thus having minimal effects of the nutritional value of the food. This produces a high-quality product, which when compared with the extreme temperatures involved when canning or freezing, is the least damaging form of food preservation. Fresh food dried from the own garden and commercially dehydrated or freeze-dried foods may even contain more nutritional value than fresh foods. Dried foods can be bought from the grocery store because they are usually dried within hours of being picked, at their peak of freshness and then processed to preserve their nutritional benefit (Kent, 2009).

2.15 Packaging materials

Food packaging is one of the most important processes in food industry which helps in maintaining quality of foods during the storage, transportation and distribution. It protects food from physical, chemical and biological damage and preserves it in its state. It also focus on attracting a consumer, provide product and nutritional information (Sarkar and Kuna, 2020).

The goal of food packaging is to maintain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact. There are different types of packaging materials used for the preservation of foods and maintaining the safety, wholesomeness, and quality of food for longer period of time (Marsh and Bugusu, 2007). Some of the important packaging materials are shown below; high density polyethylene which is stiff, strong, tough in nature and resistant to chemicals and moisture. It is also permeable to gas, easy to process and easy to form. It is used to make bottles for milk, juice, and water, grocery, trash, and retail bags another is low-density polyethylene which is flexible, strong, tough, easy to seal, and resistant to moisture. It is relatively transparent, and is predominately used in film applications and in applications where heat sealing is necessary. Bread and frozen food bags, flexible lids, and squeezable food bottles are examples of low-density polyethylene(Sarkar and Kuna, 2020).

2.16 Changes during drying of fermented bamboo shoot

2.16.1 Changes in acidity

Fermentation is the one of the traditional methods for preserving the food. The LAB fermentation in bamboo shoot could preserve the raw material from the rapid degradation process. Naturally the existence of LAB in pickle was found to vary during the fermentation. Result showed that the change trend of LAB number has positive correlation with pH and total acidity. In the optimal condition, after 24 hours of fermentation, the cell growth rapidly which initialed the indigenous LAB enter the exponential phase. According to Holzapfel *et al.* (2008) the LAB has important role in the fermentation of pickle because they provide a rapid acid accumulation in the raw material with the production of several organic acids. During the fermentation, some species of LAB produced lactic acid and acetic acid, which reduce pH of the substrates making the products more acidic in nature, and inhibit the growth of pathogenic microorganism, thus food are safe for consumption (Darmayanti *et al.*, 2018).

2.16.2 Changes in moisture

The changes in the moisture content of fresh bamboo shoots was found to be 90.57 % which increased to 91.08% on fermentation which might due to the release of water and other metabolites as by-products by the fermenting micro-organisms (Singhal *et al.*, 2021).It has also been found there is 95.1% decrease in moisture content of dried bamboo shoots..

2.17 Sensory properties

There are different changes involved during the processing of bamboo shoots. During the fermentation and drying of bamboo shoots changes in their color, flavor, texture as well as microbial changes occurs.

It have been shown that fermentation enhances the flavor and aroma of shoots including some bio nutrients and minerals (Chongtham *et al.*, 2011). Some of the others changes in the properties like color is due to the microbial action and chemical reaction. The chemical reaction includes non-enzymatic browning, enzymatic browning and maillard reaction. Unstable pigments such as chlorophyll and anthocyanin bamboo shoots degrade at different extent (Gunawan and Barringer, 2000). Fresh bamboo shoots are yellowish green in color due to the presence of lutein and chlorophyll. The acidic environment during fermentation degrades the pigments like lutein and chlorophyll and shoots undergo maillard reaction resulting browning and loss of color (Koca *et al.*, 2007).

Texture is one of the most important quality indexes for vegetables and fruits (Llorca *et al.*, 2001).The hardness of fermented bamboo shoots decrease gradually. It can be due to the breakdown of pectic substances and physical-chemical damages. During the fermentation process, microorganisms participate in the fermentation and produce enzymes that decompose cell structure, such as pectinase that decomposes the glue-layer substance in the cells and cellulase that decomposes the cellulose in the cell wall, which damage the cell structure of bamboo shoots, and leads to the decrease of texture (Zheng *et al.*, 2013).Similarly, in the early stage of fermentation, broth will be rich in dissolved oxygen and as the process continuous the oxygen content will decrease inhibiting the growth of other microorganisms, and facultative anaerobic lactic acid bacteria began to dominate(Chi *et al.*, 2013).

Similarly, during drying of bamboo shoots there causes a darker change in color using superheated steam (120-160^{O}C) in comparison to similar hot air oven temperature. It has been found out that best color of bamboo shoots is found at low temperature drying i.e.,70^{O}C (Santosh *et al.*, 2010). Gracia (1994) has found that higher temperature imparts little burnt like smell. The bitterness of bamboo shoot were least in temperature around 65^{O}C but the off flavor development was high at very high temperature i.e.,75^{O} (Prakasha *et al.*, 2004).It has also been found out that hot air flow drying produces extremely high texture, severe browning, low rehydration rate and low nutritive products. (Battcock and Ali, 1998) has found that decrease in drying time and increased oven power level in case of bamboo shoots cause effect on color, texture and rehydration properties.

Part III

Materials and methods

3.1 Materials

3.1.1 Bamboo shoot

Fresh and tender bamboo shoots (*Dendrocalamus hamiltonii)* were bought from local market of Dharan sub metropolitan city. The fermentation of those bamboo shoots was carried out during the month of *Shrawan*.

3.1.2 Salt

It was used in different concentration i.e., 0%, 1.5%, 3%, 4.5% and 6% respectively. Iodized salt (Aayo Nuun) made by Rastriya trading cooperation limited was used.

3.1.3 Turmeric powder

Turmeric was used for color. A constant amount of turmeric was used during the process of fermentation. Organic turmeric powder product made by pure organic company was used.

3.1.4 Packaging materials

HDPE and LDPE plastics packaging available in the local market of Dharan were used.

3.1.5 Equipment and chemicals

Equipment and chemicals used were available in Central Campus of Technology.

3.2 Methods

3.2.1 Preparation of bamboo shoot

Fresh and tender bamboo shoots was washed with plenty of water to remove dirt and soil. Scraping will be done manually with the help of knife. After, peeling it was washed again with water and cut into small pieces (2cm×3cm).

3.2.2 Preparation of fermented bamboo shoot

The prepared bamboo shoots are then mixed with turmeric powder and with different concentration of salt. The different concentration of salts was optimized using DOE i.e., 0%, 1.5%, 3%, 4.5% and 6% respectively. It was mixed properly and kept in plastic jar for fermentation until its acidity becomes constant (maximum 18 days) and its sensory analysis was carried out including color, taste, smell, texture and overall acceptability.

3.2.3 Drying of bamboo shoots

The properly fermented bamboo shoots were then dried in tray dryer at varying temperature of 50°C, 60°C and 70°C and its sensory analysis was carried out for taste, smell, texture, color and overall acceptability.

The preparation of dehydrated bamboo shoot is shown in fig. 2.1.

Bamboo Shoots

↓

Scraping

↓

Washing

↓

Cutting into small pieces (2cm thickness, 3cm length)

↓

Bamboo shoots pieces

↓

Addition of constant amount of Turmeric (5gm/kg of bamboo shoots)

↓

0% 1.5% 3% 4.5% 6%

(Addition of different concentration of salt)

↓

Fermentation (18 days/ 25°C-30°C)

↓

Analysis of fermented Bamboo shoots (Acidity, Sensory analysis)

↓

Drying of optimized fermented bamboo shoots (50°C, 60°C, & 70 °C)

↓

Analysis of dehydrated Bamboo shoots (Sensory analysis, moisture)

↓

Storage on Packaging materials (HDPE, LDPE)

↓

Chemical analysis (Moisture, Acidity) | Microbial analysis (Total plate count)

↓

Selection of packaging material

Fig. 2.1: Preparation of Bamboo shoots

Bamboo shoot *(Dendrocalamus hamiltonii*) was brought from local market of dharan. The young, tender bamboo shoots was harvested, scraped and cut into suitable pieces of (2cm×3cm) respectively. A constant amount of turmeric (5g/kg) was used with different salt concentration (0%,1.5%, 3%, 4.5% and 6%). Then, spontaneous fermentation was carried out till 18 days at 25-30°C by packaging in air tight container until constant acidity was obtained i.e., 0.72g/100ml of lactic acid. The sensory analysis (color, smell, taste, texture & overall acceptability) was carried out for the selection of salt concentration. The optimized bamboo shoots were dried at different temperature 50°C, 60°C and 70°C until the constant moisture content of 8-10% was obtained. Among different temperature best was selected through sensory analysis i.e., 70°C and further it was packaged in high density polypropylene and low-density polypropylene. The samples were analyzed chemically and microbiologically at every 15 days interval up to 3 months by keeping the samples at room temperature (27°C-29°C).

3.2.4 Storage stability

Dried bamboo shoots were filled in packaging materials (LDPE and HDPE plastics) and the storage stability according to the change in moisture content and microbial changes was studied up to 90 days at the interval of 15 days respectively.

3.2.5 Chemical analysis of bamboo shoots

3.2.5.1 Determination of acidity

Acidity was determined by titrimetric method given by Ranganna (1986).

3.2.5.2 Determination of moisture content

Moisture content of sample was determined as described Ranganna (1986).

3.2.6 Microbiological analysis

The total plate count (TPC) of dehydrated bamboo shoots were carried out by pour plate method as described by Harrigan and McCance (1976). The TPC of sample was expressed in terms of log colony forming units (cfu) per gram.

3.2.7 Sensory analysis

The sensory evaluation of fermented bamboo shoots was performed at Central Campus of Technology (CCT), TU by semi trained panelist. The panelists were teachers, staff and students who had some knowledge about characteristics of the product, thus considered to be semi- trained panelists. Sensory evaluation of the product was performed by 9-point hedonic rating test. The parameter for sensory evaluation for fermented and dehydrated bamboo shoots included taste, texture, color, smell and overall acceptance. Sensory evaluation was carried out in room with adequate light and free from odor. Panelists were provided with evaluation card and portable water for rinsing between the samples.

3.2.8 Statistical method

All the calculation were performed in Microsoft Office Excel (2010). For significance analysis, data were analyzed by one- way ANOVA using Genstat Release 12.1 (2013) and means were compared using LSD at 5% level of significance.

Part IV

Results and discussion

Bamboo shoot *(Dendrocalamus hamiltonii*) was brought from local market of dharan. The young, tender bamboo shoots was harvested, scraped and cut into suitable pieces of (2cm×3cm) respectively. A constant amount of turmeric (5g/kg) was used with different salt concentration (0%,1.5%, 3%, 4.5% and 6%). Then, spontaneous fermentation was carried out till 18 days at 25-30°C by packaging in air tight container until constant acidity and dried at varied temperature. Chemical and sensory analysis were performed on the final product.

4.1 Changes in acidity during fermentation

Fermentation was carried at room temperature 27-29°C using different salt concentration i.e., 0%, 1.5%, 3%, 4.5% and 6%. The acidity of the samples was analyzed at interval of 48 h for 18 days until a constant value was obtained. The development of acidity of all samples is shown in figure 4.1. The sample with 0% salt concentration had a steep rise in acidity and went to become the sample with highest acidity among others samples with different salt concentrations. The others samples had similar level of acidity during fermentation period with, sample B having 1.5% salt concentration had the highest acidity and sample E with 6% salt concentration had the lowest level of acidity. The lowest acidity in sample E with 6% salt concentration was due to the growth of homo fermentative bacteria rather than hetero fermentative bacteria as stated by Khanna (2016). The increase in titratable acidity was inversely proportional to the increase in salt concentration in the brine solution. A rapid increase of acidity in fermented vegetables is associated with the increase in organic acids mainly lactic acid which also help to minimize the influence of spoilage bacteria (Panda *et al.*, 2006).

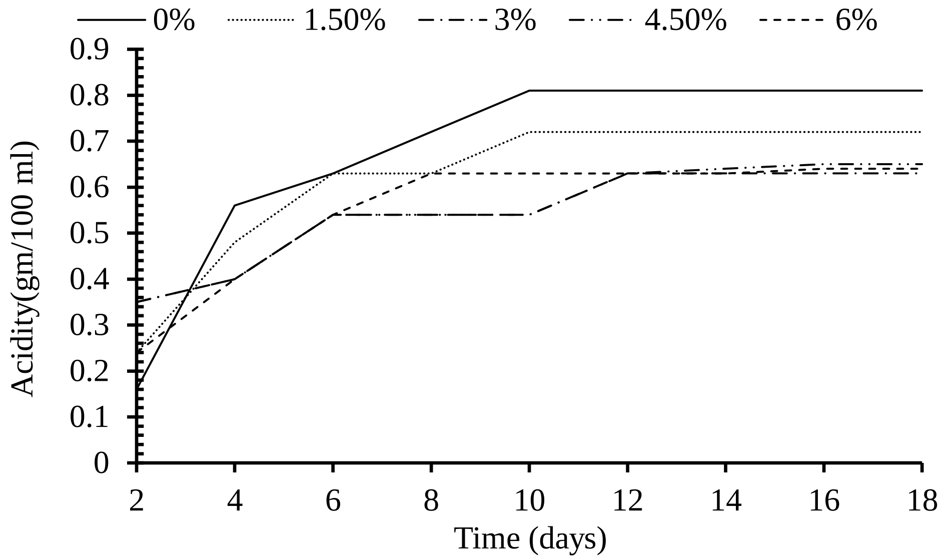

Fig 4.1: Acidity of fermented bamboo shoots

4.2 Optimization of salt concentration for natural fermentation of fresh bamboo shoots

The sensory results of best salt concentration are shown in fig. 4.2

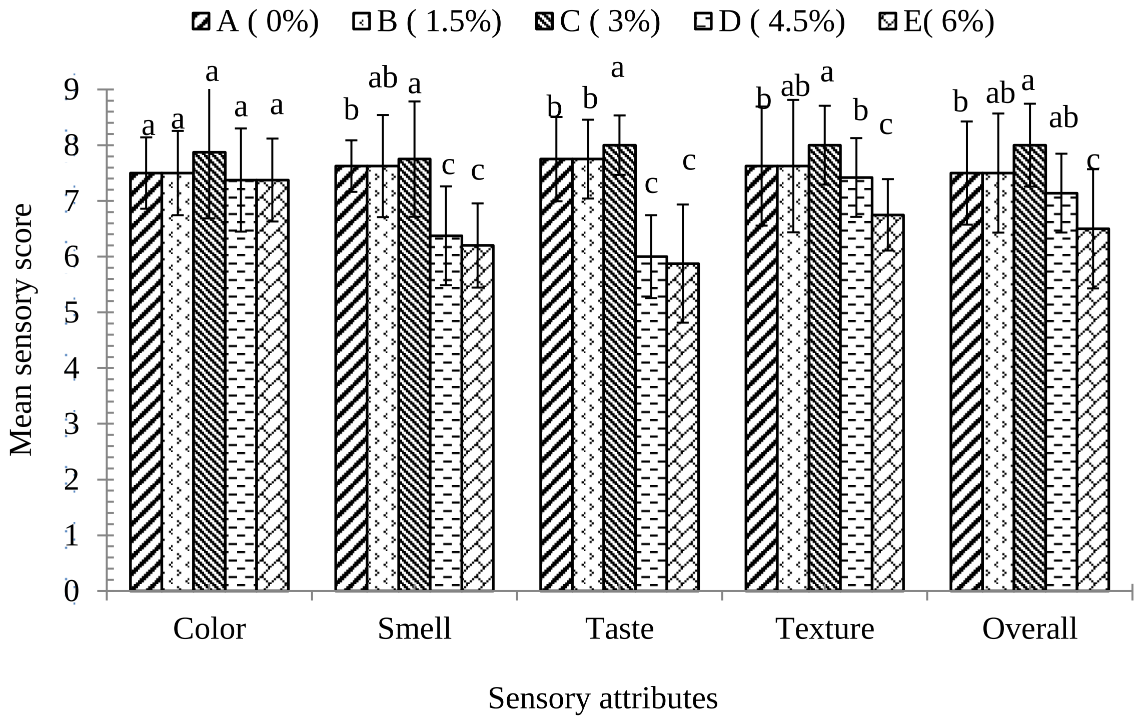

Fig 4.2: Effect of salt concentration on sensory quality of fermented bamboo shoots

*The above values shown in the Fig. 4.2 are the mean of triplicate, the same alphabet in the bar shows no significant differences and the different alphabet in the bar shows significant differences, lastly the straight line in the bar is the standard deviation. ($p<0.05$)

4.1.1 Color

The mean value of sample A, sample B, sample C, sample D and sample E was found to be 7.5, 7.5, 7.875, 7.375 and 7.375 respectively. It was found that there was no significant difference between the color of given samples as the amount of turmeric used were constant. Koca *et.al.* (2011) has focused on the research where there is a loss of color due to the acidic environment during fermentation which degrades the pigments like lutein and chlorophyll and as well as the shoots undergo Maillard reaction resulting in browning. The salt concentration has no effect on color during fermentation.

4.1.2 Smell

The mean value of sample A, sample B, sample C, sample D and sample E was found to be 7.625, 7.625, 7.75, 6.375 and 6.2 respectively. It was found that there was significant difference between the smell of samples A, C, D, E and no significant difference between samples C and B. The sample C was found to be best with the mean value of 7.75. Chongtham *et al,* (2011) have found out that fermentation enhances the flavor and aroma of shoots including some bio nutrients and minerals. The changes on the smell of bamboo shoot were associated with the fermentation process,

4.1.3 Taste

The mean value of sample A, sample B, sample C, sample D and sample E was found to be 7.75, 7.75, 8, 6 and 5.875 respectively. There was significant difference between the taste of given samples A, B, D, E with sample C which has the highest mean value 8.0. Khanna (2019) has found out the effect in taste is derived from the salt concentration and the ratio of organic acids after the complete and adequate fermentation process. Different salt concentration has effect on the taste of bamboo shoot.

4.1.4 Texture

The mean value of sample A, sample B, sample C, sample D and sample E was found to be 7.625, 7.625, 8, 7.42 and 6.75 respectively. There was significant difference between the texture of given samples A, C, D with C whereas no significant difference between sample B and C. Sample C was considered best with the mean value of 8 respectively. Zheng *et al*, (2013) found out that during the fermentation process, microorganisms participate in the fermentation and produce enzymes that decompose cell structure, such as pectinase that decomposes the glue-layer substance in the cells and cellulose that decomposes the cellulose in the cell wall, which damage the cell structure of bamboo shoots, and leads to the decrease of texture. Natural fermentation effects the texture of bamboo shoot.

4.1.5 Overall acceptability

The mean value of sample A, sample B, sample C, sample D and sample E was found to be 7.25, 7.5, 8, 7.144 and 6.5 respectively and the mean score of sample C was found to be best in comparison to others samples. It was more preferred by the panelist on the basis of color, smell, taste, texture and overall and its evaluation was further done by two-way ANOVA by using GenStat. It has also been found by Khanna (2019) that, there are factors such as adequate salt concentration and fermentation temperatures, to promote the proper ratios of hetero fermentative to homo fermentative LAB and organic acids, which contribute to the desirable flavors, textures and qualities of salt concentrated products.

4.3 Effect of drying temperature on fermented and dehydrated bamboo shoots

The sensory result of best dehydrated bamboo shoot is shown in fig. 4.3.

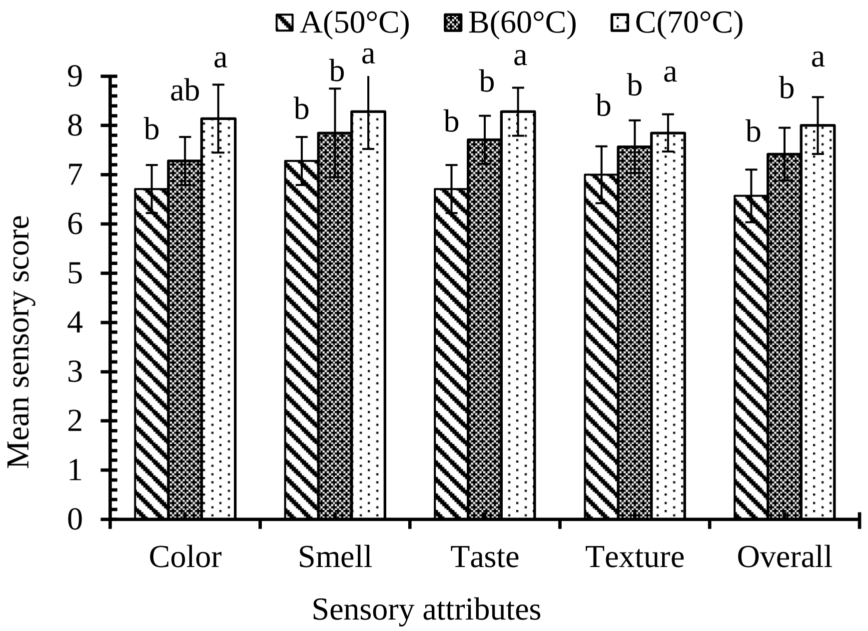

Fig 4.3: Effect of temperature on sensory quality of dried bamboo shoots

*The above values shown in Fig. 4.3 are the mean of triplicate, the same alphabet in the bar shows no significant differences and the different alphabet in the bar shows significant differences, lastly the straight line in the bar is the standard deviation. ($p<0.05$)

4.2.1 Color

The mean score of sample A, sample B and sample C was found to be 6.71, 7.28 and 8.14 respectively. There was significant difference between the samples A and C whereas no significant difference between samples B and C. Sample C was considered best with the highest mean value of 8.14 Santosh *et.al* (2010) has found on their research that color of bamboo shoots dried using superheated steam (120-160°C) is darker than color obtained from hot air even at same drying temperature and the best color of bamboo shoots (lightest color) obtained by low- temperature drying at (70°C). The difference in the temperature has effect on the color of dried bamboo shoot.

4.2.2 Smell

The mean score of sample A, sample B and sample C was found to be 7.28, 7.85 and 8.28 respectively. Sample C was significantly different from other sample A and B with the higher mean value of 8.28 The higher temperature imparts a little burnt like smell and change the color as shown in research by Gracia (1994). Higher temperature is directly associated with the smell of dried bamboo shoot.

4.2.3 Taste

The mean score of sample A, sample B and sample C was found to be 6.71, 7.71 and 8.28 respectively. There was significant difference between the samples. Sample C was significantly different from other sample A and B with the higher mean value of 8.28. Prakash *et. al.* (2004) has found out that the bitterness was least in the temperature about 65°C in comparison with other temperatures, while off-flavor development was high at very high temperature (75°C). Temperature lowers the bitterness and high temperature affects its taste.

4.2.4 Texture

The mean score of sample A, sample B and sample C was found to be 7, 7.57 and 7.85 respectively. Sample C was significantly different from other sample A and B with the higher mean value of 7.85. Li *et al,* (2002) have found out that hot air flow drying produces extremely hard texture, severe browning, low rehydration rate, low nutritive value products. Drying is related to the texture of bamboo shoots.

4.2.5 Overall acceptability

The mean value of sample A, sample B and sample C was found to be 6.57, 7.42 and 8 respectively. There was significant difference between the samples as samples C mean value was obtained more in comparison to others samples i.e., 8. It was more appealing and preferred by panelist on the basis of color, smell, taste, texture and its further evaluation was done by using two-way ANOVA using GenStat. (Battcock and Ali, 1998) also reported a decrease in drying time with increased oven power level in case of bamboo shoots which cause effect on color, texture, and rehydration properties.

4.4 Shelf-life study of optimized sample using different packaging materials

Moisture, acidity and TPC were measured in the interval of 15 days in two different packaging materials, HDPE and LDPE. The trend line for moisture is shown in figure below:

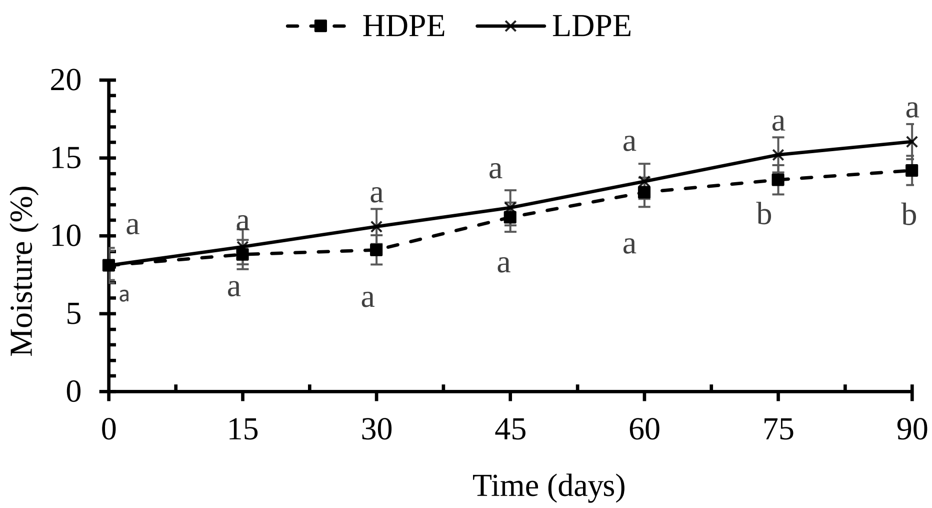

Fig 4.4: Change in moisture of packaged products

*The above values shown in Fig. 4.4 are the mean of triplicate, the same alphabet in the bar shows no significant differences and the different alphabet in the bar shows significant differences, lastly the straight line in the bar is the standard deviation. ($p<0.05$)

The initial moisture of dried fermented product was found to be 8.1% which increased considerably in both packaging materials i.e., in case of HDPE it increased up to 14.2% and in case of LDPE it increased up to 16.05% as shown in figure 4.4. The gain in moisture was slightly higher in LDPE followed by HDPE. It may be due to the absorption of moisture from atmosphere by product. HDPE gained less moisture due to low permeability to water vapor (Yadav *et al.*, 2010). As, the product was dried at high temperature and air sealed high changes in moisture was also not seen. The product was shelf stable and could be consumed for longer period of time.

The trend line for acidity is shown below in figure:

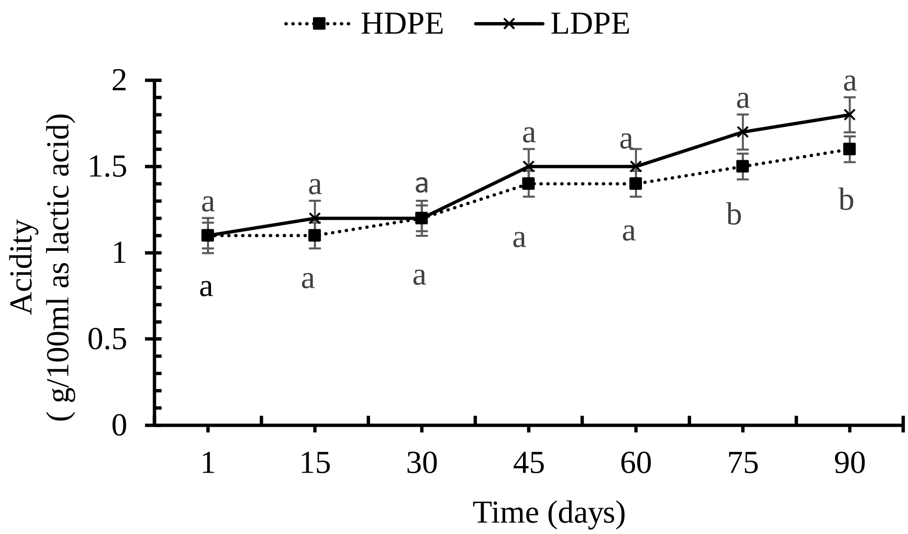

Fig 4.5: Change in acidity of packaged products

*The above values shown in the Fig 4.5 are the mean of triplicate, the same alphabet in the bar shows no significant differences and the different alphabet in the chart show significant differences, the straight line in the chart is the standard deviation. ($p<0.05$)

The initial acidity of the dried fermented bamboo shoots was found to be 1.1% which slightly increased in both packaging materials i.e., in case of HDPE it increased up to 1.6% and in case of LDPE it increased up to 1.8% as shown in figure 4.5. The acidity was calculated as lactic acid. The slight increase in acidity was seen due to the action of microorganisms as well as production of organic acids during processing and storage of the product (Goyal and Srinivasan, 1989) and the increase in titratable acidity was inversely proportional to the increase in salt concentration in the brine solution. The increase in acidity in fermented vegetables is associated with the increase in organic acids, mainly LA, which also minimizes the influence of spoilage bacteria (Montet *et al.*, 2006).

The initial total plate count of the dried fermented bamboo shoots was found to be 1cfu/g which slightly increased in both packaging materials i.e., in case of HDPE it increased up to 21cfu/g and in case of LDPE it increases up to 31cfu/g. The product of best quality i.e., C was kept in packaging material i.e., HDPE and LDPE. It was kept in normal atmospheric condition for microbiological analysis in an interval of 15 days where the total plate count (TPC) of the stored products was analyzed. Since, the products were packaged in two different packaging materials, analysis was done to determined best packaging for the dried bamboo shoot products. The trend line for TPC is shown below

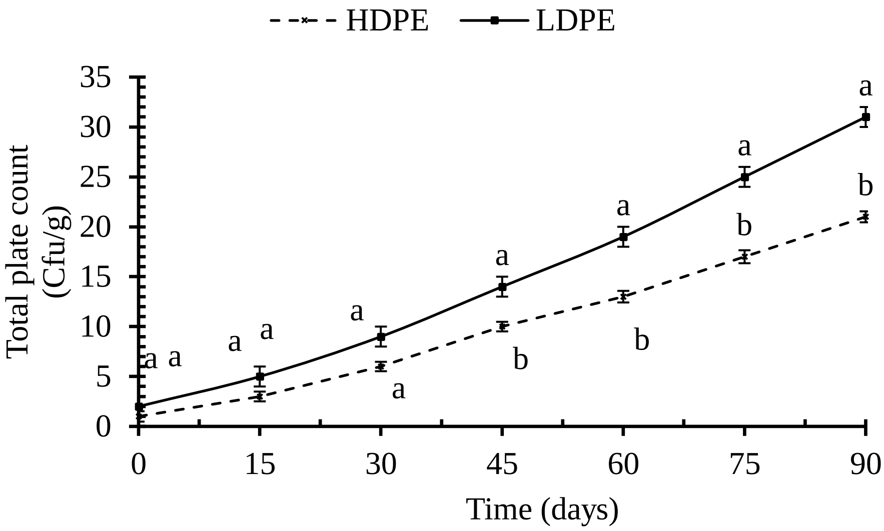

Fig4.6: Change in total plate count of packaged products

*The above values shown in the Fig. 4.6 are the mean of triplicate, the same alphabet in the bar shows no significant differences and the different alphabet in the bar shows significant differences, lastly the straight line in the chart is the standard deviation. ($p<0.05$)

From the above graph 4.6, it is shown that there was instant growth in low density polypropylene up to the range of 31cfu/g than HDPE packaging 21cfu/g respectively. Both the samples were kept in room temperature and air sealed. There was no significant difference in growth of microorganisms until 30th day while significant growth difference occurred from 45th day. Since, there was less absorption of moisture by high density polypropylene, the products were still dry in nature as we know that the water activity less than 0.9 is not suitable for the growth of bacteria (Sawhney *et al.*, 1997). Similarly, low density polypropylene is more permeable to moisture as a result there was absorption of moisture from environment and got affected by bacteria.(Yadav *et al.*, 2010).

Part V

Conclusions and recommendations

5.1 Conclusions

1. Natural fermentation of bamboo shoots using salt concentration of 3% can be done up to 18 days to obtain a constant acidity level.

2. Dried fermented bamboo shoots at 70°C until the moisture level decreased to below 10% was preferred in terms of product's sensory attributes in comparison with 50°C and 60°C.

3. The storage stability of dehydrated bamboo shoots was better in HDPE packaging than LDPE as shown by moisture, acidity and TPC analysis.

4. The moisture rose to 16.05% from 8.1%, acidity increased to 1.8 from 1.1 and TPC was 31 cfu/g at 90^{th} day in case of LDPE while in case of HDPE the 90^{th} day moisture, acidity and TPC were 14.2%, 1.6 and 21 cfu/g respectively.

5.2 Recommendations

1. Dehydrated bamboo shoots can be made by natural fermentation using 3% salt concentration up to 18 days and drying at 70°C.

2. Study on the pre-treatments for removal of cyanogenic glycoside, content of bamboo shoots can be done.

3. Study on the rehydration properties of dehydrated bamboo shoot can be carried out.

Part VI

Summary

The work is mainly focused on the proper utilization of perishable bamboo shoots by knowing the effect of salts concentration on the shoots. It is one of the oldest products of Nepal and can be found in found in various species. *Dendrocalamus Hamiltonii* species of bamboo shoot is used for the completion of work. It is obtained by choya baas. Different products like bamboo pickle, bamboo powder, vegetables, soups are prepared in context of Nepal. It is used as a good appetizer and helps to maintain a healthy life. Since the product is perishable in nature appropriate methods of preservation like fermentation, brining, as well drying is performed to extend the shelf life.

Study was carried out to know the effect of different salt concentrations i.e., 0%, 1.5%, 3%, 4.5% and 6% on the fermented and dehydrated bamboo shoots as well as evaluating their extended shelf life for three months. Five samples of bamboo shoots were packed in plastic jar with different salt concentration and constant amount of turmeric. Acidity of the samples were measured on the intervals of one day until it becomes constant. It was measure till 18days and sensory analysis was performed. Sensory evaluation (color, smell, taste, texture, overall) was done in Central Campus of technology on 9-point hedonic rating scale. Statistical analysis was performed which showed that the sample with 3% salt was preferred by the panelists. Then the best product was further lead to drying.

Drying of the sample was done different temperature i.e., 50°C, 60°C and 70°C respectively. Further sensory analysis was performed on similar basis, sample dried at 70°C was mostly preferred by the panelists. The obtained sample was then packaged in two different packaging materials i.e., high density polypropylene and low-density polypropylene. The storage stability was study in every 15 days interval in room temperature (27°C-29°C) up to 3 months. Analysis of acidity, moisture and total plate count was performed. Between the packaging materials HDPE was more preferred as there was no such increase in acidity, moisture and no growth of colonies expect few growths was seen by lab or process contamination.

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Appendices

Appendix A

Sensory analysis score card

Name of the panelist: Date:

Name of the product: Fermented Tama

Dear panelist, you are provided with 5 samples of Fermented tama which include different salt concentration on the samples. Please test the following samples of fermented tama and check how much you prefer for each of the samples. Give the points for your degree of preferences for each parameter for each sample as shown below:

Judge the characteristics on the 1-9 scale as below:

Like extremely – 9
Like very much – 8
Like moderately – 7
Like slightly – 6
Neither like nor dislike – 5
Dislike slightly – 4
Dislike moderately – 3
Dislike very much – 2
Dislike extremely – 1

Parameters	Sample				
	A	B	C	D	E
Color					
Smell					
Taste					
Texture					
Overall acceptability					

Any comments: Signature:

Appendix B

Name of the panelist: Date:

Name of the product: Dehydrated Tama

Dear panelist, you are provided with a sample of dehydrated tama which include salt concentration on the given sample. Please test the following sample of dehydrated tama and check how much you prefer the sample. Give the points for your degree of preferences for each parameter for each sample as shown below:

Judge the characteristics on the 1-9 scale as below:

Like extremely – 9 Like slightly – 6 Dislike moderately – 3

Like very much – 8 Neither like nor dislike – 5 Dislike very much – 2

Like moderately – 7 Dislike slightly – 4 Dislike extremely – 1

Parameters	Sample		
	A	B	C
Color			
Smell			
Taste			
Texture			
Overall acceptability			

Any comments:

Signature:

Appendix C

ANOVA results of sensory analysis of fermented bamboo shoots

Table C.1 ANOVA for color of fermented bamboo shoots

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Fermented Tama	4	1.3500	0.3375	0.61	0.658
Panelist	7	11.1750	1.5964	2.89	0.021
Residual	28	15.4500	0.55		
Total	39	27.975			

Table C.2 ANOVA for smell of fermented bamboo shoot

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Fermented Tama	4	13.2500	3.3125	4.23	0.008
Panelist	7	8.3000	1.1857	1.51	0.204
Residual	28	21.9500	0.7839		
Total	39	435.000			

Table C.3 ANOVA for taste of fermented bamboo shoots

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Fermented Tama	4	33.6500	8.4125	9.37	<.001
Panelist	7	9.1000	1.3000	1.45	0.226
Residual	28	25.1500	0.8982		
Total	39	67.9000			

Table C.4 ANOVA for texture of fermented bamboo shoots

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Fermented Tama	4	13.9000	3.4750	4.04	0.010
Panelist	7	22.7750	3.2536	3.78	0.005
Residual	28	24.1000	0.8607		
Total	39	60.7750			

Table C.5 ANOVA for overall acceptability of fermented bamboo shoots

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Fermented Tama	4	16.6000	4.1500	4.88	0.004
Panelist	7	9.2000	1.3143	1.55	0.193
Residual	28	23.8000	0.8500		
Total	39	49.600			

Appendix D

ANOVA results of sensory analysis of dehydrated bamboo shoots

Table D.1 ANOVA for color of dehydrated bamboo shoots

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Dried	2	7.2381	3.6190	15.72	<.001
Panelist	6	2.9524	0.4921	2.14	0.124
Residual	12	2.7619	0.2302		
Total	20	12.9524			

Table D.2 ANOVA for smell of dehydrated bamboo shoot

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Dried	2	3.5238	1.7619	4.72	0.031
Panelist	6	5.2381	0.8730	2.34	0.099
Residual	12	4.4762	0.3730		
Total	20	13.2181			

Table D.3 ANOVA for taste of dehydrated bamboo shoots

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Dried	2	2.6667	1.3333	4.80	0.029
Panelist	6	1.2381	0.2063	0.74	0.626
Residual	12	3.3333	0.2778		
Total	20	7.2381			

Table D.4 ANOVA for texture of dehydrated bamboo shoots

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Dried	2	8.8571	4.4286	13.95	<.001
Panelist	6	0.4762	0.00794	0.25	0.950
Residual	12	3.8095	0.3175		
Total	20	13.1429			

Table D.5 ANOVA for overall acceptability of dehydrated bamboo shoots

Source of variance	d.f.	s.s.	m.s.	v.r.	F pr.
Dried	2	7.2381	3.6190	12.67	0.001
Panelist	6	2.0000	0.3333	1.17	0.385
Residual	12	3.4286	0.2857		
Total	20	12.6667			

Color plates

Plate 1: Pretreatments of bamboo shoots

Plate 2: Fermented Bamboo Shoots

Plate 3: Chemical analysis of fermented bamboo shoots sample

Plate 5: Sensory analysis of fermented bamboo shoots

Plate 5: Sensory analysis of Dehydrated bamboo shoots

Plate 6: Packaging of samples in HDPE and LDPE plastics