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Preservation of carrot, green chilli and brinjal by fermentation and pickling

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Abstract

The study was conducted to develop the mixed fermented vegetable pickles from carrot, green chilli and brinjal. Fermentation was carried in 10% salt solution, 8% salt plus 1% sugar solution and 8% salt plus 1% sugar and 1% acetic acid solution. During fermentation the acidity (expressed as lactic acid) increased with fermentation time progressed resulting in first order kinetics as carbohydrates converted to acid and two rate periods were observed for all cases, one indicating (First period or higher rate period) increase in acidity very fast having higher k value and the other (Second period or slower rate period) increase in acidity slowly with lower k value. The acidity attained maximum value for the samples which were kept in 8% salt plus 1% sugar and 1% acetic acid. High concentration of salt (10% salt) results in low acid production. Moisture content reduced as water molecules diffused freely across the membrane from dilute to concentrated solution. Protein content increased moderately where ash content increased highly due to reduction of moisture content and salt uptake. Vitamin C content reduced drastically. Fat, protein, ash and acidity were higher in fermented pickles than the fresh pickles. Total viable bacteria were less in the pickle which was fermented in 8% salt plus 1 % sugar and 1 % acetic acid and followed by the pickle which was fermented in 8% salt plus 1% sugar and 10% salt solution, respectively. No fungal growth was visible during 4 months of storage. Organoleptic taste testing showed that all the developed pickles were accepted by the panelists and all fermented pickles were ranked as `like moderately' where as fresh pickle was ranked as `like slightly'. The samples which were fermented in 10% salt solution and in 8% salt plus 1% sugar secured the highest mean score. Color, flavor and texture were not changed in fermented pickles at room temperature (22°C-28°C) up to 4 months of storage while the unfermented pickle changed slightly in flavor and texture after 4 months.

Introduction

Vegetables play an important role to supply a balanced diet particularly from micronutrient point of view. It is the main component of human food that supplies protein, carbohydrates, fats and oils, vitamin and minerals, which are essential for body building and keeps body active. At present, the country is producing 52.5 million tones fruits and vegetables. It is worthwhile to mention that the loss of fruits and vegetables during handling, transportation and storage is estimated at 25% to 30% due in inadequate infrastructure required for extending storage life (B.B.S 2000).

Carrot (*Daucus carota* L.) is one of the popular root vegetables grown throughout the world and is the most important source of dietary carotenoids in Western countries including the United States of America (Block 1994; Hashimoto and Nagayama, 2004). It is one of the important root vegetables rich in bioactive compounds like carotenoids and dietary fibers with appreciable levels of several other functional components having significant health-promoting properties. In recent years, the consumption of carrot and its products have increased steadily due to their recognition as an important source of natural antioxidants besides, anticancer activity of β-carotene being a precursor of vitamin A (Speizer *et al*., 1999; Sharma *et al.*, 2012). It contains many important vitamins and minerals and rich in antioxidants beta-carotene which have protective properties against certain forms of cancer and cardiovascular diseases (Basu *et al.*, 2001). Carrot is also helpful in the obesity, poisoning of the blood, gum disease, insomnia, inflamed kidney, liver, gallbladder, Alzheimer's disease, colitis, ulcer and painful urination.

Green chilli (*Capsicum frutescens* L.) is a good source of plant derived chemical compounds that are known to have disease preventing and health promoting properties. Fresh chillies are an excellent source of vitamin A, tocopherol and ascorbic acid

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as well as neutral and acidic phenolic compounds which are important antioxidants (Howard *et al.*, 2000; Ahmed and Shivhare, 2001; Ajaykumar *et al.*, 2012). They are also good sources of provitamin A, carotenoid, viz., β-carotene, α-carotene, β-cryptoxanthin and oxygenated carotenoids or xanthophylls which can vary in composition and concentration due to differences genetics and degree of ripening (Markus *et al.*, 1999). Capsaicin helps in arthritic pain, post herpetic neuropathic pain, sore muscles etc. Studies showed that capsaicin has anti-bacterial, anti-carcinogenic, analgesic and anti-diabetic properties. It also found to reduce LDL cholesterol levels in obese persons.

Brinjal (*Solanum melongena* L.) is low in calories and fats, contains mostly water, some protein, fiber and carbohydrates. It is a good source of minerals and vitamins and is rich in total water soluble sugars, free reducing sugars, amide proteins among other nutrients (Nisha *et al.*, 2009). Brinjal is known to have ayurvedic medicinal properties and is good for diabetic patients and high blood pressure (Kiran and Shruti, 2007).

Carrot, green chilli and brinjals are important to their inexpensiveness and valuable nutrient contents. Since these vegetables are perishable, there is necessity of processing and preservation for future use. Fortunately, most perishable foods can be made stable and acceptable by the judicious application of present day technology. There are several methods for processing of these vegetables. Among them pickling is one of the best methods for processing of these vegetables and it can be used whole the year round. When any food (fruits, vegetables, fish or meat) is preserved by natural salt or vinegar or oil, then the processed food is called pickles. Pickles are good appetizers and add to the palatability of a meal.

Fermentation is the oldest method of pickling, where a naturally occurring bacterium transforms the sugars present in the ingredient into an acid, and though they take as many as five weeks to cure, they last up to 2 years. They have a very sharp flavor and their texture is somewhat softer than other types. Fermentation is the controlled decomposition of food. In the case of fermented pickles, salt controls the pickle's texture, limits unwanted micro-organisms, and ensures ingredients. Fermentation is the best process for growing acidity in fruits and vegetables (Caplice and Fitzgerald, 1999). The nature of fermentation will depend upon the nature of food, the types of microorganism present and environmental conditions affecting their growth and metabolic patterns. Commercially, fermentation of vegetables can be done by sodium chloride (NaCl) brines. NaCl serves two primary functions in the preservation of vegetable fermentation; it regulates the type of microbial activity, and it prevents softening and other degradative changes in the tissues (Fernandes, 2000). Fermentation of vegetables not only improves their flavor but also make them more nutritious and easier to digest.

Processing and preservation of vegetable pickles reduce wide fluctuation of prices between the peak harvesting period and off season. It encourages and initiates efficient food production practices and simultaneously reduces losses due to spoilage and decay in harvested foods. Pickle based on fruits and vegetables is an important processed product from viewpoint of its export potential. But in our country, the pickles produced from vegetables on commercial scale, especially by fermentation are not so common. Bangladesh is an agricultural country whose economic development depends on the accomplishment of higher efficiency in food production and utilization of the available supply of food to the best advantage. There is good scope to produce vegetable pickles by fermentation on commercial scale. Therefore, the overall aim of the research is to process and preserve mixed pickles from fermented carrot, green chilli and brinjal. The specific objectives of the research are as follows: To observe the fermentation kinetics of carrot, green chilli and brinjal at different fermentation conditions; to determine the chemical composition of fresh and fermented carrot, green chilli and brinjal and of developed pickles and to conduct organoleptic taste to assess the acceptability and shelf life of processed fermented pickles.

Materials and Methods

The research has been carried out in the laboratory of the Department of Food Technology and Rural Industries, Bangladesh Agricultural University, Mymensingh, Bangladesh. Fresh carrot, green chilli and brinjal were collected from local market. Other necessary materials and chemicals were used from the laboratory stock.

Experimental design

Fresh carrot, green chilli and brinjals were fermented using three diffrent salt solutions. The salt solutions were prepared by using 10% salt; 8% salt plus 1% sugar; and 8% salt plus 1% sugar and 1% acetic acid. After the completion of fermentation the samples were ready to prepare mixed pickles and stored at room temperature. A mixed vegetable pickle was prepared from fresh carrot, green chilli and brinjal as a control sample.

Salting and Fermentation of carrot, green chilli and brinjal

At first, fresh green chilli, carrot and brinjal were separated from panicle and washed thoroughly; undesirable portions were removed and cut into pieces. Then carrot, green chilli and brinjal were separated into three equal parts and kept in three different salt solutions separately in the following way:

a. One part of carrot, green chilli and brinjal were placed separately in 10% salt solution and the concentration was maintained during the first week. This salt concentration was increased 1% a week. Therefore, until 16% salt concentration is reached (9 g salt was added per 100 g of sample per day) and the salt concentration maintained up to the completion of fermentation. The sample was stirred daily to protect spoilage by yeast and molds. The complete fermentation takes place after 49, 25 and 30 days, respectively, for carrot, green chilli and brinjal.

b. Another part of green chilli, carrot and brinjal were placed separately in 8% salt and 1% sugar solution. Firstly, the samples were immerged into 8% salt solution and when fermentation proceeds then 1% sugar was added. This 8% salt concentration was increased 1% a week until 16% salt concentration is reached (9 g salt were added per 100 g of sample per day). This salt concentration maintained up to the completion of fermentation occurs. The sample was stirred daily to protect spoilage by yeast and molds. The complete fermentation occurred after 49, 25 and 30 days, respectively, for carrot, green chilli and brinjal.

c. The third portion of carrot, green chilli and brinjal were placed separately in 8% salt, 1% sugar and 1% acetic acid solution. At first, the samples were immerged into 8% salt solution and 1% acetic acid solution. When fermentation proceeds, 1% sugar was added and this salt concentration maintained. The fermentation completed requires 49, 25 and 30 days for carrot, green chilli and brinjal, respectively.

Salt removal from fermented carrot, green chilli and brinjal

The salt stock is not considered a consumer commodity. The salt must be removed after fermentation from the salt stock by soaking in water. This was accomplished by leaching the salt from the salt stock with warm water of temperature 45°C for 14 hr. This was repeated in 3 times. Then the samples were ready to prepare mixed pickles. Proper care was taken during handling of the samples to avoid breaking.

Processing of Mixed Vegetable pickles

Carrot (500 g), green chilli (500 g), and brinjal (100 g) were used in the preparation of mixed pickle sample (i.e., 5:5:1 proportion by weight). The vegetables were cut into pieces and dried in the sun for 2 hours. All the spices (Turmeric-2.5 g, Cinnamon-2.5 g, Cardamom-2.5 g, Pachforon-1 g, Joyfall and joyatri-5 g, Postadana-10 g, Ginger paste-25 g, Garlic paste-10 g etc) were mixed. Then mustard oil (250 ml) was heated till smoking and the spices mixed were poured on it and heating continued until the mixed materials attain brown color. Pieces of vegetables were then mixed with the fried spices and cooked till oil floated on top. Then sugar (20 g) and vinegar (75 ml) were added and simmered for 2 minutes. The prepared product was then cooled and bottled.

Chemical analysis

The raw materials as well as the fermented sample and developed pickles were analyzed for their moisture, total solids, ash, protein, acidity as per the methods of AOAC (2005), pH and vitamin C content as Ranganna (2003).

Sensory evaluation

The consumer's acceptability of developed product was evaluated through a taste testing panel. The hedonic rating test was used to determine this acceptability. The panelists were untrained and selected from the students and employees of the Department of Food Technology and Rural Industries. The panelists (13) were asked to assign appropriate score to each product tested on a 1 to 9 point hedonic scale for characteristics color, flavor, texture and overall acceptability of mixed vegetables pickles developed from carrot, green chilli and brinjal with and without fermentation. The scale was arranged such that: 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like or dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = dislike extremely.

Storage studies

The mixed vegetable pickles were stored at room temperature (20-32°C). The different parameters like color, flavor and texture were observed at a regular interval of 1 month up to 4 months.

Results and Discussion

Chemical composition of fresh carrot, green chilli and brinjal

The Chemical composition of the fresh and fermented carrot, green chilli and brinjal was determined and the results are given in Table 1. The moisture content, protein, ash, acidity and vitamin

Table 1. Chemical composition of fresh carrot, brinjal and green chilli

Chemical composition (%)	Fresh vegetable			Fermented vegetable		
	Carrot	Green chilli	Brinjal	Carrot	Green chilli	Brinjal
Moisture	88.2	86.2	92.5	83.4	81.3	87.58
TS	11.8	13.8	7.5	16.6	18.7	12.42
Protein	1.16	2.6	1.4	2.25	2.3	2.1
Ash	0.52	3.2	1.68	6.32	6.1	9.3
pH	6.74	6.25	5.52	4.47	5.58	4.379
Acidity	0.135	0.25	0.128	0.795	0.81	0.78
Vitamin C (mg/100g)	8.56	83.88	2.9	0.001	10.02	0.001

Table 2. Rate equations during fermentation of carrot, green chilli and brinjal

Vegetable	Fermentation condition	Higher rate	Slower rate
	A	% Acidity=$0.138e^{0.096t}$	% Acidity =$0.519e^{0.007t}$
Carrot	B	% Acidity =$0.140e^{0.11t}$	% Acidity =$0.619e^{0.005t}$
	C	% Acidity =$0.144e^{0.125t}$	% Acidity =$0.778e^{0.002t}$
	A	% Acidity =$0.249e^{0.085t}$	% Acidity =$0.517e^{0.013t}$
Green chilli	B	% Acidity =$0.254e^{0.098t}$	% Acidity =$0.624e^{0.010t}$
	C	% Acidity =$0.264e^{0.109t}$	% Acidity =$0.714e^{0.007t}$
	A	% Acidity =$0.131e^{0.140t}$	% Acidity =$0.499e^{0.011t}$
Brinjal	B	% Acidity =$0.138e^{0.152t}$	% Acidity =$0.563e^{0.011t}$
	C	% Acidity =$0.142e^{0.174t}$	% Acidity =$0.679e^{0.006t}$

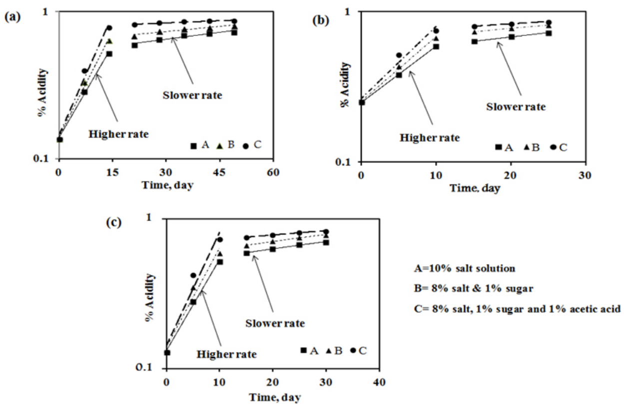

Figure 1. Change in acidity production with time during fermentation: (a) carrot, (b) green chilli and (c) brinjal

C content of carrot (from Table 1) are obtained 88.2%, 1.16%, 0.52%, 0.135% and 8.56 mg/100 g, respectively. These values including calorie content (approximately 47 Cal/100 g) are more or less similar to the result obtained by Gopalan *et al.* (1991) who have reported the chemical constituents of carrot as moisture (86%), protein (0.9%), and ash (1.1%); whereas, the values reported by Karmoker *et al.* (2011) moisture (86%), protein (1.70%) and ash (0.70%). The variation may be due to the maturity and varietal differences.

From Table 1, the moisture content of green chilli is 86.2%, protein 2.6%, ash 3.2%, acidity 0.25% and vitamin C 83.88 mg/100 g, respectively. The chemical compositions as well as energy content (approximately 55.2 Cal/100 g) are more or less similar to those reported by Ferdous *et al.* (2007) who found 87.4% moisture, 2.8% protein, 3.1% ash, 0.27% acidity and 94.86 mg/100 g vitamin C. The little variation may be due to differences in the maturity stage, variety and climatic condition as well.

The chemical composition of brinjal (Table 1) shows moisture, protein, ash, acidity and vitamin C content as 92.5%, 1.4%, 1.68%, 0.128% and 2.9 mg/100 g, respectively. The chemical compositions as well as energy content (approximately 30 Cal/100 g) are very close to the results found by Chen and Li (2003) who reported the 92% moisture, 1.4% protein, 12% vitamin C. Chen and Li (2003) reported that the fat content of carrot is negligible (0.3%) and hence it is not determined in this study. The variation in composition may be due the variation in maturity stages, variety, gaps between harvest and determination.

Fermentation kinetics of carrot, green chilli and brinjal

Carrot, green chilli and brinjals were allowed to undergo fermentation using three levels of salt solutions. The salt solutions were prepared by 10% salt, 8% salt plus 1% sugar; and 8% salt plus 1% sugar and 1% acetic acid. Periodic inspection was conducted during the fermentation up to the completion of fermentation. The periodic inspection was observed in terms of acidity of carrot, green chilli and brinjal during the whole period of fermentation. The experimental data were analyzed as per the methods described by several researchers (Stanbury *et al*., 2000; Gardner *et al*., 2001; Iqbal and Islam, 2005; Dalsenter *et al*., 2005). Fermentation progressed and the acidity (expressed as lactic acid) increased with immersion time. The rate of acid formation is higher at the initial period and then the rate falls as time progressed. It is seen that two rate periods are obtained in one period increase in acidity is faster (later termed as higher rate) and the other increase in acidity is slower (later termed as slower rate). The acidity production versus fermentation time of carrot, green chilli and brinjal were plotted on a semi-log coordinate and regression lines were drawn in Figure 1.

From the developed regression lines (Figure 1) and regression equations (in the form of % Acidity = Ae^{kt} as shown in Table 2) it is seen that acid production continues at faster rate (higher k value) during first 15 days and thereafter the rate is slower (with lower k value) for carrot. From Figure 1 (a) and equations (Table 2), the acid production is the fastest and highest in 8% salt plus 1%sugar and 1% acetic acid solution (for k value 0.125) and followed by acid production in 8% salt plus 1% sugar solution (with k value 0.11) and the lowest rate of acid production was in 10% salt solution (low k value 0.096) for the higher acid production period. For the slower rate period, it is seen that carrot in 10% salt solution gave the highest k value (0.007) and the lowest k value (0.002) is for carrot fermented in 8% salt plus 1% sugar and 1% acetic acid solution. The initial acid content of carrot was 0.135%. Maximum acidity (0.865%) observed at the 49th days of fermentation for sample which was

Table 3. Changes in chemical composition fermented carrot green chilli and brinjal

Chemical composition	Carrot	Green chilli	Brinjal
Moisture	83.4	81.3	87.58
TS	16.6	18.7	12.42
Protein	2.25	2.3	2.1
Ash	6.32	6.1	9.3
pH	4.47	5.58	4.379
Acidity	0.795	0.81	0.78
Vitamin C (mg/100g)	0.001	10.02	0.001

Table 4. Average chemical composition of mixed vegetable pickles

Chemical composition	Pickle without fermentation	Fermented Pickle		
		10% salt	8% salt plus 1% sugar	8% salt plus 1% sugar and 1% acetic acid
Moisture	63.745	58.91	59.48	59.23
TS	36.25	41.09	40.52	40.77
Protein	1.915	2.74	2.81	2.62
Fat	5.94	6.805	6.33	6.57
Ash	2.132	6.887	6.69	6.65
pH	3.95	3.145	3.04	2.71
Acidity	0.8072	1.94	1.99	2.248

Table 5. Mean score for color, flavor, texture and overall acceptability of processed pickles

Sample	Sensory attributes			
	Color	Flavor	Texture	Overall acceptability
101	6.85^a	6.31^b	7.31^a	6.31^b
201	7.31^a	7.08^a	6.54^b	7.00^a
301	7.15^a	7.46^a	6.54^b	7.00^a
401	6.92^a	6.92^a	7.15^{ab}	6.62^a

*Sample means having the same letter suffix do not differ significantly at 5% ($P < 0.05$) level of significance.
101= pickle from fresh vegetables
201= pickle from vegetables fermented in 10% salt solution
301= pickle from vegetables fermented in 8% salt and 1% sugar solution
401= pickle from vegetables fermented in 8% salt, 1% sugar and 1% acetic acid solution

fermented in 8% salt, 1% sugar and 1% acetic acid and followed by the sample fermented in 8% salt plus 1% sugar solution (0.795% acidity) and the lowest acid production was in 10% salt solution (0.725%).

It is seen that two rate periods exists in fermentation of green chilli (faster and slower period) and follows similar order in k value Figure 1 (b) as noted for carrot. Maximum acidity observed at the 25th days of fermentation for all samples. Among the three samples, the sample which was fermented in 8% salt plus 1% sugar and 1% acetic acid solution contains the highest acidity (0.855%) followed by the sample fermented with 8% salt plus 1% sugar solution (0.81% acid). Sample fermented in 10% salt solution contained the lowest acid (0.72%) after fermentation for 25 days.

Brinjal when fermented in three different solutions noted above gave increased level of acidity with time and plotted data in Figure 1 (c) showed first order reaction kinetics as before for carrot and green chilli and the regression equations were developed (Table 2). Again two rate periods were observed. For the first period k value was high for sample fermented in 8% salt plus 1% sugar and 1% acetic acid and was followed by that fermented in 8% salt plus 1% sugar while the lowest k value was given by brinjal fermented in 10% salt solution. On the other hand, for the second period however the k values were reversed to that of first period. Maximum acidity observed at the 30th days of fermentation for all samples. Among the three samples, the sample which fermented with 8% salt plus 1% sugar and 1% acetic acid contains the highest acidity (0.83% acid) followed by sample fermented with 8% salt plus 1% sugar (0.78% acid).

The observed faster periods (higher rate period) at the beginning of fermentation has also been observed by Iqbal & Islam (2005) and Ferdous *et al.* (2007). The slower period (second period or slower rate period) with lower rate constant may be attributed to destruction of lactic acid by some acid tolerant yeasts (grow generally at 10 to 15% salt) such as genera of Mycoderma, Debaromyces and Pichia (commonly termed as Mycoderma). They destroy lactic acid by oxidation noted by Mitchell et al. (2004) and Iqbal and Islam (2005). This first order type trend in acid development may be related to exponential growth of bacteria responsible for fermentation (Menezes, 1995; Ikasari and Mitchell, 2000; Iqbal and Islam, 2005; Dalsenter *et al.*, 2005). The sample which was allowed to undergo fermentation with 8% salt and 1% sugar fermented rapidly compared with 10% salt, which is similar to that reported by Iqbal and Islam (2005) and Ferdous *et al.* (2007). The reason behind this is that some vegetables are deficient in sugar and are liable to develop undesirable types of bacteria unless a small amount of sugar is added and the lactic acid bacteria require small amount of salt in the medium for optimal growth, but excess salt inhibits growth. The highest acidity attained by fermentation of all vegetables which allowed fermentation at 8% salt, 1% sugar and 1% acetic acid probably due to the acetic acid (in presence of sugar and salt) which may diffuse into the product by diffusion due to concentration gradient resulting in rate constant similar to first order type reaction constant (Menezes, 1995; Iqbal and Islam, 2005; Dalsenter *et al.*, 2005; Ferdous *et al.*, 2007).

During fermentation, carrot changed its color from deep orange to light orange, green chilli changed its color from bright green to olive green and brinjal changed its color from purple to light purple and became soft. Vegetables became very permeable and consequently absorb salt rapidly to come to equilibrium with the surrounding brine. The flesh became translucent rather than opaque. Amoa-Awua *et al*. (1997) reported that softening occurred due to the decomposition of pectic substances. The activity of enzymes causes softening of vegetables. Softening may also be due to the growth of *Bacillus vulgates* which is chiefly responsible for softening. Pickle blackening may be caused by *Bacillus nigrificans*, which produces a dark water-soluble pigment. Pickle softening results from the production of pectinases, which break down the cement like substance in the wall of the product (Jay *et al*., 2005). *Enterobacter* spp., lactobacilli, and pediococci have been implicated as causes of a condition known as "bloaters," produced by gas formation within the individual pickles. Pickle softening is caused by pectolytic organisms of the genera *Bacillus*, *Fusarium*, *Penicillium*, *Phoma*, *Cladosporium*, *Alternaria*, *Mucor*, *Aspergillus*, and others. The actual softening of pickles may be caused by any one or several of these or related organisms. Jay *et al.* (2005) and Gardner *et al.* (2001) have reported that fermentation was initiated by the species *Leuconostoc mesenteroides* and continued by the other lactic acid bacterial species. In general this species initiate more rapidly than species of genera *Lactobacillus* and *Pediococcus*; however, this species is not equally tolerant to salt. Since it is desired to produce acid as rapidly as possible and thus to lower the PH and to produce a low oxidation-reduction potential, it is logical to use salt concentrations low enough to favor the growth of *Leuconostoc*. There is also evidence to indicate that the *Leuconostoc* tend to produce condition favorable for rapid growth of the Lactobacilli and Pediococci. Jay *et al.* (2005) pointed out that for traditional fermentation in most brine; *L. planterum* is the most important bacterium developing acidity in both low and high salt brines. The rapid growth of lactic acid producers and a lowered oxidation-reduction potential are unfavorable to growth of yeast as well as the non-spore and spore forming bacteria.

Proximate composition of fermented carrot, green chilli and brinjal

After fermentation, the vegetables which were fermented in the solution of 8% salt plus 1% sugar were considered the best and the chemical analysis were carried out for these samples only. The results are given in Table 3. The composition of carrot, green chilli and brinjal was changed after the completion of fermentation. Moisture content reduced and total solids (TS) increased. Protein content increased slightly where ash content increased highly probably due to the reduction of moisture content and salt uptake during fermentation in brine solution. This process of salt uptake and moisture reduction is somewhat similar with osmotic dehydration process in which product become concentrated due to water removal and solute uptake. The vitamin C content was drastically reduced after complete fermentation. Vitamin C follows first order types reaction kinetics as the k value is temperature dependent (Gardner *et al*., 2001; Heldman and Lund, 2007). Long time exposure in room temperature use a factor influencing vitamin C degradation with heating, oxidation, water activity, pH and metal traces (Jay *et al*., 2005; Heldman and Lund, 2007). Acidity (expressed as lactic acid) increased as carbohydrates and sugar converted to acid. Moisture content reduces as water molecules diffused freely across the membrane from dilute to concentrated solution. If salting causes vegetable to lose water, the fat-soluble vitamins become more concentrated. During fermentation carbohydrates are converted to acid which has more nutritional value than carbohydrates (Hui and Özgül Evranuz, 2012). The stabilized foods contain other nutrients in adequate amounts when compared with the original perishable tissues. The proliferation of lactobacilli in fermented vegetables enhances their digestibility and increases vitamin levels. These beneficial organisms produce numerous helpful enzymes as well as antibiotic and anti carcinogenic substances. Nutrients levels are sometimes increased due to presence of yeast.

Proximate composition of mixed vegetable pickles with and without fermentation

The chemical composition of mixed vegetables pickle was compared with fermented vegetables pickles. From Table 4, it is seen that the fermented pickles contain less moisture and high amount of protein, fat and ash than the pickle without fermentation. The pickles which were fermented by 10% salt contain the lowest amount of moisture and highest amount of fat and ash content. The pickle which was fermented by 8% salt plus 1% sugar contains the highest amount of protein. Acidity was highest in the pickle which was fermented by 8% salt plus 1% sugar and 1% acetic acid which may be due to diffusion of acetic acid and the process is similar to first order type reaction with identical rate constant (Iqbal and Islam, 2005; Ferdous *et al*., 2007).

Sensory evaluation of fermented pickles

The mean score for color, flavor, texture and overall acceptability of processed fermented pickles are given in Table 5. A two way analysis of variance has been carried out for color, flavor, texture and overall acceptability and result revealed that there is no significance difference ($P < 0.05$) in the color of samples. However, the samples differ significantly in terms of flavor, texture and overall acceptability. From the mean score of overall acceptability (Table 5) it is seen that the samples 201, 301 and 401 are the best product securing score 7.00, 7.00 and 6.62, respectively and are ranked as 'like moderately' and are significantly different from sample 101 securing lowest score (6.31) out of 9 and ranked as 'like slightly'. It is thus concluded that fermented mixed pickles are better than mixed pickles using fresh vegetables.

Storage studies of mixed vegetables pickles

Four different samples of pickle were used for storage studies at room temperature (20°C-32°C) from 0 to 4 months on physical properties such as color, flavor and texture of pickle samples. All the processed samples were in good condition up to 4 months of storage at ambient temperature except the sample 101 (which was slightly spoiled after 4 month). The color of all samples was unchanged. No off flavor was observed in samples up to 4 months of storage except sample 101 (which gave off flavor).

Conclusion

This study focused on the effective means of processing and preservation of mixed fermented vegetable pickle from carrot, green chilli and brinjal, as well as to observe the shelf life of mixed fermented pickle. The study revealed that the selected vegetables may be processed by fermentation technique. It has the potential of becoming one of the most profitable food items in Bangladesh and can diversify the use of such vegetables round the year. Besides the canned and frozen or salted food, rural-based fermented food processing industry may be planned and developed in this country.

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