2. REVIEW OF LITERATURE

The term fermented foods are used to describe a special class of foods that contain a complex mixture of carbohydrates, proteins, fats, etc., undergoing simultaneous modification under the action of a variety of microorganisms and enzymes. Fermented foods are of great significance because they provide and preserve vast quantities of nutritious foods in a wide diversity of flavours, aromas and texture, which enrich the human diet. There is an evidence of humans fermenting foods for the last 5000 years (Ray, 1992). Sumerians worshiped a goddess of beer. In the tropics, fruit is placed in a hole in the ground to ferment. In the Arctic, fish are fermented to the consistency of mush, and the natives claim it is their health secret. Africans drink sorghum beer and eat fermented millet porridge. The Swiss eat fermented dairy products. The Scotch ferment oak cakes. The French love wine and cheese. Russians drink rye Kvass and Kombucha, fermented tea. Asians eat soy sauce, miso, sake, pickled ginger, daikon radish and other vegetables. The Japanese love umeboshi plums. Indonesians eat tempeh. Koreans love spicy kimchi. Indians eat idli, dosas and yogurt. Germans eat sauerkraut and Americans used to make and eat live-ferment foods. A clear picture is seen on the regional practices and importance for the utilization of fermented foods (Shivani, 2004).

2.1 General fermented products

The development of fermented products is a worldwide application based on agricultural produce and food habits. Over the years, several products fermentation have been attempted. Some of the products are used with the traditional background of preparation and in recent years attempts have been made for industrialization of some of the products. Thus rice based (Navarro and Dizon, 1991; Lee et al., 2002;
Fruits and vegetables are rich sources of vitamins and minerals and play an important role in human nutrition. They are consumed as such or after being acted upon by natural microorganisms and thus are known as fermented foods. Fruits are naturally rich in juices and sugar and are slightly acidic, therefore, they are suitable medium for the growth of yeast, which can in turn induce alcoholic fermentation and rapid conversion of sugars into ethanol (Strobel and Tarr, 1990; Runge et al., 1996; Araujo et al., 2011). The alcoholic fermentation of fruits for wine preparation (Akubor, 1996; Hwan et al., 1997, Ayogu, 1999; Wang, 2009; Hui et al., 2010; Reddy and Reddy, 2011) and acetic acid fermentation for vinegar preparation (Yae et al., 2007; Yang, 2007; He et al., 2008) is utilized. Fruits can also be stabilized via lactic acid fermentation (Mousavi et al., 2011; Pereira et al., 2011; Kretschmer and
Vegetables which have a low sugar content and neutral pH provide a natural medium for microbial development. Vegetables are routinely fermented with lactic acid bacteria (Sethi, 1990; Chavasit et al., 1991; Delclos, 1992; Fedorova et al., 1993; Nabais and Malcata, 1995; Kraevska et al., 1996; Desai and Sheth, 1997; Noguchi, 1998; Karovicova et al., 1999; Ozcelik and Ulu, 2002; Yoon et al., 2006; Panda et al., 2007; Hua et al., 2009; Diaz and McFeeters, 2011), by natural fermentation (Uma et al., 1998; Xiaoyang et al., 2009) and a very few studies are based on alcoholic fermentation (Lee and Cho, 1996; Nakamura et al., 1996; Horiuchi, 2000; Dianfeng et al., 2009), acetic acid fermentation (Hur and Lee, 1998; Horiuchi, 2000; Zhaojun et al., 2003) and also on mixture of lactic acid bacteria and yeast fermentation (Moroz and Roczniakowa, 1993; Passos et al., 1997; Kim et al., 1997; Kohajdova and Karovicova et al., 2004). Some of the researchers have carried out fermentation in combination with fruits and vegetables too. (Tsukui et al., 1996; Cheigh et al., 1998; Jung et al., 2000; Shanhai et al., 2005; Feng and Ying, 2007; Marques et al., 2010; Mestry et al., 2011).

### 2.2 Fermented vegetable products

Vegetables are strongly recommended in the human diet since they are rich in antioxidants, vitamins, dietary fibres and minerals. The major part of the vegetables consumed in the human diet are fresh, minimally processed, pasteurized or cooked by boiling in water or microwaving. Minimally processed and, especially, fresh vegetables have a very short shelf-life since subjected to rapid microbial spoilage and the above cooking processes would bring about changes in physical characteristics and chemical composition of vegetables (Zia ur Rehman et al., 2003; Zhang and Hamauzu, 2004). Among the various technological options, lactic acid fermentation
may be considered as a simple and valuable biotechnological application for maintaining and/or improving the safety, nutritional, sensory and shelf-life properties of vegetables (Buckenhuskes and Holzapfel, 1997; Steinkraus, 1996). Some of the salient work carried out on vegetable fermentation are as follows.

Mukerjee (1987) demonstrated that Indian farmers can safely preserve their surplus vegetables by lactic acid fermentations on the farm. This improves the supply and availability of vegetable foods throughout the year and improves nutrition of Indian population.

Kuensch et al. (1992) reported that vitamin C in cabbage plays an important role in sauerkraut manufacture, both as an antioxidant and as an indicator of the fermentation process. Cooking the sauerkraut followed by packaging in aluminium pouches and gentle pasteurization improved product shelf-life and resulted in a vitamin C content of more than 15 mg/100g even after several years.

Garlic and cucumber fermentation were studied by Gerdauskene et al. (1992) in a search for ways of combating taste monotony in foods experienced by submarine and spaceship crews. The products were packaged in multicomponent foil (polyester-saran-polyethylene type) packs. They could be kept for 2 year at 4±2°C or for approximately 1.5 months at 25±1°C.

Biosynthesis of B vitamins such as folacin, pyridoxine, pantothenic acid, pH and sensory properties were studied by Hozova et al. (1993) during fermentation (8-9 days at 20±2°C) and storage (4°C) of cut cabbage samples. Results were compared with those for a naturally fermented cabbage control. After 40 hrs of fermentation, folacin content in samples increased from an initial level of 0.077 mg/kg to 0.460 mg/kg. Pantothenic acid increased by 83% after 30 days of storage. Pyridoxine
contents with initial value 14.6 mg/kg varied during fermentation for all samples. During fermentation, pH with an initial value 6.53 decreased more rapidly in samples than in control samples.

**Sapundzhieva et al. (1994)** optimized the conditions for lactic fermentation of vegetables and developed new relish type items based on these fermented products. Acceptable fermented cucumber was obtained from sliced vegetables after 18 hrs of fermentation at 37°C using 5% starter culture. Sliced carrots required 24 hrs of fermentation at 37°C using 2% starter culture, while celery required 42 hrs. The fermented products were developed by incorporating into 2 types of relish: 50% fermented vegetable plus tomato puree, seasoning and modified starch; or 60% fermented vegetable, vinegar, sugar, seasoning and xanthan gum.

**Kuchta et al. (1994)** fermented vegetables such as gourd, cabbage, celery by *Lactobacillus plantarum, Lactobacillus brevis* and *Lactobacillus pentosus*. The gourds were fermented for 4 days, cabbage for 7 days and celery for 9 days.

Response surface methods were utilized by **Nabais and Malecata (1995)** to preserve carrot slices using a brine containing lactic acid. Results indicated that temperature may be manipulated to give rise to any desired increase or decrease in the quality factor chosen, which may be relevant in attempts to industrially improve carrot preservation processes based on lactic acid fermentation.

**Lee and Cho (1996)** evaluated dried pumpkin powder as a substrate for alcohol fermentation by *Saccharomyces cerevisiae*. Optimum conditions for alcohol fermentation by *Saccharomyces cerevisiae* were an incubation temperature of 30°C, initial pH of 6.0, ripe pumpkin powder concentration of 10% and inoculation level of
1.3x10^6 cells/ml liquid medium, with 4 days as incubation period. Ethanol production under the optimum conditions was 5.85g/100g.

**Desai and Sheth (1997)** selected the six isolates of lactic acid bacteria and studied their homo and hetero fermentative character, salt tolerance and rate of acid production. The controlled fermentation of brined beet, carrot, cabbage, cucumber, cauliflower, ginger, green chilli, onion, radish and turnip was carried out using the combination of the 6 isolates. The fermented brined vegetables attained the desired acidity within 4 days at 28-30°C and could be preserved at 28-30°C by adding 0.1% sorbic acid to the brine.

Effects of lactic fermentation on sensory and nutritional properties of bittergourd (*Momordica charantia*) and fenugreek leaves (*Trigonella foenumgraecum*) were determined by **Uma et al. (1998)**. *Pediococcus pentosaceus* was selected from isolates obtained from the naturally fermenting bittergourd and fenugreek leaves based on its high titre and broad spectrum of inhibitory activity against spoilage organisms. This strain was then employed for fermentation of bittergourd and fenugreek which resulted in a more acceptable product having enhanced fat, pyridoxine and ascorbic acid levels. In addition vitamin B_{12} was formed in the fenugreek as a result of the fermentation.

Studies were conducted by **Preiss et al. (1999)** to assess effect of lactic acid fermentation on biogenic amine content of red beets, red and green peppers and green beans. Small amounts of tyramine were formed during fermentation of green beans, red peppers and green peppers, and small amounts of spermidine were formed during fermentation of red beets. No significant change in biogenic amine concentration occurred during storage. Biogenic amine concentration in these fermented vegetables were low, thereby no health hazard is expected.
Effects of starter culture (*Lactobacillus curvatus* or *Lactobacillus plantarum*) on biogenic amine content during fermentation of sauerkraut was investigated by Halasz et al. (1999). Starter culture concentration for effective sauerkraut fermentation was found to be in the range 5×10⁶-2×10⁷/100g cabbage; for *Lactobacillus curvatus* the lower value was preferable to avoid increased tyramine concentration.

Experiments were conducted by Ic and Ozcelik (1999) for over 2 years on natural fermentation of cucumbers in brines containing up to 0.4% calcium chloride, 3 to 5% sodium chloride and 0.2% acetic acid. Lactic acid bacteria count was maximum (10⁸/ml) on days 5 to 8 of fermentation, after which a decrease was observed. Yeast growth was not observable initially, but considerable yeast growth (10⁶ cells/ml) was determined at the end of fermentation.

A technology for the manufacture of yoghurt incorporating vegetable puree (tomato, cucumber, green bean, red pepper, carrot or beetroot) and fermenting the vegetables was developed by Lozanova and Spasov (1999) by a mixture of vegetables whereas Kudoh and Matsuda (2000) developed yoghurt by using sweet potato and reported that antioxidative activity of yoghurt increased rapidly during fermentation.

Pyo et al. (2000) isolated fourteen volatile compounds from mustard leaf kimchies during fermentation. Fermentation of kimchi markedly decreased the content of isothiocyanates, which are responsible for the pungency of mustard leaf.

Different ratios of starter cultures – *Leuconostoc mesenteroides*, *Lactobacillus plantarum* and *Pediococcus acidilactici* for fermentation of vegetable mix composed of carrots, cabbage, onions were studied by Savard et al. (2000). The results showed
that higher levels of acetic acid and a lower content of lactic acid was found in higher ratio inoculated fermented vegetables.

Two different strains of *Lactobacillus plantarum* (P27-7 and P27-8) and 1 strain of *Leuconostoc mesenteroides* were assessed for their abilities to produce lactic acid and to degrade sugars, as indicators of their suitability for use in pickling vegetables by *Girado and Mazas (2000)* and they concluded that all three organisms are capable of lactic fermentation suitable for application in pickling of vegetables.

*Gardner et al. (2001)* studied various lactic acid bacteria for the fermentation of cabbage, carrot and beet-based vegetable products. It was found that a starter culture consisting of *Lactobacillus plantarum*, *Pediococcus acidilactici* and *Leuconostoc mesenteroides* accelerated the fermentation process and prevented deterioration of fermented products for up to 90 days.

Effects of salt content, fermentation temperature and lactic starters on changes in microbial flora, pH and acidity of cabbage were investigated during sauerkraut fermentation by *Yu et al. (2001)*. Sauerkraut of desirable quality could be obtained when cabbage with 2.5% added sodium chloride was simultaneously inoculated with $10^6$cfu/g *Leuconostoc mesenteroides* and $10^6$cfu/g *Lactobacillus plantarum*, and fermented at 18°C for 14 days or at 25°C for 7 days.

Problems related to shelf life and microbiological quality of fermented cucumber pickles during storage were evaluated by *Ozcelik and Ulu (2002)*. Cucumber was fermented in brine containing 4% sodium chloride, 0.2% calcium chloride, 0.2% acetic acid and *Lactobacillus plantarum* starter and were kept at 20°C for 6 months and monitored for physicochemical, microbiological and sensory
properties. Reducing brine pH, retarded microbial growth, but did not inactivate microbes. Pasteurization ensured microbiological safety.

Investigations were conducted on changes in oxalic acid, nitrate, phenolic acid and biogenic amine contents of vegetables (including red beets, kohlrabi and white cabbage) as a result of lactic acid fermentation by Preiss et al. (2002). Oxalic acid concentration, in red beets decreased by approximately 70% during lactic fermentation and storage for up to 4 months. Approximately half of the oxalic acid originally present was decomposed, while, the rest of acid was approximately equally distributed between the beets and the brine. Fermentation decreased nitrate concentration in red beets, kohlrabi and white cabbage by approximately 50, 50 and 87% respectively. Concentration of biogenic amines increased considerably during lactic acid fermentation of white cabbage. Concentration of phenolic acids in white cabbage showed only small decrease during lactic acid fermentation. While Spicka et al. (2002) optimized the dose of starter with respect to biogenic amines content and sauerkraut quality and reported that for practical application, a dose of $>=5 \times 10^6$ cfu/g Lactobacillus plantarum CCM 3769 is optimum and it decreased biogenic amine levels and also depressed proteolysis and resulted in sauerkraut with favourable sensory properties.

Gasztonyi et al. (2002) attempted to develop a sliced carrot and orange juice lactic fermented product, using a combination of Lactobacillus plantarum fermentation and enzyme treatment. The combination of lactic fermentation and enzyme treatment (Rohament-PL used as an endo-polygalacturonase and a mixture or Rohament-PL and Rohalase used 7069 as a cellulase) of sliced carrot and orange juice
resulted in a homogeneous product, with pleasant sensory properties, after an 18 hrs fermentation period.

**Viander et al. (2003)** examined the impact of low sodium chloride and mineral salt concentrations on the spontaneous fermentation process of white cabbage into sauerkraut and sauerkraut juice. It was shown that sauerkraut and sauerkraut juice could be produced with a very low sodium chloride concentration as well as with a low mineral salt percentage. The sauerkraut juice fermented with 0.5% mineral salt was considered to have the best taste.

**Ishikawa et al. (2003)** investigated 2 strains of lactic acid bacteria, *Leuconostoc sp.* D-133 and *Lactobacillus casei* L-14, as a mixed-starter culture for akakabu-tsuke-Japanese pickle. Fermenting red turnip pickles developed good flavour, and no off flavour compounds were produced. Addition of these strains also suppressed colouring of akakabu-tsuke for a long period.

Quality of kimchi prepared from red pepper powder irradiated at 0, 5, 10, 15 or 20 kGy to reduce the microbial load, was determined by Lee et al. (2004). Kimchi fermented using red pepper powder irradiated at 5 kGy had better aroma and colour, and scored highest for flavour than the untreated control and all other kimchies.

**Montano et al. (2004)** reported that from a nutritional standpoint, fermentation method of preservation is superior when compared to other packaging/preservation methods by studying the effect of processing, with or without lactic fermentation on the nutritional composition of pickled garlic. On a dry basis, the fermented product was found to have a higher content of riboflavin, α-tocopherol and most individual amino acids, but a lower thiamin level than the unfermented product.
Yunoki et al. (2004) developed a method for conducting lactic acid fermentation of potato pulp, an agricultural by-product, by *Rhizopus oryzae* NBRC4707 and they suggested that it could be useful for monitoring the extent of lactic acid fermentation and ester formation could contribute to enhanced palatability of potato pulp.

Sour onion was produced by Roberts and Kidd (2005) through lactic fermentation using sweet, white and yellow onions during at 18°C. Brine from sauerkraut or cabbage slices was used to inoculate the onions. The sour onion produced from the fermentation process contained 1.2 to 1.5 g lactic acid/100 ml and had a pH of 3.25 to 3.35. Results of sensory analysis showed that the product produced with yellow storage onions had the best flavour, texture and colour. The final product tasted similar to sauerkraut, with a tart acidic flavour. The sour onion had an onion flavour, and unlike raw onions, was not pungent.

Effects of a mineral salt preparation with a low sodium chloride content were investigated by Wiander and Ryhanen (2005) on the microbiological quality and sensory properties of sauerkraut juice. Sensory analysis revealed the juices to be highly acceptable with a mild, yet sauerkraut-like flavour. The best juice, in terms of overall sensory quality was found to be that from cabbage fermented with the mineral salt preparation and equal numbers of *Leuconostoc mesenteroides* and *Lactobacillus plantarum*.

Antioxidant activity of extracts of white cabbage and sauerkraut was studied by Ciska et al. (2005) and they found that the sauerkraut extract contained higher levels of total phenols than the white cabbage extract (8.25 vs. 5.72 mg/g), but phenols from both extracts exhibited antioxidative and free radical scavenging
properties. The total antioxidant capacity of the sauerkraut extract was stronger than that of white cabbage (0.031 vs. 0.025 mmol Trolox/g), but the ability of the white cabbage to scavenge diphenyl picryl hydrazyl radicals was slightly higher than that of the sauerkraut extract, as was its reducing power.

**Wen et al. (2006)** conducted a study on the optimum processing conditions for producing a fermented pickle with health promoting properties. The pickle was produced using longans, mustard (*Brassica juncea* var. *capitata*), *radix codonopsis*, *radix astragalus*, *Lycium barbarum*, with *Lactobacillus plantarum* as starter. Optimum processing conditions were: Chinese medicinal plant materials 8%; salt 4%; sugar 1%; inoculum size 3%; fermentation temperature 30°C; and fermentation time 4 days.

Processing technology of bittergourd yoghurt with no added sugar was studied by **Yan et al. (2006)**. Results showed that good quality bittergourd juice could be produced using 100 mg/kg zinc gluconate as a colour protection agent and 1% beta-cyclodextrin as a bitterness binding agent. Optimal processing conditions were found to be: ratio of bittergourd juice to fresh milk 3:7; aspartame 0.05%; stabilizer composition 0.15%; starter culture of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* at a ratio of 1:1 and an inoculation of 3%; fermentation temperature 42°C; and fermentation time 5 hrs.

Effects of lactic acid fermentation were investigated on the sensory properties of sweet potatoes by **Panda et al. (2007)**. Sweet potatoes (var. ST14) were pickled by lactic fermentation by brining cut and blanched roots in common salt (2 to 10%) solution and incubated the mixture with a strain of *Lactobacillus plantarum* (MTCC 1407) for 28 days. Sensory analysis rated the sweet potato pickles as acceptable on the basis of texture, taste, aroma, flavour and aftertaste.
Bayizit et al. (2007) studied the addition of yoghurt, whey, lactic acid and starter culture on the fermentation of pickled carrots were examined. Addition of acid, starter culture, yoghurt and whey were effective in controlling carrot fermentation as these favoured the growth of lactic acid bacteria. Mohapatra et al. (2007) developed a curd-like product by fermenting boiled β-carotene-rich sweet potato puree and cows' milk with curd (starter) culture (Lactobacillus bulgaricus, Streptococcus lactis, Streptococcus diacetilactis etc.).

Effects of temperature (22, 26 and 32°C) and salt concentration (2, 2.5 and 3%) were investigated on lactic acid fermentation of radishes by Sharma and Joshi (2007). Fermentation of grated radishes was carried out naturally and in the presence of Lactobacillus plantarum, Pediococcus cerevisiae and Streptococcus lactis var. diacetylis individually, or sequentially. Best results were obtained after sequential culture with 2.5% salt at 26°C. In all fermentations apart from those with Pediococcus cerevisiae and Lactobacillus plantarum, a temperature of 26°C led to optimal physicochemical and sensory properties.

Optimization of fermentation conditions for production of β-carotene by Rhodotorula glutinis DM28 using a face-centered central composite design was reported by Malisorn and Suntornsuk (2008). Maximum β-carotene yield was achieved at 30°C; pH 6 and 80% dissolved oxygen. Optimization improved biomass and β-carotene production by 15%, such that after 24 hrs of fermentation under optimum conditions, biomass and β-carotene concentration reached 2.7g/l and 201µg/l.

Fang et al. (2008) reported that fermented potherb mustard (Brassica juncea, Coss.) pickle was relatively good method for the preservation of phenolic acids and antioxidants.
Sim and Han (2008) investigated antioxidative activities of red pepper seed kimchi extracts. 7% red pepper kimchi fermented for 6 days demonstrated the highest overall antioxidative activity, apart from nitrite scavenging activity, which was higher at the beginning than at the end of the fermentation period.

Chikamatsu et al. (2008) developed a soft fresh onion by spontaneous fermentation of onion at 50 to 85°C and 70 to 95% moisture followed by ageing of the fermented onion.

Lee et al. (2008) have reported that the pungency of capsicum was reduced by fermentation using Bacillus subtilis.

Emire and Sudip (2008) have investigated the influence of natural fermentation and controlled fermentation in diminishing the content of antinutrients, α-galactosides and increments in invitro protein digestibility of beans was investigated. Both types of fermentation diminish antinutrients and improve nutritional value of the bean flour and indicate the potential use of bean flour as an ingredient for fabricated foods.

Fermentation of green chillies during preparation of green pepper sauce was investigated by He et al. (2008). They suggested that addition of sugar or sugar-containing vegetables may improve the quality of the fermented sauce, and that reducing chlorophyll loss may be the key to colour retention in the sauce.

Kusznierewicz et al. (2008) observed that fermentation processes increased the initial values of antioxidant activity of cabbage. They indicated that the antioxidant capacity of sauerkraut probably have combined effects of wounding and chemical processes incurred by lactic bacteria.
Zhi (2008) studied the production of sugarless carrot yoghurt. Results showed that the optimal process was addition of milk to 25% carrot juice, 6% of a mixture of honey and fructooligosaccharide in a proportion of 1:1 and 0.4% stabilizer, fermentation with Lactobacillus bulgaricus, Streptococcus thermophilus and Bifidobacterium in a proportion of 1:1:2 at 42°C for 6 hrs. The product had a good flavour and nutritional value.

Panda et al. (2009) studied the pickling of anthocyanin pigment-rich sweet potato cubes by lactic fermentation by brining the cut and blanched cubes in common salt (sodium chloride, 2 to 10%) solution. They were then inoculated with a strain of Lactobacillus plantarum (MTCC 1407) and incubated for 28 days. Treatment with 8 to 10% brine solution was found to be sensorially most acceptable.

Natural fermentation of wax gourd was investigated by Xiaoyang et al. (2009). The major bacterial strains identified were Corynebacterium minutissimum, Bacillus pumilus, Shewanella putrefaciens, Hansenula anomalis, Saccharomyces cerevisiae and Lactobacillus plantarum. Results confirm that naturally fermented wax gourds can be eaten safely.

Kim et al. (2009) investigated the fermentation of garlic using 4 Lactic acid bacteria strains capable of growth in media containing garlic: Lactobacillus plantarum BIF, Lactobacillus bulgaricus KCTC 3188, Lactobacillus casei KFRI 704 and Lactococcus lactis subsp. cremoris ATCC 19257 and reported that concentration of volatile compounds and the major compound allinin did not change during fermentation.

The effects of amount of lactic acid bacteria starter, fermentation temperature and fermentation time on the sensory quality of preserved cherry tomatoes were
studied and fermentation conditions were optimized by Chunling et al. (2009). Cherry tomatoes were fermented with lactic acid bacteria at $10^6$ cfu/ml at 40°C for 15 hrs. The cherry tomatoes were then cooked in water containing 0.3% carboxymethyl cellulose, 1.1% citric acid and 45% sugar for 30 min, followed by dipping for 5 hrs, and dried at 55°C for 24 hrs in an electric blast drying oven. The final product had a good taste, colour and flavour.

History of manufacture and consumption of radish-based kimchies in Korea includes data on classification of different types of radish kimchies, fermentation methods, traditional preparation/usage and key ingredients was studied by Cho (2010).

Factors influencing accumulation of nitrite in cabbage during fermentation were investigated by Mei et al. (2010). Nitrite levels were found to peak during the early stages of fermentation. Nitrate was converted into nitrite by nitrate reductase from *Escherichia coli* and *Staphylococcus* in fermented brines.

Sensory attributes, gingerol content and volatile components of ginger paste produced by microbial fermentation were determined by Ku et al. (2010). Ginger fermented using *Lactobacillus plantarum* produced a ginger aroma and putrid taste, whereas ginger fermented with *Lactobacillus brevis* had decreased ginger aroma and taste, and generated a lemon flavour. Total gingerol content in fresh and fermented ginger was 100.19 and 89.55mg%, respectively. 61 volatile compounds were identified in fresh and fermented ginger, comprising: 8 monoterpenes; 21 sesquiterpenes; 8 oxygenated monoterpenes; and 9 oxygenated sesquiterpenes. The most abundant volatile component identified in fresh ginger was α-gingerberine (26.52%), whereas fermented ginger had increased levels of alcohol components.
Probiotic strain *Lactobacillus plantarum* L4 and strain *Leuconostoc mesenteroides* LMG 7954 were applied for the controlled fermentation of cabbage heads. The results concluded the production of fermented cabbage heads with added functional (probiotic) value and with lower sodium chloride concentration with expected shortened fermentation time and the *Beganovic et al. (2011)* reported that it could not only be of economic but also of ecological importance.

The fermentation patterns of kimchi prepared with pasteurized brined cabbage and added starters were similar to those of naturally fermented kimchi as reported by *Han et al. (2011)*. It is concluded that growth of lactic acid bacteria during kimchi fermentation contributed to increased flavour and health functionality of kimchi.

The influence of thermal treatment, pickling and fermentation on the content of glucobrassicin and its selected breakdown products in broccoli and cauliflower was investigated by *Sosinska and Obiedzinski (2011)*. The lowest content of glucobrassicin and the highest content of its breakdown products were present in raw, pickled and fermented vegetables in which the myrosinase remained active.

*Kuma et al. (2011)* developed the fermented milk products by fermentation with lactic acid bacteria in the presence of promoters, such as extracts of ginger, green onion and tea or oleic acid and its derivatives.

A strain of lactic acid bacteria was applied in low-salinity pickled processing of mustard tuber, using this lactic acid bacteria as fermentation starter in order to control harmful microbes was studied by *Weng et al. (2011)*. The end product quality of pickle mustard tuber by new technique was better than that of traditional product in flavor, texture and safety by sample evaluation method.
Fermented gingers were prepared using lactic acid bacteria derived from dairy products or kimchi and their chemical and sensory properties were investigated by Chun and Chung (2011). Ginger was fermented with Streptococcus thermophilus (GSt), Lactobacillus acidophilus (GLa), Lactobacillus plantarum (GLp) and Leuconostoc mesenteroides (GLm). The characteristic flavour of all the fermented gingers, including GLp, was decreased by fermentation. The authors concluded that GLp could be used as an ingredient in processed foods without lowering the sensory quality.

Use of mineral salt (28% potassium chloride, 57% sodium chloride), herbs and spices in combination with isolated lactic acid bacteria strains, for sauerkraut fermentation was studied by Wiander and Korhonen (2011). Final sodium chloride content in a fermented sliced white cabbage mixture was 0.5%. pH decreased to the desired level in approximately 20 hrs. All pressed sauerkraut juices had good microbiological quality. Sensory properties of all pressed juices were found to be either good or acceptable.

Suitability of mineral salts (0.8 to 1.5%), in combination with garlic and algae, for the natural fermentation of white cabbage to sauerkraut and sauerkraut juice were determined Wiander and Palva (2011). Final percentages of sodium chloride in sauerkraut were 0.5 to 0.9. Sauerkraut juice fermented using 0.8% mineral salt (0.5% sodium chloride) resulted in the best sensory quality. Yield of sauerkraut juice increased as the coarseness of cabbage used for fermentation decreased.

The antioxidant activities of kimchi at different fermentation times: short-term fermented kimchi (less than 7days) and over-ripened kimchi (greater than 2years) evaluated by Park et al. (2011). In conclusion, antioxidant activity of the over-
ripened was significantly higher than the short-term. The results of this study suggested that there was an increase in the antioxidant activity of fermented kimchi during the fermentation and ripening processes.

A fermented cabbage powder was developed by Kobayashi (2011). The method includes subjecting cabbage to lactic fermentation with *Lactobacillus* homolactic acid bacteria in the presence of sodium chloride; neutralizing the lactic acid in the fermented product with calcium, drying the fermented product and pulverizing the dried fermented product.

From the above literature study it brings out the fact that the work is mainly on cabbage, beet, carrot, cucumber, cauliflower, ginger, green chilli, onion, radish, pepper, garlic, kimchi and turnip but very few studies have been found regarding vegetable juices which stresses the need for further research in the field.

### 2.3 Fermented vegetable juices

Vegetable juices are attracting more attention due to the nutritional and phytochemical value of many vegetables. The lactic acid fermented juices can be produced by two procedures. The vegetable will be fermented by usual way and then it is processed by pressing to extract the juice. Otherwise, the vegetable will be first processed to get the raw juice and it is consecutively fermented. Then, fermentation types can be followed by any of the three *i.e.*, spontaneous fermentation by natural microflora, fermentation by starter cultures which are added into raw materials, and fermentation of heat-treated materials by starter cultures. (Hammes, 1990).

In many countries the consumption of lactic acid fermented vegetable juices have increased (Kopec, 2000). The fundamental reason for the development and
acceptance of fermented foods can be ascribed variably to preservation, improved nutritional properties, better flavour/aroma, upgrading of substrates to higher value products and improved health aspects (Kalantzopoulos, 1997).

Because of low acidity and high concentration of spoilage and spore-forming bacteria it was difficult to preserve vegetable juices such as carrot. Therefore, Liepe and Junker (1984) offered fermentation for preserving vegetable juice and produced fermented vegetable juices. Fermentation may be spontaneous by utilizing the carrot’s own lactic acid bacteria or may be controlled using a starter culture.

In the production of vegetable juices, lacto fermentation may also facilitate juice yield. Lactic starters such as Lactobacillus plantarum can produce pectolytic enzymes such as polygalacturonase, pectinlyase and pectinesterase (Sakellaris et al., 1988).

Bifidobacterium bifidum, Lactobacillus casei, Lactobacillus plantarum, Lactococcus diacetylactis, Leuconostoc mesenteroides, Leuconostoc oenos, Pediococcus pentosaceus and a mixed culture of Propionibacterium shermanii and Propionibacterium pentosaceus were used to ferment a model low salt (2.5% sodium chloride) cucumber juice brine at 22-26°C for 39 days. Each fermentation differed quantitatively in substrates and products formed, suggesting use of these bacteria as cultures to ferment low salt brined cucumbers and generate a variety of unique organoleptic properties. (Chavasit et al., 1991)

Karoviova et al. (1992) published that short chain organic acids production by lactic acid fermentation of vegetables (green pea and onion) may aid in the development of fermented vegetable juices.
Fermented vegetable juices were prepared by Afanaseva et al. (1992) by adding starters at 5x10^6 to 1x10^7 cells/g of vegetables, or 2 to 3% per total volume of juice. Fermentation was carried out at 28 to 45°C for 10 to 20 hrs to pH 3.8 to 4.2, and was stopped by heating to 90°C; sugar or salt was then added. The product was sterilized (25 minutes at 85°C) and stored for 1 year at 20°C. Nutritional properties of the juices were evaluated. Sauerkraut juice had high contents of protein, vitamins such as C, β-carotene, thiamine, riboflavin and minerals. Fermented red-beet juice contained lactic acid (<=0.5%), acetyl choline, proteins (1.7%), sugars (9%) and vitamins such as thiamine, riboflavin and C. Fermented juices from carrots, celery, tomatoes and hot pepper were equally valuable.

Preparation of a beverage from Beta vulgaris using lactic bacteria cultures was described by Fedorova et al. (1993). Starter (5% of mash) contained Streptococcus faecium and Lactobacillus plantarum at a ratio of 1:4. The developed beverage was dark red and slightly acidic with an appealing aroma.

Carrot juice was mixed with cabbage juice and inoculated with Lactobacillus delbrueckii strain 37H or Lactobacillus plantarum 89H, 90H or 92H. With regard to nitrate utilization, the greatest decrease in nitrate content during fermentation was observed for Lactobacillus plantarum 92H; no detectable levels of nitrate (as NO₃⁻) were determined in carrot and cabbage juice by the end of fermentation. Good results were also obtained for Lactobacillus plantarum 90H and Lactobacillus delbrueckii 37H with 83 and 73% decrease of nitrate respectively. (Hybenova et al., 1995)

Lee et al. (1995) manufactured a vegetable juice containing juice from carrot, cabbage, peas, cucumber, celery and fermented radish. Juices containing various
ratios of different vegetable juices were prepared and their properties were examined. The vegetables showed a wide variation in pH, acidity and remaining sugar content.

Kraevska et al. (1996) developed a lactic vegetable purees and beverages. Carrot, celery and pumpkin puree were subjected to lactic fermentation by Lactobacillus plantarum. Lactic fermented puree had a lactic acid content of greater than or equal to 8g/kg and maintained most of their vitamin C and β carotene content. Beverages prepared from them were characterized by pleasant lactic smell or taste and a balanced sugar or acid ratio with a good stability and biological value.

Production of fermented beverages from white cabbage and red beet was described Nowakowskaja and Lipowski (1996). Cabbages were fermented with Lactobacillus plantarum and Leuconostoc mesenteroides (1:1); Lactobacillus plantarum (pure culture) was used for red beets. Fermentation was performed at room temperature until a pH of 3.6 to 3.8 and acidity (as lactic acid) of 0.7-1.0% were attained. Higher quality juices were obtained using pasteurized beet juice containing 0.5% sodium chloride and a 2% inoculum, or from cabbage pulp with 1.0% inoculum. The authors concluded that the fermented beverages could be kept for 1 month at approximately 4°C, without pasteurization. Pasteurized juices could be stored at 4 or 20°C for 6 months.

Simultaneous saccharification and fermentation of crude inulin (ground tuber, juice concentrate and flour) sources from Jerusalem artichoke (Helianthus tuberosus L.) tubers was conducted batchwise at 30°C using a crude enzyme preparation from Aspergillus niger 817 and Saccharomyces cerevisiae 1200 cells. Saccharification with the crude enzyme preparation followed by Saccharomyces cerevisiae fermentation
produced >20% (v/v) ethanol from Jerusalem artichoke flour after 120 hrs. (Nakamura et al., 1996).

Studies were conducted on manufacture of fermented turnip juice by Ozler and Kilic (1996). Effects of processing methods and raw materials on quality of fermented turnip juices and turnip juice blends were investigated. Effects of lactic starters (Lactobacillus plantarum or Lactobacillus brevis) and bakers' yeast were assessed, and use of red beet juice as a full or partial substitute for black carrot juice in blended fermented turnip juice products was investigated. After fermentation, the juices were bottled, pasteurized and stored for 6 months; composition, colour properties and sensory quality were assessed. Acidity was highest for turnip + black carrot juice (made by the traditional method) and turnip + black carrot + red beet juice (made with lactic starter and yeast). Colour deteriorated during pasteurization of all juice samples made with addition of red beet juice. It is concluded that red beet cannot fully replace black carrots in mixed fermented juices based on turnip juice.

Kolb et al. (1997) developed a red beet beverage by fermenting it with Paracoccus denitrificans and minimized potential health risk and maintained the high nutritional value of vegetables and vegetable products by lowering the nitrate load without excessive accumulation of nitrates or formation of nitrosamines.

The influence of 31 strains of lactic acid bacteria on the quality of a fermented beetroot juice was investigated by Gavrilova et al. (1997). Bacteria tested included Lactobacillus plantarum, Lactobacillus cellobiosus, Lactobacillus xylosus, Lactobacillus fermentum, Lactobacillus casei, Lactobacillus buchnerii and Streptococcus lactis. The best results were obtained using either Lactobacillus cellobiosus 9K or a mixture of Lactobacillus plantarum 7K and Streptococcus lactis 1m.
Passos et al. (1997) reported that fermentation of cucumbers by lactic acid bacteria alone results in a concentration of lactic acid which is too high for consumption of the final product and they carried out the study by adding a fermentative yeast, *Saccharomyces rosei*, during fermentation of cucumbers and suggested as a way of partially utilizing fermentable sugars to avoid excessive acid production by bacteria.

Addition of sugar, enzymic hydrolysis and salt concentration were evaluated for their effects on characteristics of kimchi juice during fermentation was studied by Chun et al. (1997). The kimchi juice was prepared by brining and grinding of the outer layer leaves of Chinese cabbage, one of the waste products of kimchi processing, followed by fermentation and filtration. As sodium chloride concentration decreased from 5.0 to 1.0%, fermentation proceeded at a significantly higher rate. Addition of sucrose or glucose (0.5 to 2.0%) also improved fermentation rate while, concentration had little effect. Enzymic hydrolysis of brined Chinese cabbage prior to fermentation with commercial polysaccharide hydrolases also increased fermentation rate. However, solids concentration in kimchi juice was decreased by higher concentration of sodium chloride and enzymic hydrolysis. Reducing sugar content showed a rapid decrease after 24 hrs of fermentation; enzymic hydrolysis had little effect.

Characterization of fermented carrot juice by *Bifido bacterium* was performed by Park et al. (1997). Sensory analysis of *Bifido bacterium* cultured carrot juice showed higher scores than for non fermented carrot juice. It is concluded that fermentation may lead to quality improvement of carrot juice by combining health promoting effects of *Bifido bacterium* with high nutritional value.
Samples of red beet and carrot juices were inoculated with starter cultures of lactic acid bacteria, fermented to a pH of 4 and stored at room temperature or under refrigerated conditions for 2 months. \textit{(Rasic, 1998)}

Fermented juices were produced by Gorenkov \textit{et al.} \textit{(1998)} utilizing beets, carrots or cabbages. The vegetables were cleaned, juice was expressed and fermented, and dried lactic acid bacteria were added at 0.1\% concentration with the fermentation period of 16 to 24 hrs. The product was hot-filled into containers. Lactic fermentation was responsible for increased contents of amino acids, vitamin C, iron and potassium, and for reduced contents of heavy metals. In beet juice, increase in levels of aspartic acid (7.2x); glutamic acid (4.4x); cysteine (1.2x); isoleucine (1.7x); histidine (1.2x); lysine (1.3x); and iron (1.9x) was observed while, the contents of glutamic acid, cysteine, lysine and β-carotene increased in fermented carrot juice. Heavy metals content decreased 2.4-fold, and nitrate content was halved in fermented cabbage juice.

\textit{Hur and Lee} \textit{(1998)} produced vinegar by fermenting autoclaved pumpkin juice with an \textit{Acetobacter} starter culture and ethanol at 4 and 10\% of the volume of pumpkin juice, respectively. Fermentation was carried out at 20°C for 14 days followed by ageing at 10°C for 14 days, before the flavour components present were characterized. Pumpkin vinegar showed very similar flavour characteristics to those of conventional wine vinegar and sherry wine vinegar, with acetoin, methyl acetate and butanoic acids being typically present in all 3 types of vinegar, showing that pumpkin vinegar could therefore compete with European wine vinegar for a share of the market.

Lactic acid bacteria strains isolated from kimchi, or \textit{Lactobacillus acidophilus}, \textit{Lactobacillus} plantarum, or \textit{Leuconostoc mesenteroides}, without or with
Saccharomyces cerevisiae, were used as inoculants in fruit-vegetable juice fermentation. Fermentation was carried out for 3 days at 30°C. In terms of fermentation behaviour i.e., growth rate, acid production, etc. and sensory properties of resulting beverage, a kimchi isolate, KL-1, identified as a Leuconostoc strain, was deemed most suitable for mixed culture fermentation with yeast. (Cheigh et al., 1998).

Stern (1998) reported an innovative fruit and vegetable juice beverage containing natural health promoting ingredients. These include orange carrot juice enriched with vitamins A, C and E. Orange tomato juice were enriched with vitamins B, C and E and apple capsicum beverage with added fibre.

Lactic acid bacteria strains isolated from kimchi, or Lactobacillus acidophilus, Lactobacillus plantarum, or Leuconostoc mesenteroides, without or with Saccharomyces cerevisiae, were used as inoculants in fruit-vegetable juice fermentation. Fermentation lasted 3 days at 30°C. Chemical properties were monitored during fermentation, i.e. organic acids, vitamin C, β-carotene, ethanol generation and reducing/nonreducing sugars. Mixed culture fermentation with a kimchi Leuconostoc isolate (KL-1) and yeast produced malic (26% of total), lactic (49.9%), succinic and citric acids, and decreased levels of sugars, whilst increasing ethanol concentration to around 9.6 mg% in 3 days. Levels of vitamin C and carotene stabilized of about 24 hrs at 70-80% of original values. (Kim et al., 1998).

The role of fermentation time and use of starter culture concentration was studied by Babuchowski et al. (1999) by using of propionicbacteria in the manufacture of fermented vegetable products. Red beet juice, sauerkraut and vegetable salad were made using propionicbacteria in addition to lactic acid bacteria.
Advantages of using propionicbacteria in production included increased contents of vitamin B$_{12}$ and folacin, extended shelf life, inhibition of pathogens and improved sensory properties. The source of vitamins in products depended on the fermentation time. In long fermentations, contents increased during processing and storage of the product, but in short fermentations, contents depended on the vitamin content of the propionicbacteria inoculum.

Selection of Lactobacillus strains suitable for lactic acid fermentation of vegetable juices was investigated by Karovicova et al. (1999). Six Lactobacillus strains were tested on samples of white fresh cabbage, and a sterilized cabbage and carrot juice mixture and reported that 3 strains (Lactobacillus plantarum 192, Lactobacillus plantarum 190 and Lactobacillus delbrueckii 237) were found to be acceptable. These strains reduced the content of nitrates in the juices to the lowest concentration.

Characteristics of natural lactic acid fermentation of radish juice were investigated at different sodium chloride concentration (0 to 2%) and temperature from 10 to 30°C with a view to developing low-salt kimchi. (Kim et al., 1999). Overall quality was best at 1.0% sodium chloride concentration irrespective of the temperature.

Alcohol production from waste onions using a flocculating yeast (Saccharomyces cerevisiae IR-2) isolated from Indonesian fermented food was evaluated by Horiuchi et al. (2000). The raw material for fermentation was juice from the red onion R-3, rejected mainly on the grounds of size or shape. Onion alcohol had a red colour due to its anthocyanin content (approximately 50 mg/l). The
high potassium and low sodium contents of the onion juice suggested that onion alcohol could be used in prevention of high blood pressure.

Lactic acid bacteria were isolated from traditionally made dongchimi (fermented Daikon radish with saltwater) and their fermentation characteristics investigated in a mixed fruit and vegetable juice by Kim and Choi (2000). Bacteria from each group were separately inoculated into mixed fruit and vegetable juice made from carrot, apple, celery, watercress, jujube and lychei (weight ratio 3:3:1:0.5:1:0.5) which was then fermented for 9 days at 25°C, in order to investigate the effects of the bacteria on growth rate, aroma formation and acid-producing ability. Three strains, *Leuconostoc mesenteroides* M5-17, *Lactococcus lactis* M30-11, and *Lactobacillus cellobiosus* Y30-1 were selected as the most useful starters for lactic acid fermentation of a mixed fruit and vegetable juice.

Lactic acid bacteria cultures (n = 15), both pure and mixed, were characterized during growth in vegetable juice medium, and evaluated for their fermentation of cabbage, carrot, beet and onion vegetable mixtures by Gardner et al. (2001) and they concluded that, compared to silage inoculants, the mixed lactic acid bacteria culture selected in the study were capable of producing a more stable product owing to its ability to accelerate acidification rate, reduce ethanol production, and reduce gas production during fermentation and storage.

Lu et al. (2001) carried out fermentation of cucumber juices inoculated by *Lactobacillus plantarum*. The juices were fortified with glucose, fructose or a mixture of glucose and fructose. When cucumber juice was supplemented with fructose and/or glucose, the starter culture continued to ferment fructose, but not glucose, resulting in an increase in lactic acid production and decrease in terminal pH.
Denitrification of red beet juice by fermentation with *Paracoccus denitrificans* and the influence of this fermentation process on sensory properties of the product were studied by Tomczak and Czapski (2002). The authors reported that the use of *Paracoccus denitrificans* resulted in complete reduction of nitrates in red beet juice. Denitrification also had an effect on colour and flavour of juice samples. Concentration of denitrified juices by evaporation resulted in a product having suitable properties for use as a colorant.

Comparison of different starter cultures on cabbage juice fermentation was carried out by Karovicova et al. (2002). Fermentation of cabbage juices was compared in juices spontaneously fermented, or inoculated with *Lactobacillus plantarum* 92H, or a mixed culture of *Lactobacillus plantarum* 92H and *Saccharomyces cerevisiae* C11-3. Greatest lactic acid production in juice was caused by fermentation with *Lactobacillus plantarum* 92H for 144 hrs. Highest decrease in pH (6.30 to 3.85) was observed in juices inoculated with the mixed culture. Greatest decrease (66.6%) in reducing sugars concentration was observed in juice inoculated with the mixed culture. Sensory analysis showed that all juices with 72 and 96 hrs of fermentation had the best flavour and aroma.

Effects of addition of garlic juice (0.05, 0.1 or 0.2%) to cabbage juice fermented with *Lactobacillus plantarum* CCM 7039 were investigated by Kohajdova and Karovicova (2003a). Cabbage juice mixed with 0.1% garlic juice achieved the best sensory scores and had the highest concentration of lactic and acetic acids (7.63 and 4.17 g/dm³, respectively).

Kohajdova Z et al. (2003b) studied the effect of an inulin based probiotic preparation on the chemical composition and sensory properties of fermented cabbage
juice. Addition of 2% of the prebiotic preparation which contain > 99.5% inulin markedly improved the sensory properties of final product.

Optimal fermentation temperature and inoculum size for tomato vinegar development was studied by Zhaojun et al. (2003). Alcoholic and acetic fermentation processes were carried out by solid and liquid alcoholic fermentation together, after which the liquid was separated from the solid fraction and acetic fermentation performed.

Inocula for the fermentation of sugar beet juice were developed and the preservation efficiency of this process was investigated Klewicka et al. (2004). To acidify beet juice, 3 cultures of lactic acid bacteria were used (Lactobacillus acidophilus Ch-5, Lactobacillus plantarum LOCK 0858 and Lactobacillus delbrueckii subsp.delbrueckii LOCK 0854). Fermentation of the beet juice resulted in preservation such that numbers of the following test microflora were reduced.

Yield and quality were investigated of carrot juice prepared using lactic fermentation or the addition of citric acid, with and without total enzymic liquefaction (Pectinex Ultra SP-L) by Demir et al. (2004). Results of sensory analysis demonstrated that products produced with enzyme treatment at day 0 and after 2 and 4 months storage were generally preferred and samples without enzyme treatment were preferred by the panelists after long-term (6 months) storage.

Different tomato juices were studied by Kohajdova et al. (2004) for the manufacture of lactic fermented juices. Optimum results in terms of physicochemical and sensory properties were obtained by fermenting 100% tomato juice with a refractometric content of 5.5% for 72 hrs.
Use of lactic acid fermentation to increase the bioavailability of iron in carrot juice by fermenting it with different starter cultures was investigated by Bergqvist et al. (2005). Comparisons were made between effects of two lactic acid bacterial strains (*Leuconostoc mesenteroides* FSC2 and *Lactobacillus pentosus* FSC1), two types of carrot juice (home-made and commercial) and fermentation with or without pre-treatment with a pectinolytic enzyme or cellulase. Total mineral content of home-made juice was higher than that of commercial juice. Fermentation increased iron solubility in carrot juice, an effect that was more pronounced with *Lactobacillus pentosus* than with *Leuconostoc mesenteroides*. Enzyme pretreatment led to a further increase in soluble iron concentration of approximately 10%.

Suitability of larger beets as a raw material for producing probiotic beet juice with *Lactobacillus plantarum*, *Lactobacillus delbrueckii*, *Lactobacillus casei* and *Lactobacillus acidophilus* was studied by Yoon et al. (2005) and the authors reported that beet juice was rapidly utilized for cell synthesis and lactic acid production by all the lactic cultures tested. More lactic acid was produced by *Lactobacillus plantarum* and *Lactobacillus acidophilus* than by the other cultures.

Optimal formulation and fermentation conditions for producing yoghurt with fruit and vegetable juices was carried out by Xuegen (2005). Carrot, tomato and strawberry juice were added to fresh milk and fermented using *Lactobacillus bulgaricus* and *Streptococcus*. The optimal formula for the yoghurt was *Lactobacillus bulgaricus* to *Streptococcus* ratio 1.2:1 with inoculum of 3%, vegetable and fruit juice 20%, sugar 6%, and fermentation time 2 hrs. The product was nutritious and healthy with a flavour of vegetable, fruit and lactic acid.
Lactic fermented vegetable juices contain large amounts of beneficial substances such as vitamins, minerals, dietary fibre and anticancer compounds. Six mixtures of vegetable juice (from cabbage, carrot, celery and beetroot) were inoculated with *Lactobacillus plantarum* 92H and fermented at 22°C for 150 hrs by Karovicova and Kohajdova (2005). Cabbage and cabbage-carrot (2:1, v/v) juices were found to be the most acceptable from the analytical and sensory point of view. It is recommended that fermentation is stopped after 72 hrs for cabbage and 96 hrs for cabbage-carrot juice to prevent the formation of undesirable odours.

Rakin et al. (2005) showed that fermented carrot juice with brewer’s yeast autolysate had higher contents of some minerals such as calcium, phosphorus, iron and β-carotene. Fermented beetroot juice with brewer’s yeast autolysate had higher contents of betanin and vitamin C. The fermented juices, which was a mixture of beetroot and carrot juices with brewer’s yeast autolysate, represents the product with optimum proportions of pigments, vitamins and minerals.

A probiotic, fermented cabbage juice was produced by Yoon et al. (2006). Cabbage juice was fermented at 30°C using 24 hrs old cultures of *Lactobacillus plantarum* C3, *Lactobacillus casei* A4 and *Lactobacillus delbrueckii* D7. The authors suggested that produced fermented cabbage juice could serve as a healthy beverage for vegetarians and lactose-allergic consumers.

Effects of lactic acid fermentation were investigated on pigment stability in red beetroot juice. Two red beetroot varieties (Czerwona Kula and Chrobry) were used by Czyzowska et al. (2006). After fermentation, betanidin and isobetanidin were also observed. Huge amounts of betanidin were found, especially in fermented cv. Chrobry juice, which contained higher betanidin than betanin levels. In juice prepared
from Czerwona Kula, however, betanin levels were much higher than those of betanidin.

A study by Demir et al. (2006) reported that Carrot juice (Daucus carota L.) is one of the most popular vegetable juices and represents a rich source of natural β-carotene. Vegetable juices are available either fermented or not fermented. With the production of lacto fermented juices, carrot juices are microbiologically stable, delicious and potentially provide high nutritional value.

Suitability of different vegetables (cabbages, tomatoes, pumpkins and courgettes) for manufacture of lactic fermented vegetable juices was studied by Kohajdova et al. (2006). Freshly extracted vegetable juices were inoculated with Lactobacillus plantarum CCM 7039 at 10^6 cfu/ml and fermented for <=168 h at 21°C. Results indicated that cabbages and courgettes could be recommended for manufacture of lactic fermented vegetable juices.

Effects of long term storage on a health-promoting, fermented multi-vegetable juice enriched with vitamin B<sub>12</sub> through the addition of Propionibacterium cell biomass was investigated by Radyko et al. (2006). The juices were stored at a temperature of 5°C for 21 days, with periodical controls of the cell count of introduced bacteria.

Lactobacillus bulgaricus and Streptococcus thermophilus derived from yoghurt and Lactobacillus plantarum from pickles were used together to ferment a fruit and vegetable juice containing carrots, apples and tomatoes. (Feng and Ying, 2006).

A procedure is described for producing fermented ginger juice with health promoting effects, but none of the bitterness or pungency normally associated with
ginger by Kuboi (2006). Fine ginger grains were fermented with yeasts. The fermented ginger juice can be used as a food or beverage ingredient.

Optimized functional food and improved nutritious fermented beverage was developed by the beetroot and carrot juices enriched with brewer's yeast autolysate were subjected to lactic-acid fermentation with *Lactobacillus acidophilus* NCDO1748. (Rakin et al., 2007). Chemical compositions of produced fermented bioproducts showed that fermented carrot juice with brewer's yeast autolysate had higher contents of some minerals such as calcium, phosphorus, iron and β-carotene as compared to beetroot juice with brewer's yeast autolysate. The fermented bioproduct 3, which was a mixture of beetroot and carrot juices with brewer's yeast autolysate, represented the product with optimum proportions of pigments, vitamins and minerals.

Fresh carrot juice was fermented using commercial starters and isolated lactic acid bacteria strains with special focus on the duration of the fermentation process and the sensory quality of the fermented juices. The fermented carrot juice had excellent sensory properties. (Wiander and Ryhanen, 2007).

Kohajdova et al. (2007) developed lactic fermented cucumber juices with *Lactobacillus plantarum* CCM 7039 as starter culture and addition of onion juice (0.5, 1.0 or 2.0%) and analysed for pH, composition and sensory properties after <=120 hrs of fermentation at 21°C. Highest scores for harmonized taste, aroma and flavour plus acceptable pH (3.50 to 3.55) were obtained after 48 hrs of juice fermentation. Optimum level of onion juice addition in terms of sensory properties was 0.5%. Addition of onion juices also positively influenced lactic acid production in initial stages of fermentation.
Lactic acid fermentation of anthocyanin-rich sweet potato (*Ipomoea batatas* L.) into lacto-juice was prepared by the fresh juice inoculating with *Lactobacillus plantarum* culture at 28 ± 2°C for 48 hrs by Smita et al. (2007)

A probiotic product suitable for lactose-intolerant individuals was developed by fermenting with *Bifidobacterium lactis* Bb-12 and *Bifido bifidum* strains B7.1 and B3.2, in pasteurized carrot juice by Yang (2007). Significant decrease in the glucose and sucrose contents of the carrot juice occurred during the fermentation, while the fructose concentration of the juice was not altered. Concentration of α- and β-carotenes in the carrot juice decreased by 15 to 45% during the fermentation.

Physico-chemical characteristics of celery and beetroot juices, with and without pulp fermented with a *Bifidobacteria* culture was carried out by Moraru et al. (2007). The fermented beetroot juice had a pleasant taste while the celery juice had a pronounced sour taste and needs to be corrected.

*Leuconostoc mesenteroides* SM isolated from a raw carrot was used for the fermentation of carrot juice by Jo et al. (2008). Lactic acid fermentation of carrot juice was performed at 25°C for 24 hrs with a sucrose concentration of 0 to 20%. The fermented carrot juice had improved body, texture, red colour and stability without sedimentation.

A study by Jose-Maria et al. (2008) focused on the efficient production of ethanol from waste onions by transforming the onion juice into onion liquor via alcoholic fermentation with the yeast *Saccharomyces cerevisiae*. The onion bioethanol produced could be later used as a favorable substrate for acetic fermentation to finally obtain onion vinegar.

Son et al. (2008) studied the physicochemical properties of a carrot juice beverage containing *Phellinus linteus* extract and beet extract fermented using
Leuconostoc mesenteroides SM, isolated from carrot juice. The polyphenol content and antioxidative activity of the fermented carrot beverage increased as the content of beet extract increased.

A packaged beverage was developed by Furuse et al. (2008) which contained fermented vegetable juice, fermented soymilk and gamma-aminobutyric acid (35 to 100mg/100g). The beverage was obtained by fermentation using lactic acid bacteria, and had regulatory actions in the intestine and improved sensory properties.

A study by Buruleanu et al. (2008) reported that the undesirable sensorial characteristics of vegetables as cabbage, radish and celery can be successfully lessened through lactic acid fermentation of mixing juices.

Preparation of a novel fruit vinegar beverage was developed by Zhang (2008) in addition with vegetables. Firstly, juice was prepared from fresh navel oranges and then a navel orange acetic acid vinegar was produced by alcoholic and acetic fermentation. Fresh carrot, tomato and hawthorn juices added to the vinegar preparation. The resulting beverage had a good flavour and appearance, and was nutritious.

The influence of the addition of two probiotic strain Lactobacillus rhamnosus and Lactobacillus bulgaricus, the prebiotic components inulin and fructo oligosaccharides on carrot juice was investigated in order to evaluate the possibility of producing a functional vegetable beverage. (Filomena et al., 2008)

Preparation of lactic acid by industrial scale fermentation using concentrated raw beet juice as a fermentation substrate was described by Visser et al. (2009). The beet juice was diluted to the desired initial sugar concentration, nutrients were added and the juice is fermented to lactic acid and/or lactate by means of a lactic acid-producing microorganism. The concentrated beet juice was prepared by washing and
cutting sugar beet and extracting the cossettes in water. The beet pulp was removed from the raw beet juice, heat treated at a temperature of 50 to 90°C and then concentrated to >=60 degrees Brix.

A lactic acid beverage was prepared by fermenting tomato juice with *Lactobacillus* and *Streptococcus thermophilus*. Best results were achieved after fermentation with a 9:1 ratio of water to tomato juice at pH 6.5 and 42°C, a 1:1 ratio of *Lactobacillus* to *Streptococcus thermophilus* and an inoculum size of 6% for 35 hrs. The optimal combination of additives was 4% sugar, 4% honey, 0.06% citric acid and 0.015% malic acid. *(Hua et al., 2009).*

**Sahota et al. (2009)** prepared the low alcoholic self carbonated beverages from carrot and amla (50:50), having shelf life of 3 months and reported it as an economically viable technology.

Lactic acid fermentation of vegetable juices was developed by **Buruleanu (2009)**. Various probiotic bacterial species were added to carrot and beetroot juices, which were then fermented at 37°C. All tested strains were able to use the vegetables for cell synthesis and lactic acid production, reducing pH from 6.4 to <4.4 after 48 hrs of fermentation.

Lactic acid bacteria isolated from various fruits and vegetables were screened in order to find starters suitable for manufacture of fermented onion juice. The optimal temperature, pH and starter inoculation concentration (v/v) required for growth of the isolated strain were 40°C, pH 4.0 to 6.0 and 2%(v/v), respectively. *(Choi et al., 2009).*

**Koh et al. (2010)** characterized the chemical properties of tomato juice fermented with *Bifidobacterial* species. Tomato juice was prepared from fresh tomatoes and heated at 100°C prior to fermentation. *Bifidobacterium breve,*
Bifidobacterium longum and Bifidobacterium infantis were inoculated in tomato juice and kept at 35 to 37°C for up to 6 hrs. The lycopene contents of tomato juice were significantly increased from 88 to 113µg/g by heat treatment at 100°C (P<0.05), however did not exhibit any significant change after fermentation with bifidobacterial species.

Lactic fermented juice was developed by Manea and Buruleanu (2010) from cabbage, carrots and beetroot and the authors suggested that fermentation of juices with lactic acid bacteria may be preferable for obtaining products with optimum chemical composition and sensory properties.

A newly developed functional food was developed by watermelon and carrot juice mixture in the ratio 70:30 by volume was fermented at 37°C with Lactobacillus acidophilus to produce an innovative non-dairy-based food formulation with good flavor and high nutritional value. (Mestry et al., 2011).

The capacity of the juices obtained from cucumber, white and red cabbage respectively to represent a substrate for the growth of Lactobacillus acidophilus, in order to obtain probiotic products, was investigated (Buruleanu et al., 2012). Although some differences between the growth trends of Lactobacillus acidophilus LA-5 were determined, all the analyzed vegetables were suitable for obtaining lactic acid fermented juices with a higher shelf-life.

From the literature lactic acid fermented vegetable juices are produced mainly from cabbage, red beet, carrot, celery, cucumbers, tomatoes, cauliflower, peppers, onions, radishes, pumpkin and their blends. The desirable properties of fermented vegetable juices can be achieved by choosing Lactobacillus strains suitable for the lactic acid fermentation of individual raw materials. The criteria used for finding out were suitability of a strain, the rate and total production of acids, change in pH, loss of
nutritionally important substances, decrease in nitrate concentration and production of biogenic amines (Karovicova et al., 1999), ability of substrate to accept a starter culture, type of metabolism and ability of culture to create desirable sensory properties of fermented products (Holzapfel 2002).

The combination of experimental design and multivariate methods should, therefore, be a powerful tool for improving the process of product development (Ellekjaer et al., 1996). The vegetables routinely used in India, especially different types of gourds, roots, tubers are not attempted at all for fermentation process, which have got the functionality. The area of fermentation is very well known and the process is not only preservation of the product but also its mode for nutrient formation but still the work on nutrients formation has not been covered so far and thus, because of non existence state of literature on vegetable based fermented beverages, its nutrient formation, there is a need to develop vegetable based fermented beverages and study their impact on human health benefits.

2.4 Evaluation of fermented vegetable juices

The lactic acid fermented vegetable juices preserve themselves high proportion of protective substances of the previous raw material. During fermentation, a great amount of other substances useful for health is produced by lactic acid bacteria and by other microorganisms. Thus produced organic acids, aldehydes, flavour substances, some antibiotics and others, that reduce the risk of civilization illnesses and so contribute to the importance of this group of food for health (Etherton et al., 2002). The consumption of lactic acid fermented food should be increased in population. An important factor is also the supply of lactic acid fermented vegetable juices with new quality characteristics, without application of preserving agents
(Kopec, 2000). Some of the health benefits related research work carried out on vegetable fermentation are as follows.

Kakimoto et al. (1998) prepared a fermented product by fermenting enzymically deactivated garlic with Aspergillus oryzae and/or Monascusanka. The composition was odourless and was useful as a prophylactic or therapeutic agent for diseases such as diabetes, hepatic diseases, cancer, immunopathy and hyperlipidaemia.

Red pepper puree was fermented for 3 months to reduce pungency and increase palatability, and a product made from the fermented puree was evaluated for hypolipidemiac activity in male Sprague-Dawley rats (Suh and Chang, 2002). Thirty two rats were assigned to 1 of 4 dietary groups: untreated low fat control; high fat control (HF-control); high fat with fermented red pepper puree (HF-S-1); and high fat with the red pepper product (HF-S-2). Plasma and hepatic lipid profiles in rats were examined after feeding on diets for 3 wk. The addition of fermented red pepper to high fat diets, HF-S-1 and HF-S-2 groups, resulted in significantly lower fat pad weight compared with the HF-control group. Both HF-S-1 and HF-S-2 groups had lower plasma triacylglycerol levels, atherogenic-index, and liver triacylglycerol levels than the HF-control group (P < 0.05). Liver cholesterol levels were significantly lower in the HF-S-2 group than the HF-control group. Results suggest a hypolipidemic effect of the fermented red pepper puree and the fermented red pepper product.

Effects of a fermented vegetable beverage was investigated by Kim et al. (2003) on faecal microflora, moisture contents and pH. Fermented vegetable beverage was prepared by fermentation of fresh vegetable juices (broccoli, peppers, pumpkin, tomato, black radish) with Lactobacillus plantarum JCM 1149 and administered to 7 healthy male volunteers (aged 24-28 yr) daily for 3 wk. During administration of fermented vegetable beverage, number of beneficial bacteria, such as Bifidobacterium
and *Lactobacillus* species, significantly increased (from 6.78 to 8.58 and 7.31 to 9.05 log cfu/g wet faeces, respectively), whereas significant decreases were observed in levels of potentially harmful bacteria, such as *Clostridium perfringens* and *Escherichia coli*. After 3 weeks of beverage consumption, faecal moisture contents increased from 78.2 to 83.12% and pH decreased from 6.91 to 6.69 to 6.79. Results suggest that regular consumption of fermented vegetable beverage may exert health-promoting effects on the gastrointestinal tract.

Acetate fermented ethanolic extract from bittermelon malt vinegar was fed to male rats for 12 week and compared to rats fed on commercial rat chow with respect to respiratory quotient and blood or plasma parameters associated with diabetes mellitus by Ichikawa et al. (2003). The authors concluded that long-term administration of bittermelon malt vinegar would suppress the lowering of energy turnover that is inherent with ageing and improve anorexia rather than exert a preventive effect against non-insulin-dependent diabetes mellitus.

Effects of a fermented vegetable product prepared by yeast and lactic acid bacteria fermentation of fruits, black sugar, vegetables and seaweeds, on body weight and fat deposition after ovariectomy in 10-week-old Sprague-Dawley rats were investigated by Shimada et al. (2004). Rats were divided into the following 5 groups: ovariectomized rats fed as usual (OVX); rats receiving fermented vegetable product at a daily dose of 100 mg/kg (LOW); rats receiving fermented vegetable product at a daily dose of 1000 mg/kg (HIGH); rats receiving a Ca-free diet (Ca-FREE); and sham-operated rats (SHAM). A slight increase in body weight was observed in the LOW group compared with the OVX group. The rate of increase in total fat content was lowest in the LOW group, but both bone weight and strength were similar to those in the other ovariectomized groups.
Klewicka et al. (2009) aimed at determination of the effect caused by ingestion of beetroot juice fermented by *Lactobacillus casei* 0920 and *Lactobacillus brevis* 0944 strains on the state of cecal ecosystem of experimental rats. The considerable decrease in activities of β-glucosidase and β-glucuronidase was observed in all three experimental groups fed with the fermented beetroot juice. They proved that the fermented beetroot juice benefits cecal microbial activity.

The above literature reveals that in the development of fermented vegetable juices the main emphasis is on the use of particular microflora more than the fermentation conditions to be followed and the generation of nutrients during the process of fermentation. However the commercialization of fermented products needs a backup of information on the optimization of fermented foods process, use of commercially available cultures as starters and the increased nutritional strength. Therefore, still the field of fermentation is open for research. And it is more clear from the above literature that only a few animal studies are conducted for some of the vegetable products and the evaluation of fermented food products in the humans through human trials is still need to be attempted and it is an absolute requirement to convince the customers and increase the use of fermented food products in the society.

In view of the above studies on fermentation of vegetable juices there is a need for optimization of the fermentation processes with respect to starter culture and fermentation time on nutrients formation and the evaluation of the developed product on human health benefits is very necessary and it has been taken up for the study.