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Development of Shelf Stable Fermented Vegetable Products

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Abstract

In the present study, attempts were made to develop shelf stable fermented products from vegetables. Sauerkraut like fermented products using indigenous vegetables like Bitter gourd (BGS), Drumstick leaves (DLS), Chakramuni leaves (CLS) and Gogu leaves (GLS) were developed. Control sauerkraut was standardized with 100 per cent cabbage. Experimental sauerkrauts were standardized using vegetables in different proportions (5 per cent, 25 per cent and 50 per cent) with cabbage. Among the variations, sauerkraut with 75 per cent cabbage + 25 per cent vegetable combination was more acceptable and selected for further study. Scores for the developed fermented products were in the range of liked slightly to liked moderately. Two sauerkraut samples (DLS and BGS) were incorporated in fillings and were accepted up to 50 percent for chapathi rolls and up to 25 per cent for stuffed breads. Nutritional analysis of sauerkraut combinations showed that CLS had higher content of protein (1.85 g/100 g), fat (1.02 g/100 g) and energy (36.03 Kcal/ 100 g). Total ash and crude fibre were found higher in DLS. The calcium, iron and zinc composition of sauerkraut ranged from 30.90 to 102.00 mg/100 g, 0.93 to 1.12 mg/100 g and 0.28 to 0.39 mg/100 g per gram respectively. Vitamin C and vitamin B12 were found higher in CLS and BGS respectively. Storage study results revealed that the developed fermented products can be successfully stored for twenty one days at room temperature. Thus, shelf - stable as well as acceptable value added products can be developed from vegetables by fermentation.

Vegetables are considered as essential for well-balanced diets since they supply vitamins, minerals, dietary fiber, and phytochemicals. India is the world's largest producer of fruits and vegetables, next only to China with a production of 66 million tons/ annum. But less than 2 per cent of fruits and vegetables are processed in the country, as compared to 30 per cent in Thailand, 70 per cent in Brazil and 80 per cent in Malaysia (Ravindranath, 2005). Average household consumption of fruits and vegetables in India is 149g to 152 during this decade though far below the recommended intake but slightly better from the previous survey (120-140 g/capita/day) (Sandeep *et. al.,* 2013). Preservation of these vegetables can prevent huge wastage as well as making them available in lean season.

Fermentation is one of the oldest means of food preservation and reduces the risk of food borne illness and food spoilage. The fermentation process for vegetables can result in nutritious foods that may be stored for extended periods, one year or more, without refrigeration. The preservation of vegetables by fermentation is thought to have originated before recorded history and the technology was developed by trial and error. Lactic acid fermentation is considered as the simple and valuable biotechnology and one of the most practical and widely applied empirical methods for preserving and often enhances the organoleptic, nutritional quality, sensory and shelf life properties of vegetables and fruits (Tamang *et al*., 2005). Sauerkraut called as 'sour cabbage' in German is made by the fermentation of cut and salted cabbage by naturally occurring lactic acid bacteria (Johanningsmeier et al., 2005). Fermentation of white cabbage into sauerkraut is an ancient preservation method (Wiander and Ryhanen, 2005). Sauerkraut is a traditional fermented vegetable food which is widely consumed in many regions of China (Xiong *et al*., 2014). In 2001 three billion pounds of cabbage consumed in the United States, twelve percent was consumed as processed cabbage, mainly sauerkraut (Uva *et al*., 2005). Sauerkraut has many health benefits offered by the cruciferous vegetables such as cauliflowers, brussel sprouts and cabbage, with the probiotic benefits derived from fermentation process due to lactic acid bacteria (Lactobacilli) produced as a bye-product of the pickling process. The glucosinolate moieties in sauerkraut induce the body's antioxidant enzymatic activity and the flavonoid components confer protection to blood vessels from oxidative damage. Also, lacto-fermented sauerkraut provides an

array of lactobacilli probiotics and vitamin C. Thus, in a study entitled Development of shelf stable fermented vegetable products an attempt was made to standardize process of sauerkraut like fermentation using indigenous vegetables like Bitter gourd (Momordica charantia), Drumstick leaves (Moringa oleifera), Chakramuni leaves (Sauropus androgynous) and Gogu leaves (Hibiscus cannabinus). Evaluation of these products and also storage stability was undertaken.

Material and Methods

Procurement of vegetables

The vegetables required for the research work were procured from local vegetable market and Department of Horticulture, UAS, GKVK, Bengaluru, and used for research purpose.

Standardization and development of fermented vegetable sauerkraut variations

Fermented vegetable product sauerkraut was standardized with 100 Per cent cabbage and considered as control (Cs) (Holzapfel et al, 2008 and Swain et al., 2014). Experimental fermented vegetable sauerkraut variations were developed using different vegetables [Bitter gourd (BGS), Drumstick leaves (DLS), Chakramuni leaves (CLS) and Gogu leaves (GLS)] in different proportions (5%, 25% and 50%) with cabbage (95%, 75% and 50%) respectively similar to sauerkraut and the procedures were standardized (Table I). Among different combinations for all the four vegetables variations, the experimental sauerkraut with 75 per cent cabbage and 25 per cent other vegetable combination were found to be acceptable. Hence 25 per cent incorporation with 75 per cent cabbage combination for all four vegetables was selected for the further evaluation. Common products like stuffed chapathi rolls and stuffed bread were prepared using fermented vegetable sauerkraut variations and given for sensory evaluation.

Sensory evaluation of developed products

The products developed were evaluated for organoleptic qualities by 20 semi trained sensory panelist using 9 point hedonic scale.

Physical characteristics of the developed products

The colour of developed sauerkraut combinations was assessed by Munsell colour Chart. The texture of the developed products was determined by using Texture Analyzer (Stable Micro Systems, UK).

Nutrient composition of the developed products

Moisture, protein, fat, fibre, carbohydrate Energy, total ash, calcium, iron, zinc, carotene were estimated using standard protocol. pH, titrable acidity, vitamin C and vitamin B_{12}, oxalates were also estimated following standard procedures.

Shelf-life study of developed products

Shelf-life study was conducted for 21 days for the samples stored in sterilized glass jars which were kept at ambient temperature (28ºC) for the sensory characteristics, microbial load, moisture content, pH and titrable acidity parameters.

The suitable statistical package was used to analyze the consolidated data.

Results and Discussion

Sensory evaluation of the developed fermented vegetable sauerkraut variations : Table II presents the mean sensory scores for the characteristics of appearance, colour, texture, aroma, taste and overall acceptability of fermented vegetable products after 7 days. The score for appearance ranged from 6.85 to 7.83, for colour ranged from 6.23 to 7.93, for texture ranged from 5.95 to 7.44, for the aroma ranged from 6.15 to 7.00, taste ranged from 6.40 to 6.73 and overall acceptability ranged from 6.25 to 7.33. As expected control (Cs) sample was highly accepted by the panel members. Control sample was standard sauerkraut with 100 Per cent cabbage and people are more used to the standard taste of sauerkraut. Sauerkraut called as 'sour cabbage' in German, is made by the fermentation of cut and salted cabbage by naturally occurring lactic acid bacteria (Johanningsmeier *et al.,* 2005). The gogu leaves sauerkraut scored the least for all the characteristics except for taste. Among other variations, sauerkraut with bitter gourd and drumstick leaves were better accepted. The difference in sensory characteristics

TABLE 1

Standardization of fermented vegetable sauerkraut variations with 2.25 per cent salt

Variations	Combinations	Cabbage	Bitter gourd	Drumstick leaves	Chakramuni leaves	Gogu leaves
Cs		100				
BGS (1)	A	95	5			
BGS (2)	B	75	25			
BGS (3)	C	50	50			
DLS (1)	A	95		5		
DLS (2)	B	75		25		
DLS (3)	C	50		50		
CLS(1)	A	95			5	
CLS(2)	B	75			25	
CLS(3)	C	50			50	
GLS(1)	A	95				5
GLS(2)	B	75				25
GLS(3)	C	50				50

Cs-Cabbage sauerkraut, BGS-Bitter gourd sauerkraut, DLS- Drumstick leaves sauerkraut, CLS - Chakramuni leaves sauerkraut and GLS-Gogu leaves sauerkraut

TABLE II

Mean sensory scores of fermented vegetable sauerkraut variations (at 25%) after 7 days

Variations	Appearance	Colour	Texture/ Consistency	Aroma	Taste	Over all a cceptability
Cs	7.83	7.93	7.44	7.00	6.73	7.33
BGS	7.50	7.70	7.24	7.04	6.10	6.70
DLS	7.35	7.00	6.93	6.38	6.03	6.72
CLS	7.44	7.05	6.60	6.40	6.03	6.69
GLS	6.85	6.23	5.95	6.15	6.40	6.25
F - value	*	*	*	*	*	*
SEm±	0.16	0.15	0.23	0.26	0.25	0.26
CD	0.43	0.94	0.62	0.71	0.74	0.73

Cs-Cabbage sauerkraut, BGS-Bitter gourd sauerkraut, DLS- Drumstick leaves sauerkraut, CLS-Chakramuni leaves sauerkraut and GLS-Gogu leaves sauerkraut. * Significance at 5 per cent level

viz. appearance, colour and texture, among different variations was statistically significant ($p<0.05$). The scores were in the range of like slightly to like moderately.

The mean sensory scores of bitter gourd sauerkraut stuffed chapathi rolls are presented in Table III A. The score for appearance ranged from 8.05 to 8.25, colour ranged from 7.95 to 8.15, texture ranged from 7.71 to 8.20, aroma ranged from 7.80 to 8.25, taste ranged from 8.03 to 8.20 and overall acceptability ranged from 7.83 to 8.10. The control scored highest for all the characteristics. The difference in sensory characteristics *viz.,* appearance, colour, texture, aroma taste and overall acceptability among different combinations of BGS was found to be statistically significant ($p<0.05$).

The mean sensory scores of bitter gourd sauerkraut stuffed breads are also presented in Table III B. The control sample had the highest score for all the sensory characteristics. Among three combinations of BGS, BSB3 scored the least for all the characteristics. The difference in mean sensory scores was also found to be statistically significant ($p<0.05$) for aroma, taste and overall acceptability.

The mean sensory scores of stuffed chapathi rolls with different combination of drumstick leaves sauerkraut (DLS) are presented in Table III B. The score for appearance ranged from 7.70 to 7.87, colour ranged from 7.69 to 7.72, texture ranged from 7.81 to 8.17, aroma ranged from 7.60 to 7.85, taste ranged from 7.81 to 8.27 and overall acceptability ranged from 7.80 to 8.24. The control scored the highest for all characteristics. The overall acceptability was found to be highest for DSC3 sample. The difference in sensory characteristics of texture, aroma, taste and overall acceptability among all the different combinations of DLS found to be statistically significant ($p<0.05$).

The mean sensory scores of stuffed bread with different combination of drumstick leaves sauerkraut (DLS) are also presented in Table III B. The control sample had the highest score for all the sensory attributes. Among all three combinations of DLS, DSB3 scored least for all the characteristics. The difference in mean sensory score was also found to be statistically significant ($p<0.05$) for texture, aroma, taste and overall acceptability. However non-significant difference was observed for appearance and colour.

Thus, Stuffed chapathis were acceptable with samples of BGS and DLS sauerkrauts up to 50 per cent incorporation. In stuffed bread, it was up to 25 per cent. Stuffed products were found to be more acceptable by the panel compared to serving sauerkraut with different vegetables as such. Higher per cent incorporation of sauerkrauts stuff was not liked by the sensory panelist. This may be due to the change in natural sensory attributes of experimental products and the concept of stuffing sauerkraut is new as well.

Physical characteristics of developed fermented vegetable products

Colour : Johanningsmeier (2007) observed the colour of sauerkraut with 2 per cent NaCl Sauerkraut had 63±1.0 L value which indicated the overall lighter color, which is a desirable quality. In the present study colour of all combinations of sauerkrauts ranged with the hue of yellow according to the Munsell colour chart. The colour of experimental products might be different due to the incorporation of vegetable which can be attributed to the hue of yellow (Table IV).

Yield / Volume : Data given in Table IV also depicts the percent yield of sauerkraut combinations which ranged between 2.81 to 2.93 per cent. GLS samples showed the highest yield (2.93%) followed by BGS (2.90%) the lowest yield was observed in sample CLS (2.81%). Overall, there was increase in yield in the variations. According to the Holzapfel *et al.* (2008), sodium chloride (salt) causes the osmotic withdrawal of water from the cabbage cells of which the emerging liquid fills up the space between pieces of cabbage and supports the development of anaerobic conditions and it may increase yield of the product.

Texture : Table V presents the texture of the developed sauerkraut combinations analyzed. Toughness of sauerkraut combinations ranged from 45.60 to 44.65 on the first day of fermentation. The toughness was found to be increased among all the products during seventh day of fermentation. This may be because of osmotic forces extract more juice from the plant cells, making them firmer.

TABLE III A

Mean sensory scores of stuffed chapathi rolls and stuffed breads with bitter gourd sauerkraut

Variations	Stuffed chapathi rolls							Stuffed bread						
	Cs	BGS 1	BGS 2	BGS 3	F - value	S. Em ±	CD	Cs	BSB 1	BSB 2	BSB 3	F - value	S. Em ±	CD
Appearance	8.25	8.10	8.05	8.05	NS	0.156	0.435	8.09	8.08	8.05	8.05	NS	0.158	0.439
Colour	8.15	7.97	7.95	7.95	NS	0.144	0.400	7.98	7.98	7.95	7.95	NS	0.147	0.407
Texture/Consistency	8.20	7.79	7.71	8.13	NS	0.145	0.403	7.90	7.70	7.70	7.63	NS	0.155	0.432
Aroma	8.25	7.80	7.80	8.23	*	0.149	0.413	8.25	7.80	7.80	7.79	*	0.149	0.413
Taste	8.20	8.03	8.05	8.16	*	0.246	0.697	8.25	6.98	6.98	6.03	*	0.208	0.578
Overall acceptability	8.10	7.83	7.89	8.09	*	0.134	0.373	7.40	7.35	7.36	6.74	*	0.188	0.523

Cs -Control, BSC1-15% incorporation, BSC2 -25% incorporation and BSC3-50% incorporation* Significant at 5 % level, NS- Non significant

Cs-Control, BSB1-15% incorporation, BSB2-25% incorporation and BSB3-50% incorporation* Significant at 5 % level, NS- Non significant

TABLE III B

Mean sensory scores of stuffed breads and stuffed chapatti rolls with drumstick leaves sauerkraut

Variations	Stuffed chapathi rolls							Stuffed bread						
	Cs	DSC 1	DSC 2	DSC 3	F - value	S. Em ±	CD	Cs	DSB 1	DSB 2	DSB 3	F - value	S. Em ±	CD
Appearance	7.87	7.70	7.70	7.78	NS	0.194	0.539	7.15	7.03	7.15	7.09	NS	0.689	1.94
Colour	7.72	7.69	7.71	7.71	NS	0.193	0.535	7.20	6.88	7.12	7.10	NS	0.403	1.140
Texture /consistency	8.17	7.81	7.85	8.14	*	0.146	0.406	7.45	7.38	7.40	7.05	*	0.413	1.169
Aroma	7.85	7.60	7.60	7.73	*	0.160	0.445	7.05	6.83	7.00	6.75	*	0.455	1.287
Taste	8.27	7.81	7.83	8.22	*	0.127	0.354	7.20	6.83	7.19	6.85	*	0.546	1.537
Overall acceptability	8.24	7.80	7.88	8.18	*	0.148	0.294	7.05	6.78	7.00	6.73	*	0.561	1.587

Cs-Control, DSC1-15% incorporation, DSC2-25% incorporation and DSC3-50% incorporation* Significant at 5 % level, NS- Non significant

Cs-Control, DSB1-15% incorporation, DSB2-25% incorporation and DSB3-50% incorporation* Significant at 5 % level, NS- Non significant

TABLE IV

Colour values and yield of developed sauerkraut combinations

Colour values for developed sauerkraut combinations				Yield of developed sauerkraut combinations			
Combinations	Hue	Value / Chroma	Colour	Fermenation duration	Intial weight (g)	Final weight (g)	yield (%)
BGS	5.0Y	8/4	5.0Y/4	7 days	200.43	206.25	2.90
DLS	5.0Y	6/4	5.0Y/4		199.92	205.68	2.88
CLS	5.0Y	6/4	5.0Y/4		200.20	205.82	2.81
GLS	5.0Y	6/4	5.0Y/4		200.32	206.19	2.93

BGS-Bitter gourd sauerkraut, DLS-Drumstick leaves sauerkraut, CLS-Chakramuni leaves sauerkraut and GLS-Gogu leaves sauerkraut.

TABLE V

Texure, pH and Titrable acidity (%) of sauerkraut combinations during fermentations

Texture			pH		Titrable acidity (%)	
Combinations	1st Day	7th Day	1st Day	7th Day	1st Day	7th Day
BGS	45.60	51.91	5.7	4.7	0.70	0.92
DLS	44.90	50.21	5.6	4.5	0.69	0.87
CLS	44.84	50.10	5.6	4.6	0.72	0.90
GLS	44.65	50.23	5.4	4.2	0.75	0.89

BGS-Bitter gourd sauerkraut, DLS-Drumstick leaves sauerkraut, CLS-Chakramuni leaves sauerkraut and GLS-Gogu leaves sauerkraut.

pH and Titrable acidity : Table V also depicts that pH of the sauerkrauts variations was slightly acidic ranging from 5.4. to 5.7 BGS showed highest pH (5.7) and lowest was in the GLS (5.4). It was observed that pH decreased in all the products and ranged from 4.5 to 4.2 on the seventh day of fermentation. Table V also shows the titrable acidity of the sauerkraut products on first and seventh days of fermentation. On the first day the titrable acidity ranged from 0.75 to 0.69 per cent, highest being in GLS (0.75%) followed by CLS (0.72%). Titrable acidity increased after seven days and the value ranged from 0.87 to 0.92 per cent. BGS had highest titrable acidity on seventh day (0.92%) and DLS had the least (0.87%). Sweet potato roots were pickled by lactic fermentation by brining the cut and blanched roots in common salt (NaCl, 2–10%) solution and subsequently inoculated with a strain of *Lactobacillus plantarum* (MTCC 1407) for 28 days. There was a gradual but quick fall of pH during the first 7 days (5.0–5.2 on day 2, 4.2 - 4.5 on day 4 and 3.3 - 3.5 on day 6) of fermentation. After fermentation for 7 days, the pH values were reduced to 2.6 - 2.9. The decrease in pH during lactic acid fermentation was probably due to the accumulation of organic acids, mainly lactic acid. The titratable acidity values of sweet potato fermented in brine solutions increased in the range of 2.3–6.6 g / kg roots after fermentation for 7 days. A rapid increase in acidity in fermented vegetables is associated with the increase in organic acids (Panda *et al.,* 2007).

Nutrient composition of developed fermented vegetable combinations : Table VI revealed that moisture content ranged from 86.00 to 91.20 per cent for the developed fermented vegetable variations having the lower values for DLS and higher values for BGS samples. Per cent protein content ranged from 0.90 to 1.85 where the control sample had the lowest value and the highest value was with CLS sample. The per cent fat content ranged from 0.10 to 1.02. The lowest value was found to be in control sample and highest in CLS sample. Crude fibre ranged from 0.09 to 1.01 g /100 g. Control sample had lowest value for total ash *i.e.,* 3.40 g and DLS sample had the highest content i.e. 7.00 g / 100 g. Carbohydrate content was found to be in the range of 3.39 g / 100 g to 5.28 g / 100 g with the lowest found to be in BGS samples and the highest found to be in DLS samples. The energy content of samples ranged from 20.74 to 36.03 Kcal per 100 g higher being in CLS sample (Table VI) Table VI also depicts that calcium content ranged from 30.90 to 102.00 mg / 100 g. The lowest value was found to be in control sample (30.09 mg) and highest was in CLS (102.00 mg) sample. Iron content of sauerkraut samples ranged from 0.93 to 1.12 mg /100 g. DGS sample had lowest value of iron i.e. 0.93 mg and CLS sample had the highest content i.e. 1.12 mg / 100 g. Zinc content of samples ranged from 0.28 to 0.39 mg / 100 g. The lowest value found

TABLE VI

Nutrient composition of sauerkraut variations

Combination	Cs	BGS	DLS	CLS	GLS	F - value	S. Em ±	CD
Moisture (%)	90.0	91.20	86.0	86.50	87.80	*	0.337	1.062
Protein (g)	0.90	0.94	1.04	1.85	1.04	*	0.015	0.047
Fat (g)	0.10	0.14	0.68	1.02	0.14	*	0.054	0.170
Crude fiber (g)	0.91	0.99	1.0	1.01	0.09	*	0.037	0.118
Total ash (g)	3.40	5.00	7.00	5.70	5.80	*	0.126	0.397
Carbohydrate (g)	4.69	3.39	5.28	4.93	3.61	*	0.040	0.127
Energy (Kcal)	23.26	20.74	31.40	36.03	24.72	*	0.236	0.745
Calcium (mg)	30.09	31.00	100.20	102.00	80.52	*	0.332	1.048
Iron (mg)	0.96	0.93	0.97	1.12	1.05	*	0.020	0.062
Zinc (mg)	0.28	0.37	0.39	0.31	0.28	*	0.008	0.025
Vitamin B12(µg)	1.89	1.92	1.91	1.90	1.90	NS	0.014	0.044
Vitamin C (mg)	52	110	142	145	60	*	0.512	1.645
Totalcarotene(mg)	0.82	0.91	2.81	2.13	1.65	*	0.492	1.567
Oxalate (mg)	3.00	3.01	26.02	30.1	3.07	*	0.233	0.736

BGS-Bitter gourd sauerkraut, DLS- Drumstick leaves sauerkraut CLS – Chakramuni leaves sauerkraut and GLS- Gogu leaves suerkraut * Significant at 5 % level, NS- Non significant

to be in control (Cs) 0.28 mg / 100 g and highest was in DGS (0.39 mg /100 g) followed by CLS (0.31 mg / 100 g). Vitamin C content of sauerkraut samples ranged from 52 to 145 mg / 100 g. The highest Vitamin C found in CLS sample followed by DLS and lowest was in the control (Cs). Total carotene content of sauerkraut samples ranged from 0.82 to 2.81 mg /100 g. The sample DLS had highest content of total carotene (2.81 mg / 100 g) followed by CLS (2.13 mg) and found less in the control (Cs) 82 mg / 100 g. Oxalate content of samples ranged from 3.00 to 30.10 mg / 100 g. The lowest content of oxalate found to be in control and highest content was in GLS followed by DLS.

Kwak *et al*. (2008) studied the vitamin B12 content in some Korean fermented foods and reported that traditional type of Doenjang and Chungkookjang contained 1.85 ìg / 100 g and 0.69 ìg / 100 g of vitamin B12 respectively, while the factory-type of Doenjang and Chungkookjang contained 0.04-0.86 ìg / 100 g and 0.06-0.15 ìg / 100 g. Vitamin B12 was not detected in steamed soybeans and Tofu which is a not-fermented soybean product, indicating that vitamin B12 might be synthesized during the fermentation process. Similarly in the present study Vitamin B12 content of sauerkraut variations were analyzed which ranged between 1.89 to 1.92 ìg / 100 g. The highest was found in BGS 1.92 ìg followed by DLS 1.91 ìg and lowest was found to be in control (1.89 ìg).

Storage studies of developed products : Effect of storage on physico-chemical parameters of developed sauerkraut samples : pH of the product tells about the acidity or basicity of the products. Weekly evaluation of pH of products revealed that the effect of storage on pH of two sauerkraut samples *i.e.* BGS and DLS. Decreased from 5.76 to 3.82 and from 5.60 to 3.78 from first to twenty first day of storage duration respectively. The decrease in pH from first to twenty first day in both the samples was found to be statistically significant ($p<0.05$). The effect of storage on titrable acidity of sauerkrauts depicted that in both samples (BGS and DLS) the significant ($p<0.05$) increase in titrable acidity was found during the storage duration of twenty one days. The increase was from 0.70 to 1.61 in samples BGS and from 0.69 to 1.61 in sample DLS during storage period. Suganya and Kailappan (2013) conducted a study to analyze moisture content during pearl millet fermentation and reported that fermentation increased the moisture content significantly with fermentation time. Similarly in the present study, the moisture content of DLS sample increased from 85.52 to 86.62 per cent during storage (Table- VII).

Effect of storage on microbial population : Table VII also depicts that the increase in microbial count of developed sauerkraut samples was negligible. The increased in total bacterial count in BGS sample was from 150 x 103cfu on the first day to 153 x 103cfu on twenty first days. The same was increased from 147 x 103cfu on first day in DLS sample to 149 x103cfu on twenty first days during storage. The lactic acid bacteria counts also found to increase from 1.3 x 103cfu to 8 x 103cfu for BGS and from 1.2 x 103cfu to 7 x 103cfu for DLS on storage. The fungi count found to be reduced from 2.3 x 103cfu to1.0 x 103cfu in BGS sample during storage for twenty one days. The same trend was observed in case of DLS sample *i.e.,* a reduction of 2.0 x 103cfu of fungi count to 1.0x103cfu on twenty first days. Statistically the reduction was significant for change in lactic acid bacteria count and fungi count at 5 per cent level whereas it was non-significant for total bacterial count.

Pundir and Jain (2010) analyzed the microbial load during the storage of sauerkraut for 90 days and reported that no fungal colony was found up to 28th day of fermentation. Fungal growth was observed on sauerkraut after 60th day of storage and completely spoiled on 90th day. Sauerkraut spoiled by molds growing on the surface exposed to air. The authors have reported that the spoilage might be due to higher acidity. In the present study total bacterial count and lactic acid bacteria increased from first day of storage to twenty first days and fungi population was decreased in both samples.

Effect of storage on sensory characteristics : Effect of storage on sensory characteristics of sauerkraut samples is presented in Table-VIII. The reduction in sensory attributes for both the

TABLE VII

Effect of storage on pH, titrable acidity, moisture content and microbial population (x103 cfu.g-1) of sauerkraut samples

Samples	Duration	pH	Titrable acidity (%)	Moisture (%)	Group of micro organism		
					Total Bacterial Count	Fungi	Lactic Acid Bacteria
	1st day	5.76	0.70	90.92	150	2.3	1.3
	7th day	4.70	0.92	91.20	153	1.0	3.0
	14th day	3.90	1.20	91.59	153	1.0	5.0
BGS	21st day	3.82	1.61	91.98	153	1.0	8.0
	F –value	*	*	*	*	*	*
	SEm±	0.0131	0.0222	0.0092	0.577	0.064	0.709
	CD	0.0427	0.0727	0.0302	1.88	0.210	2.313
	1st day	5.60	0.69	85.92	147	2.0	1.2
	7th day	4.50	0.87	86.00	148	1.1	2.5
DLS	14th day	3.92	1.25	86.38	149	1.0	4.0
	21st day	3.78	1.57	86.62	149	1.0	7.0
	F –value	*	*	*	NS		
	SEm±	0.0336	0.0066	0.0306	-	0.074	0.410
	CD	0.1097	0.0217	0.1000	-	0.243	1.338

BGS-Bitter gourd sauerkraut, DLS- Drumstick leaves sauerkraut * Significant at 5 % level, NS- Non significant

TABLE VIII

Effect of storage on sensory characteristics of sauerkraut samples

Samples	Duration	Appearance	Colour	Texture	Aroma	Taste	Overall acceptability
	7th day	7.50	7.70	7.24	7.04	6.80	6.70
	14th day	7.00	7.25	7.00	6.8	6.75	6.65
	21st day	6.8	6.9	7.75	6.6	6.65	6.30
BGS	F –value	*	*	*	*	*	*
	SEm±	0.471	0.470	0.376	0.413	0.471	0.596
	CD	1.347	1.345	1.075	1.183	1.347	1.704
	7th day	7.35	7.00	6.93	6.38	6.03	6.72
	14th day	6.95	6.8	6.60	6.25	5.9	6.50
DLS	21st day	6.75	6.56	6.45	6.00	5.74	6.30
	F –value	NS	*	*	*	*	*
	SEm±	0.50	0.451	0.374	0.276	0.259	0.402
	CD	1.430	1.289	1.070	0.790	0.741	1.150

BGS-Bitter gourd sauerkraut, DLS- Drumstick leaves sauerkraut * Significant at 5 % level, NS- Non significant

experimental samples was evident on weekly observation and was significant over the storage period ($p<0.05$). As the storage period increased the mean sensory scores were decreased. Only the reduction in mean sensory score of appearance of drumstick leaves sauerkraut was non-significant during storage.

The study showed that perishable vegetables can be successfully fermented to extend the shelf life, enhance nutritional value and enrich health benefits. Shelf - stable as well as acceptable value added products can be developed from vegetables by fermentation. It was suggested that several other traditional fermented products like sauerkraut juice, kimchi, khalpi *etc.* could be standardized with different vegetables/combination of vegetables.

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