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Influence of appropriate starter cultures on the sensory qualities and volatiles of fermented broccoli and onion pickles

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Abstract

In addition to the limitations in infrastructure and existing low technologies in most developing countries, lack of experience in applying starter cultures in small-scale operations presents a significant obstacle and an exciting challenge to food technology. In this study, fresh plain yogurt and baker's yeast were used an appropriate starter cultures for the pickling of broccoli and onion through fermentation as a source of lactic acid bacteria and *Saccharomyces cerevisiae*. Traditional broccoli and onion pickles produced via preservation in vinegar and salt were used as a control sample. Simple description to all experiments done through the work before going to illustrate the gained results. The organoleptic evaluation demonstrated that fermented pickles with fresh yogurt were the best in all sensory attributes and the overall acceptability, followed by pickles fermented with baker's yeast autolysate and control ones. Significant differences in the color parameters were observed between fermented pickles and control. Thirty - two volatile compounds were identified using Gas Chromatography-Mass Spectrometry in the fermented and preserved onion, while 37 constituents were revealed in the fermented and preserved broccoli. Acetic acid, dimethyl disulfide, ethyl butanoate, 2,5-dimethyl thiophene, and 1,3-butanediol were the predominant components in fermented and preserved onion with a quantitative variation. In fermented broccoli, dimethyl disulfide, pentenol and hexenol derivatives, and ethyl hexadecanoate were the most abundant aroma volatiles, while the same pattern was detected in the control sample except for hexenol derivatives. Therefore, the present study opens perspectives for healthier solutions employing appropriate starter cultures as a source of probiotics in the food industry.

Keywords: broccoli, onion, yogurt, baker's yeast, fermentation, pickles

1. Introduction

Pickles are made from vegetables or fruit with an extended history of over 3000 years in ancient Egypt, Greece, and western Asia. Nowadays, pickles are used in most of the world's countries as appetizers with every meal to accompany the savory and spicy notes to the food [1]. However, type, additives, and production are varied based on culture and food habits. For example, in Egypt, broccoli, carrots, cucumbers, turnips, cauliflower, olives, onions, and peppers are among the known vegetables pickled. Pickles can be prepared using two main techniques: lactic acid bacteria (LAB) or yeast fermentation of vegetables, and preservation of vegetables in acetic acid or salt, whereas vegetables or fruit are submerged in a salt brine solution, include flavorings like spices, herbs, garlic, or chiles. The pickles produced by the above methods are very different in taste and texture [2] .

Compared to the pickling of vegetables or fruit using preservation by vinegar and salt, fermentation by yeasts like Saccharomyces cerevisiae (SC) and lactic acid bacteria LAB constitutes an ideal choice for nutritional, organoleptic, and health properties of the final product. However, it is an unknown technique in Arab countries, especially in Egypt, with the middle East's highest population. LAB in pickles enhances human nutrition by providing vitamins, minerals, and carbohydrates and produces various unique aroma components, bacteriocins, and exopolysaccharides [3]. These metabolic products impart some characteristic properties such as taste, texture, and longer shelf life to products. LAB reduce naturally – occurring toxins and antinutritional compounds or elements and, therefore, can minimize the health risk. They are also useful to inhibit the pathogenic microflora in food and feed [4]. Genera of LAB include, among others,

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Lactococcus, Enterococcus, Oenococcus, Pediococcus, Streptococcus, Leuconostoc, and Lactobacillus. They are often considered probiotics which are beneficial for human health as active in lowering the serum cholesterol level, stimulate immune responses, reduce serum cholesterol, and lower the risk of cancer in the gastrointestinal tract and colon [5]. Meanwhile, [6] reported the beneficial effects of yeasts on human health, including preventing and treating intestinal diseases, anti-inflammatory effects, immunomodulatory effects, and improvement bioavailability of minerals through the hydrolysis of phytate, folate biofortification, and detoxification of mycotoxins.

Salt – stock (≤ 16%) and vinegared unfermented pickles are based on pasteurization and heating, which affect the benefit microorganisms negatively like probiotics may found naturally in vegetables and fruits [7]. However, these techniques are mostly applied in Egypt and Arab countries, especially by small–scale manufacturers, spread everywhere and constitute a major part of the pickling business. Many researchers have been reported pickling by fermentation by fermentation using LAB and S. cerevisiae [8-10], but preparation and availability of such starter culture by the small – scale manufacturers seem to be complicated. According to Holzapfel [11], appropriate and mixed starter cultures have been used for small scale fermentation in developing countries. In agreement with this context, the fermentation of beetroot and carrot juices, with the addition of baker's yeast, was conducted by various workers like Rakin et al., [12].

Therefore, the present work aimed to find out simple, reliable, and available inoculums for pickling fermentation. Commercial plain yogurt contained LAB strains' live cultures and baker's yeast as a source for S. cerevisiae were applied for such purpose. The sensory properties, color analysis, and identification of volatiles were performed onion and broccoli pickles compared to control samples pickles.

2. Experimental

Materials

Onion (Allium cepa) and broccoli (Brassica oleracea), salt (NaCl), vinegar, lemon, spices, fresh yogurt as a source of LAB, and baker's yeast as a source of S. servecia were purchased from the outlet of Agriculture Research Center (Dokki and Giza, Egypt). Calcium chloride was obtained from The El-Nasr Pharmaceutical Chemicals Co. (ADWIC).

Methods

Preparation of fermented pickles

Six pickle samples were prepared and encoded as 2 control samples containing vegetables and prepared according to the traditional preservation method, 4 samples in 5% brine solution containing yogurt as a starter culture as a source of LAB, and another 4 samples in 5% brine solution containing baker's yeast as a source of S. servecia [2].

Preparation of pickles according to the traditional method

Wash and slice onion (Allium cepa) and broccoli (Brassica oleracea). Place in a bowl, sprinkle with 1/4 cup salt, and let stand 4 to 6 hours. Drain. Heat and stir sugar in vinegar until dissolved. Tie mustard seed, allspice, celery seed, and cloves in a spice bag. Add to vinegar with onions and broccoli. If needed, add minimum water to cover pieces. Bring to boil and simmer 30 minutes, stirring as needed to prevent burning. Remove spice bag. Fill a hot jar with solids and cover with hot pickling solution, leaving 1/2-inch headspace. Remove air bubbles and adjust headspace if needed. Wipe rims of jars with a dampened clean paper towel. Adjust lids and process [2].

Preparation of fermented pickles: A total of 400 g of washed and dried vegetables were put into1.3 L pickle jars. A total of 650 mL brine water containing5% salt was added into each jar; and 7.4% of yogurt or brewer's yeast, whereas the concentration of such appropriate starter culture used as the inoculum was doubled from the single-strain cultures may be applied in similar products to counteract the potential dilution of bacterial count in the commercial product [13]. The pickle jars were left at room temperature for 14 days. Fermentation of pickles was conducted in 3 repetitions.

Colour analysis of pickles

Pickles mesocarp color was measured using a Minolta Chromameter model CR-200 (Minolta Co., Ltd., Osaka, Japan) to record the $L*$, $a*$, and $b*$ values of a different lobe of each of the 30 slices used for firmness measurements. The total parameters measured during this analysis were: the L* value — expressed the lightness (in %); the a* value — redness

(+ve) to greenness (-ve); the b* value —yellowness (+ve) to blueness (-ve); the hue angle: h* = tan–1 b*/a*; and the chroma: c* = (a*2 + b*2)0.5 [14].

Sensory evaluation assay

According to the 7 points hedonic scaling method summarized by Khaskheli et al. [15], all samples were evaluated. The sensory qualities were estimated by 10 members of students and staff, Food industries and nutrition division, National research centre, Dokki, Giza, Egypt. Appropriate questionnaire description presented to the panelist to evaluate the differences in color, taste, aroma, color, texture, appearance, and overall acceptability. Samples were evaluated in triplicate, whereas water was present for taste cleansing amongst samples.

Isolation of headspace volatiles

The volatiles in the headspace of each sample were collected using a dynamic headspace system. The samples (200 g) were purged with a nitrogen gas stream (>99.99%)at 100 mL min-1 for 1 h, and the volatiles were trapped in a500 mL diethyl ether/pentane (1/1, v/v) solution at –10 °C. After the solution was dried over anhydrous sodium sulfate for 1 h, it was condensed to 0.5 mL in volume. The sample was analyzed by GC and GC/MS for volatile components [16].

Gas chromatographic (GC) analysis

GC analysis was performed by using Hewlett-Packard Model 5890 equipped with a flame ionization detector (FID). A fused silica capillary column DB-5 (60mx0.32 mm id) was used. The oven temperature was maintained initially at 50°C for 5 min, then programmed from 50 to 250°C at a rate of 4°C/min. Helium was used as the carrier gas at a flow rate of 1.1 ml/min. The injector and detector temperatures were 220 and 250°C, respectively. The retention indices (Kovats index) of the separated volatile components were calculated using hydrocarbons (C8-C22, Aldrich Co.) as references.

Gas chromatographic-mass spectrometric (GC-MS) analysis

The analysis was carried out using a coupled gas chromatography Hewlett-Packard model (5890)/ mass spectrometry Hewlett-Packard MS (5970). The ionization voltage was 70 eV, mass range m/z 39-400 a.m.u. The GC condition was carried out as mentioned above. The isolated peaks were identified by matching with data from the library of mass spectra (National Institute of Standard and Technology) and compared with those of authentic compounds and published data [17]. The quantitative determination was carried out based on peak area integration.

Statistical analysis

Data of organoleptic evaluation of biscuits were subjected to analysis of variance and least significant difference (L.S.D) at 0.05 level according to the method described by McClave & Benson [18].

3. Results and Discussion

Pickles mesocarp color was evaluated by colorimetric analysis using $L*a*b*$ color space and converted to hue (h*) and chroma (c*) values (Table 1). Pickles fermented with yogurt as a source of LAB and brewers' yeast as S. servecia had significantly higher h* values than those preserved for onion. Simultaneously, no significant differences showed between the control and both fermented types for broccoli pickles. Meanwhile, no significant differences in h* could be observed between pickles fermented by yogurt and yeast (Table 1). The c* was significantly higher in the fermented products for onion and broccoli than in the preserved or control samples. However, broccoli fermented with yogurt is significantly had a lower c* compared to the control. Both types of fermented pickles by yogurt and yeast showed a significant difference in c* (Table 1). Degradation of chlorophyll is the main reason for color changes occurring during broccoli fermentation. The degradation of chlorophyll leads to pheophorbide has been suggested to form in plants by two pathways, through pheophytin as an intermediate or through chlorophyllide as an intermediate [19]. Meanwhile, color changes in broccoli pickled in acidic brine have been formed by combining pheophorbide and pheophytin pigments [14]. This degradation of bright green chlorophyll gives a pale olive-yellow or olive green in fermented or preserved food products [20] .

The pickling via fermentation resulted in a significant decrease in redness a* and increased yellowness b* of onion (Table 1). In fermented onion, values of a* in all treatments were negative, which means a tendency of the onions towards a green color. The values of b* were positive for the three treatments. They showed a tendency towards yellow. Based on the above coordinate color values, the chroma c* and the hue angle h* values of fermented onions tended to increase, which denotes a yellowish color for the onions analyzed (Table 1). Such yellowness might be due to chlorophyll biosynthesis, as reported by Rios-Gonzalez et al. [21], catalyzed by exposure to artificial light during fermentation or storage.

Table 1. Color values of preserved and fermented pickles (mean ± standard deviation).

Samples	**L***	**a***	**b***	**h***	**c***
Onion					
Control	75.11± 0.01 ^{f}	0.55 ± 0.13 ^{c}	16.60 ± 0.00 ^{f}	88.04	16.61
Fermented with LAB	84.17 ± 0.11 ^{a}	-1.68 ± 0.11^{e}	18.11 ± 0.11 ^{c}	95.44	18.19
Fermented with yeast	80. 7 9± 0.06 ^{c}	-1.19 ± 0.16 ^{d}	20.60 ± 0.00 ^{a}	93.40	20.63
Broccoli					
Control	74.03 ± 0.49 ^{b}	-2.17 ± 0.21 ^{f}	18.11 ± 0.09 ^{b}	97.01	18.24
Fermented with LAB	84.73± 0.11 ^{a}	-1.69 ± 0.11 ^{e}	17.22 ± 0.17 ^{c}	95.77	17.31
Fermented with yeast	80.31 ± 0.06 ^{c}	-1.21 ± 0.02 ^{d}	20.13 ± 0.01 ^{a}	93.52	20.17
LSD at 0.05	0.24	0.27	0.54	-	-

Means within a row sharing a typical letter were not significantly different ($p < 0.05$).

Organoleptic evaluation is a general guide of the quality from the consumer's point of view. Data presented in (Table 2) show those significant differences among samples. Panelist scores demonstrated that fermented pickles with yogurt were the best in all sensory attributes and the overall acceptability, followed by pickles fermented with yeast and control ones.

The lowest sensory attributes in the control samples might be due to the blanching during processing, which decreases in texture firmness and bringing could be related to ultrastructural changes [15] . However, the breakdown of carbohydrates, proteins, and lipids in a fermented pickle can lead to the formation of volatile organic compounds (VOCs) that can drastically affect the organoleptic characteristics (good flavor and nutritional value, as well as long shelf-life) of the final products [22] .

It was reported that the sensory attributes, acidic, green, and fresh, were more pronounced in fermented broccoli through the LAB source. In contrast, the most apparent change in fermentation by the LAB source comprises the production of acids, which increases sourness [23]. Meanwhile, sensory evaluation in a published study showed that the yellow storage sour onion was a favorable product with respect to color, texture, and flavor. The sour onion had a tartaric acidic taste, characteristic of sauerkraut, with the onion flavor but without the pungency of raw onions [24] . Therefore, the significant differences detected in the present study between the control and the fermented broccoli and onion samples are agreed with the previous reports and expected.

Table 2. Sensory characteristics of preserved and fermented pickles

Samples	Taste (20)	Aroma (20)	Color (20)	Texture (20)	Appearance (20)	Overall acceptability(100)
Onion						
Control	17.32^{ef}± 0.14	16.22^{c}± 0.16	16.70^{bc}± 0.05	17.71^{cd}± 0.19	17.19^{d}± 0.13	85.14^{g}± 0.61
Fermented with LAB	19.36^{a}± 0.09	18.22^{a}± 0.20	17.19^{a}± 0.07	18.22^{ab}± 0.11	19.11^{a}± 0.19	92.10^{a}± 0.66
Fermented with yeast	18.19^{d}± 0.16	17.17^{b}± 0.33	16.95^{b}± 0.11	17.65^{d}± 0.09	18.35^{b}± 0.26	88.31^{c}± 0.71
Broccoli						
Control	17.20^{f}± 0.32	15.60^{d}± 0.11	16.70^{bc}± 0.10	17.80^{abcd}± 0.11	16.12^{ef}± 0.21	83.42^{h}± 0.39
Fermented with LAB	19.01^{b}± 0.15	17.10^{b}± 0.18	17.19^{a}± 0.12	18.09^{abc}± 0.16	18.05^{bc}± 0.25	89.44^{k}± 0.62
Fermented with yeast	18.27^{cd}± 0.17	16.25^{a}± 0.23	16.95^{d}± 0.15	17.86^{abcd}± 0.13	17.65^{cd}± 0.13	86.98^{d}± 0.56
LSD at 0.05	0.210	0.187	0.162	0.444	0.532	0.211

Means within a row sharing a typical letter were not significantly different ($p < 0.05$).

Table 3. Volatile constituents identified from the preserved and fermented Onion (*Allium cepa* L) using GC-MS

S/N	Compound	KI[a]	Area %			Method of Identification[c,d]
			Control[e]	LAB[f]	SC[g]	
1	Acetic acid	600	12.01	5.20	6.11	KI, MS, STD
2	2-Pentanol	705	1.2	0.55	0.61	KI, MS
3	Dimethyl disulfide	720	4.12	7.11	5.78	KI, MS, STD
4	2-Methyl-2-butenal	749	2.06	1.88	0.98	KI, MS
5	2,3-Butanediol	769	6.20	5.25	4.22	KI.MS,STD
6	1,3-Butanediol	789	11.66	8.11	9.34	KI, MS, STD
7	Ethyl butanoate	799	10.09	8.61	9.49	KI, MS, STD
8	Dimethyl sulfoxide	820	-	2.33	1.87	KI, MS
9	1-Pentanol, 2-methyl-,	822	-	9.22	13.56	KI, MS
10	2-Methyl-2-pentenal	830	-	8.65	10.11	KI, MS
11	Ethylmethyl disulfide	861	-	3.33	2.54	KI, MS
12	2,5-Dimethyl thiophene	877	2.00	12.08	8.77	KI, MS
13	Diethyl disulfide	912	0.93	3.87	0.65	KI, MS
14	Methyl-1-propenyl disulfide	922	-	2.23	1.21	KI, MS
15	Methyl propyl disulfide	946	-	5.11	2.39	KI, MS
16	Benzaldehyde	961	3.52	-	-	KI, MS, STD
17	Ethyl hexanoate	996	-	1.27	2.09	KI, MS
18	2,4- Heptadieneal	1009	2.29	-	-	KI, MS
19	Limonene	1031	1.04	-	-	KI, MS, STD
20	2-Ethyl hexanoic acid	1129	-	0.85	0.09	KI, MS
21	Hexyl isothiocyanate	1209	3.61	-	-	KI, MS
22	Dipropyl trisulfide	1313	1.44	0.76	0.59	KI, MS
23	2,4-Decadienal	1314	1.24	-	-	KI, MS
24	Tetradecane	1400	1.65	0.61	-	KI, MS,STD
25	Hexadecene	1578	1.33	-	-	KI, MS
26	Hexadecane	1600	2.02	0.8	-	KI, MS, STD
27	Hexadecanoic acid	1940	5.34	-	1.22	KI, MS, STD
28	Ethyl hexadecanoate	1991	8.78	1.34	0.66	KI, MS
29	Linoleic acid, ethyl ester	2150	4.18	2.77	3.11	KI, MS
30	Oleic acid, ethyl ester	2170	3.47	1.10	1.44	KI, MS
31	Tricosane	2300	2.11	-	1.07	KI, MS, STD
32	Tetracosane, n-	2410	1.87	-	0.6	KI, MS, STD
-	**Total**	**-**	**94.16**	**93.03**	**88.5**	**-**

a Confirmed by comparison with Kovats index on a DB-5 column (Adams, 2007) [17]. b Values represent averages ± standard deviations for triplicate experiments. c Confirmed by comparison with the mass spectrum of the authentic compound. d Identification by comparison with data obtained from the National Institute of Standards and Technology (NIST)mass spectra library. e Preserved samples. f Fermented samples with yogurt as a source of LAB. G Fermented samples with baker's yeast as a source of S. cerevisiae

Tables (3&4) summarize GC-MS data obtained from the analysis of volatile compounds of fermented onion and broccoli compared to the preserved ones as a control. Thirty - two volatile compounds were identified in the fermented onion through yogurt and yeast and the control, representing 94.16, 93.03, and 88.5% of the total volatiles, respectively (Table 3). Thirty - seven constituents were revealed in the broccoli fermented by yogurt and yeast and the preserved control, accounting for 90.37, 93.71, and 94.17% of the volatile material (Table 4). Acetic acid, dimethyl disulfide, ethyl butanoate, and butanediols were the predominant components in fermented and preserved onion with a quantitative variation. However, other volatiles were detected as major components in fermented onion and not detected in the control one like 2,5-dimethylthiophene, methylpropyl disulfide, 2-methyl-1-pentanol and 2-methyl-2-pentenal.

The same volatile pattern could be observed in both fermented onion samples, however quanitative differences could be observed in both extracts (Table 3). In fermented broccoli, dimethyl disulfide, 1-hexanol, pentenol and hexenol derivatives, and many other sulfur compounds were the most abundant aroma volatiles, while palmitic acid, hydrocarbons like C14, C15, and C23, pentenol derivatives and dimethyl disulfide were the major compounds in the control broccoli extract (Table 4).

Table 4. Volatile constituents identified from the preserved and fermented Broccoli (Brassica oleracea L.) using GC-MS

S/N	**Compound**	**KI[a]**	**Area %**			**Method of Identification[c,d]**
			Control[e]	**LAB[f]**	**SC[g]**	
1	1-Penten-3-ol	678	6.11	4.12	5.43	KI, MS, STD
2	Furan, 2-ethyl-	702	0.78	1.12	2.33	KI, MS
3	Thiocyanic acid, methyl ester	713	1.80	3.72	2.72	KI, MS
4	Dimethyl disulfide	720	5.80	6.11	4.08	KI, MS, STD
5	2-Penten-1-ol	759	7.16	10.31	4.80	KI, MS, STD
6	Hexanal	800	1.81	0.54	1.4	KI, MS, STD
7	Furfural	830	-	1.12	3.17	KI, MS, STD
8	2-Hexenal, (*E*-)	854	-	1.1	1.32	KI, MS
9	3-Hexen-1-ol, (*Z*-)	860	0.65	5.43	1.87	KI, MS
10	2-Hexen-1-ol, (*E*-)	862	-	8.13	2.56	KI, MS
11	1-Hexanol	868	-	7.78	8.98	KI, MS, STD
12	*p*-Xylene	887	-	0.11	-	KI, MS
13	3-Hexen-1-ol, formate, (*Z*-)	920	0.11	2.10	1.6	KI, MS
14	Dimethyl trisulfide	964	0.72	2.6	1.88	KI, MS, STD
15	1-Octen-3-ol	980	0.20	0.48	1.02	KI, MS
16	Furan, 2-pentyl-	991	-	1.1	1.56	KI, MS
17	1-Pentanol	993	-	0.98	0.35	KI, MS
18	1-Butene, 4-isothiocyanto-	1001	-	1.21	1.06	KI, MS
19	*cis*- 2-(2-Pentenyl)furan	1003	-	0.11	0.80	KI, MS
20	2,4-Heptadienal (*E*,*E*-)	1012	-	1.83	1.01	KI, MS
21	S-Methyl methanesulfonate	1078	0.09	2.54	0.69	KI, MS
22	Disulfide, isopentyl methyl-	1102	-	0.31	0.55	KI, MS
23	1-Nonen-4-ol	1103	1.11	-	2.33	KI, MS
24	Disulfide, methyl (methylthio) methyl-	1143	0.12	-	0.90	KI, MS
25	Benzaldehyde, 3-ethyl-	1168	1.77	-	-	KI, MS
26	Tetrasulfide, dimethyl-	1240	2.11	3.45	1.88	KI, MS, STD
27	Benzene propanenitrile	1244	0.43	-	-	KI, MS
28	Benzene, 1,3-bis(1,1-dimethylethyl)-	1247	2.21	-	-	KI, MS
29	Indole	1290	2.33	0.55	-	KI, MS
30	Tetradecane	1400	6.32	1.03	5.14	KI, MS, STD
31	Pentasulfide, dimethyl-	1428	1.55	3.30	2.86	KI, MS
32	Pentadecane	1500	7.6	4.44	5.77	KI, MS, STD
33	Hexadecanal	1818	6.11	3.56	4.18	KI, MS
34	Hexadecanoic acid	1940	8.39	6.66	5.79	KI, MS.STD
35	Ethyl hexadecanoate	1991	7.98	2.78	5.82	KI, MS
36	Tricosane	2300	5.99	3.12	4.14	KI, MS, STD
37	Tetracosane, n-	2410	11.12	1.97	6.18	KI, MS, STD
-	**Total**	**-**	**90.37**	**93.71**	**94.17**	**-**

a Confirmed by comparison with Kovats index on a DB-5 column (Adams, 2007). b Values represent averages ± standard deviations for triplicate experiments. c Confirmed by comparison with the mass spectrum of the authentic compound. d Identification by comparison with data obtained from the National Institute of Standards and Technology (NIST)mass spectra library. e Preserved samples. f Fermented samples with yogurt as a source of LAB.G Fermented samples with baker's yeast as a source of S. cerevisiae.

These findings are consistent with the previous reports of Cheng et al. [25] , Wieczorek et al. [26], Jeong and Cha [27], and Xu et al. [23] despite the differences in the nature of the strains used as a starter culture, whereas acids, esters, alcohols, and sulfur compounds were the major classes identified in fermented onion and broccoli.

The onion's unique odor is mainly due to sulfur-containing compounds affected dramatically by the salt added during fermentation. According to Cheng et al. [25], fermentation without salt leads to a high decrease in sulfur-containing compounds' concentration, causing the unique onion odor's disappearance. However, the sulfur-containing compounds remained at the same original levels for the samples fermented with salt. These results suggested that salt can maintain the onion's unique odor, which is agreed with our findings. Six esters were detected in both fermented onion and the control sample. Only two esters were reported in raw onion; however, ten and 12 types of esters were found in the samples fermented without and with salt, respectively [25] . Most ester compounds have sweet and fruity aromas. The increase in esters makes fermented onion more palatable and increases in other classes like alcohols, ketones, phenols, and aldehydes. Jeong and Cha [27] showed an increase in acids and alcohols due to onion fermentation in acetic acid. For example, 1,3-Butanediol (odorless) and 2,3-butanediol (onion flavor) were increased upon fermentation, which is consistent with the results of the current study.

Previous studies demonstrated that breakdown products of glucosinolates during fermentation, such as isothiocyanates, give a characteristic flavor with "pungent" and "sulfurous" notes to many members of the Brassica genus [28] . Alcohols and aldehydes are believed to be responsible for "fresh" and "green" flavors, which arise from the lipid oxidation pathway [29]. Hence, the sensory analysis's significant changes between the control and fermented samples indicate that volatile metabolites' investigation could help us understand such differences perceived in the flavor. Lactobacillus spp can commonly form long-chain aliphatic alcohols like hexanol, heptanol, and others. via the α- or β-oxidation of fatty acids [30]. However, unsaturated alcohols, such as 1(3)-penten-3(2)-ol, are volatile metabolites emitted by microorganisms, associated with odors, and can be produced by reducing aldehydes or other alcohols by dehydrogenases [31] .

Conclusion

Yogurt and baker's yeast were applied as appropriate starter cultures as a source for LAB and S. servecia in pickling to avoid limitations in infrastructure, experience and to keep the benefits of probiotics in the final products. The organoleptic sensory attributes of the fermented pickles using yogurt were superior, followed by pickles fermented with baker's yeast. Meanwhile, significant differences were observed in the color parameters between fermented pickles and control samples preserved in salt and vinegar. The volatile analysis showed quantitative variations between fermented and traditional pickled ones, which revealed and affected sensory properties' differences. The present study opens perspectives for safer and easier solutions employing appropriate starter cultures with no need for a particular treatment to be applied simply in the food industry with all probiotics' benefits.

Conflicts of interest

There are no conflicts to declare.

Formatting of funding sources

No funding source to declare

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