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Pickling and storage of caperberries (*Capparis* spp.)

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Abstract Caperberries (0.7–1.9 cm diameter), collected in June 1996, were pickled for 1 month in 5% and 10% brine. Some physical, chemical and microbiological analyses were made during their fermentation and storage. While lactic acid bacteria (LAB) increased during fermentation in 5% brine, they did not increase after 15 days in 10% brine. In some cases, total bacterial (TB) growth decreased. In both brines, yeasts/moulds and coliforms (except for 5% brine on day 15) were not present after 15 and 20 days, respectively. For both caper species, the most suitable salt concentration, for LAB activity was 5–10% NaCl, and the best length of fermentation with respect to product colour, flavour, acidity, pH and LAB activity in brine was 20–25 days. The texture was maintained well during storage. Acidity and pH were markedly affected by the concentration of brine. The quality of all samples was maintained with a 15% concentration of old or fresh brine during storage. The colour of the samples, especially those of *C. ovata*, stored with old brine was darker that of fresh berries. As no "off" flavour was observed, it was concluded that pickled caper berries can be stored in fresh brine with a 15% NaCl concentration.

Key words Capers · Caperberries · Fermentation · Pickled products · Storage

Introduction

Caperberries, fruits of perennial shrubs of the genus *Capparis,* have medical and aromatic properties. Caper flower buds, root, fruits and young shoots are used as foodstuffs. Some parts of the plants are used for the production of medicines, cosmetics and insecticides. Some *Capparis* species provide erosion control and food for grazing animals. Even though the fruits and young shoots of capers are less abundant than their flower buds, its fruits are pickled for consumption. Fruits with small, soft seeds are preferred for the production of pickles [1].

Capers plays an important role in the food industry; the flower buds are stored brine and have become a costly product during recent years. Although the world production of capers has changed with time, approximately 10000 tons are produced annually and the main producers and/or manufacturer/exporter countries are Spain, Morocco and Italy. Turkey has become a major exporter of capers in the last decades, and exports 3000–5000 tons of fermented capers. There is little information on caper berries compared to capers. Work has been carried out on the characteristic properties of the plant, the composition of raw and fermented buds, and the effect of brine and packing on the quality of capers [2–8]. There is no commercial production of caper berries. In contrast, capers are exported to the United States, United Kingdom and Venezuela [5, 9]. Law, mature fruits of *C. decidua* are fermented in brine for 1 month. After fermentation, the fruits are crushed, mixed with salt, spices, oil and vinegar, and kept at room temperature for 3 months. After storage, the sensory properties of samples are determined.

The objective of this work was to study the fermentation of caperberries and the effect of storage on the sensory, chemical and microbiological qualities of pickled caperberries from different plant species.

Materials and methods

Samples. Fruits of *C. spinosa* L. var. *spinosa* and *C. ovata* Desf. var. *canescens* (Coss.) Heywood were collected from wild plants in İçel (Büyükeceli-Gülnar) and Konya (Selçuklu) in June 1997. The fruits were 0.7–1.9 cm in diameter. Before being added to the fermenters, the fruits were washed with tap water and separated from the stamens.

Processing. Fruits of both species were put into 3L jars and brined at a pack-out ratio of 2/1 (brine/fruits). For each jar the

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following salt concentrations were prepared: 5% and 10% NaCl. After 5 days, the salt concentration of each jar was increased regularly to maintain the original level. So the last concentration level of each brine was reached in certain intervals on 15 days. All the samples were subjected to fermentation at room temperature for 25 days. Brine analysis, in order to follow the pickling process, was undertaken at 5-day intervals. After fermentation, pickled fruits of *C. spinosa* and *C. ovata* were stored in either 15% old or fresh brine for 180 days. Brine analysis, in order to assess the effect of storage, was undertaken at specific intervals. Experiments and analyses were replicated and duplicated.

Physical, chemical and microbiological analyses. Brine was analysed at specific intervals. Some chemical, physical and microbiological analyses of brine were undertaken during fermentation and storage [10, 11]. Rogosa agar (Merck, Darmstadt, Germany), nutrient agar (Oxoid, England), potato dextrose agar (Merck) and eosin methylen blue agar (Oxoid), respectively, were used for lactic acid bacteria (LAB), total bacteria (TB), yeasts/moulds (YM) and coliforms (CB) in the microbiologial analyses. Dilutions were prepared ($\times 10^4$) and colonies were measured as colony forming units/ml [12, 13]. Firmness was determined according to [14], by using a biological material test instrument (Vibro-meters, Fribourg, Switzerland; frequency range 0–2200 Hz, linearity 0.05%, working temperature −10 to 50 °C) modified by [15].

Statistical analysis. Results were analysed by variation [16], and differences among groups were determined by Duncan's multiple range test [17, 18].

Results and discussion

Brine characteristics

The results of the chemical and microbiological analyses of brine during fermentation are given in Table 1. Except for 5% brine used for *C. spinosa* and *C. ovata* measured after 5 days of fermentation, differences among acidity values on other days were significant at the $P<0.01$ level. pH values on other days (except for *C. spinosa* brine on day 25) were significantly different at the $P<0.01$ level (Table 1). Differences at the same significance level were found for LAB activity during fermentation. Acidity increased until 15 days of fermentation and was then stable. The highest acidity (0.80%) was determined for the 10% brine, *C. ovata* treatment after 15 days of fermentation. The pH was high in the 5% brine treatments during fermentation, and LAB grew at this concentration of brine during fermentation. LAB growth was not observed in 10% brine (except in the 10% brine, *C. ovata* treatment) after 10 days. YM and CB did not grow after 10 and 15 days of fermentation, respectively.

The increase in acidity inhibited the growth of CB and YM after 15 days (except for the 5% brine, *C. ovata* treatment). The high salt concentration inhibited the growth of LAB. CB present at the start of fermentation were probably due to handling, and contamination of raw material and equipment. YM growth is not desirable during fermentation, because it can cause softening and changes in colour of the product and the formation of a slight film on the brine surface and further spoilage.

The most suitable salt concentration of LAB growth was 5% NaCl. Undesirable microorganisms can grow in 5% brine, however, and the fermentation must be continuously controlled. For both species, optimal pickling time was determined at 20–25 days, as regards end-product odour, brine acidity and pH, and LAB activity.

The growth of LAB was significantly reduced by increasing the salt concentration. Also, environmental

Table 1 Brine analysis during fermentation of caper berries. Differences between means within a colum followed by *different letters* are significant ($P<0.01$). *CFU* Colony forming units

Days	Species	Brine (%)	Acidity (% lactic acid)	pH	Salt (%)	Lactic acid bacteria (CFU/ml $\times 10^4$)	Total bacteria (CFU/ml $\times 10^4$)	Coliforms (CFU/ml $\times 10^4$)	Yeast moulds (CFU/ml $\times 10^4$)
5	*C. spinosa*	5	0.335 ± 0.010K	4.29 ± 0.01F	3.198 ± 0.026	1067.75 ± 25.7A	5.250 ± 3.594	– [a]	1.75 ± 5.00
		10	0.380 ± 0.016J	4.22 ± 0.06E	5.903 ± 0.010	7.25 ± 3.50C	–	–	0.500 ± 0.077
	C. covata	5	0.345 ± 0.010JK	4.28 ± 0.02F	3.458 ± 0.096	623.50 ± 310.43B	1.000 ± 0.817	6.250 ± 2.228B	0.500 ± 0.077
		10	0.375 ± 0.053JK	4.16 ± 0.04H	6.098 ± 0.044	14.75 ± 11.03C	–	–	–
10	*C. spinosa*	5	0.575 ± 0.031H	4.87 ± 0.01A	4.005 ± 0.070	191.00 ± 67.80C	5.750 ± 1.500	10.750 ± 4.992A	0.750 ± 0.500
		10	0.520 ± 0.016I	4.74 ± 0.01B	7.738 ± 0.229	–	0.250 ± 0.500	–	–
	C. ovata	5	0.540 ± 0.016HI	4.76 ± 0.02B	3.945 ± 0.081	439.25 ± 199.77B	0.250 ± 0.100	1.750 ± 0.957BC	0.250 ± 0.100
		10	0.540 ± 0.016HI	4.58 ± 0.06D	7.665 ± 0.151	5.50 ± 2.02C	0.500 ± 0.077	4.250 ± 315BC	–
15	*C. spinosa*	5	0.630 ± 0.037G	4.86 ± 0.02A	4.060 ± 0.064	23.00 ± 5.19C	1.000 ± 0.817	–	–
		10	0.758 ± 0.013AB	4.77 ± 0.04B	7.653 ± 0.108	–	1.250 ± 0.893	–	–
	C. ovata	5	0.745 ± 0.010BC	4.80 ± 0.04E	3.988 ± 0.073	444.50 ± 16.90B	0.250 ± 0.100	1.000 ± 0.155C	–
		10	0.800 ± 0.012A	4.64 ± 0.01CD	7.825 ± 0.220	–	2.750 ± 1.708	–	–
20	*C. spinosa*	5	0.755 ± 0.010ABD	4.86 ± 0.01A	4.170 ± 0.041	28.50 ± 8.74C	2.500 ± 1.317	–	–
		10	0.670 ± 0.029EFG	4.76 ± 0.01B	8.045 ± 0.013	–	0.500 ± 0.077	–	–
	C. ovata	5	0.710 ± 0.026CDE	4.74 ± 0.02I	4.025 ± 0.024	656.25 ± 172.55B	0.250 ± 0.100	–	–
		10	0.680 ± 0.016DEF	4.65 ± 0.01C	8.088 ± 0.028	–	0.500 ± 0.077	–	–
25	*C. spinosa*	5	0.640 ± 0.012FG	4.91 ± 0.01A	4.223 ± 0.013	28.75 ± 15.76C	1.750 ± 0.957	–	–
		10	0.563 ± 0.031HI	4.86 ± 0.02A	8.248 ± 0.057	–	0.500 ± 0.077	–	–
	C. ovata	5	0.650 ± 0.016FG	4.90 ± 0.05A	4.108 ± 0.071	938.5 ± 177.76A	0.250 ± 0.100	–	–
		10	0.715 ± 0.019BCD	4.73 ± 0.02B	8.328 ± 0.021	–	0.750 ± 0.257	–	–

[a] No growth

conditions and general microbial flora are factors which inhibit LAB growth [1, 19, 20].

Because the use of brine at a high concentration in pickling inhibits LAB growth, low concentration brines lead to microorganism growth and high acidity [5, 20, 21]. In studies examining 5%, the effects of 7.5%, 10% and 20% brine, the most rapid fermentation occurred with a 5% salt concentration. According to other authors, LAB activity is not inhibited by high salt concentrations and increasing of brine acidity [4, 20].

Sanchez et al. [5] found that in all cases of fermentation studied, LAB were the main microorganisms responsible for the process. Fermentation of samples in stored in water and 4% salt was similar, while 7% and 10% salt concentrations delayed fermentation. Also, the buffered series fermented to a greater extent than the unbuffered treatments.

The results of the present study were generally similar to the literature findings, with minor differences due to different raw materials and processing parameters.

Storage characteristics

Brine analysis results for both species of fermented caperberries (15% old and fresh brine) are given in Table 2. While acidity values during storage were high in the samples with old brine, pH values were decreased. All samples had an acceptable texture which differed between treatments ($P<0.01$). Growth of TB was observed during fermentation (except in old and fresh brine at the start of fermentation and on day 30, old brine of *C. ovata* treatments on day 30, and old and fresh brine of *C. ovata* treatments on day 150) until the acidity of old brine was high and the pH was low. This condition can be due to lactic acid occurred during fermentation before storage. Growth of TB during storage showed that there are species resistant to salt. The decrease in "off" flavours, prevention of sedimentation, and desirable firmness of the berries suggested that fresh brine should be used for the long-term storage of pickled caper berries. Sanchez et al. [5] pointed out that an increase in the salt level up to 10% NaCl at equilibrium was found to be suitable for bulk storage of berries. They also found that an acceptable colour and texture was achieved in all cases. Storage conditions of several fermented products may be affected by the physical, chemical and microbiological properties of brine in conjunction with the salt concentration. Also, to guarantee storage, a higher salt concentrations, such as 15%, should be selected.

Conclusions

The fermentation of caper fruits was carried out almost entirely by LAB. Fermentation was affected by brine strength. LAB in lower salt concentrations had a faster growth rate. Salt concentrations at the beginning of fermentation were diminished, especially in 5% and 10%. LAB activity was high with these concentrations, especially 5% brine. While decreasing salt levels are detrimental to LAB activity, the growth of spoilate microorganisms like TB, CB and YM might be inhibited by these. The qualities of both species, fruits were similar, apart from their colour. The colour of *C. spinosa* was

Table 2 Brine and firmness analysis during storage of caper berries. Differences between means within a column followed by *different capital letters* are significant ($P<0.01$). Differences between means within a column followed by *different small letters* are significant ($P<0.05$)

Days	Species	Brine (15%)	Acidity (% lactic acid)	pH	Salt (%)	Total bacterial (CFU/ml $\times 10^4$)	Coliforms (CFU/ml $\times 10^4$)	Yeasts/ moulds (CFU/ml $\times 10^4$)	Firmness (kg/cm^2)
0	*C. spinosa*	Old	0.530 ± 0.026	4.87 ± 0.06G	10.720 ± 0.075	–[a]	–	–	13.427 ± 0.528DEF
		Fresh	0.160 ± 0.016	5.47 ± 0.06J	11.398 ± 0.107	1.75 ± 1.26A	–	0.25 ± 0.10	13.065 ± 0.161FG
	C. ovata	Old	0.530 ± 0.026	4.68 ± 0.06I	12.182 ± 0.280	1.25 ± 1.06AB	2.75 ± 0.89a	–	13.530 ± 0.250DEF
		Fresh	0.175 ± 0.019	5.55 ± 0.02D	12.262 ± 0.321	0.25 ± 0.10AB	0.75 ± 0.06b	0.50 ± 0.18	13.905 ± 0.095BCDE
30	*C. spinosa*	Old	0.548 ± 0.044	4.92 ± 0.01G	13.398 ± 0.344	0.50 ± 0.18AB	0.75 ± 0.50b	–	14.190 ± 0.208ABC
		Fresh	0.235 ± 0.010	5.14 ± 0.4E	12.795 ± 0.150	–	–	–	13.995 ± 0.241BCD
	C. ovata	Old	0.568 ± 0.022	4.76 ± 0.02H	14.323 ± 0.546	–	–	–	14.645 ± 0.497A
		Fresh	0.240 ± 0.012	5.16 ± 0.04E	13.570 ± 0.312	0.50 ± 18AB	–	–	14.538 ± 532AB
90	*C. spinosa*	Old	0.403 ± 0.015	4.91 ± 0.01G	14.993 ± 0.010	0.75 ± 0.50AB	–	0.50 ± 0.18	12.592 ± 0.125GH
		Fresh	0.205 ± 0.048	5.04 ± 0.09F	14.245 ± 0.462	0.50 ± 0.18AB	–	–	12.565 ± 0.421GH
	C. covata	Old	0.550 ± 0.026	4.67 ± 0.07I	14.990 ± 0.012	0.75 ± 0.16AB	–	0.50 ± 0.18	13.915 ± 0.060CDE
		Fresh	0.275 ± 0.025	4.88 ± 0.06G	14.665 ± 0.387	0.50 ± 0.18AB	–	–	12.920 ± 0.117FG
150	*C. spinosa*	Old	0.345 ± 0.096	6.04 ± 0.02A	15.682 ± 0.293	1.00 ± 0.41AB	–	0.50 ± 0.18	12.195 ± 0.424HI
		Fresh	0.163 ± 0.045	6.07 ± 0.06A	15.408 ± 0.495	0.50 ± 0.18AB	–	–	12.080 ± 0.436HI
	C. ovata	Old	0.510 ± 0.087	5.79 ± 0.06C	15.747 ± 0.224	–	–	0.75 ± 0.50	13.280 ± 0.098EF
		Fresh	0.235 ± 0.010	5.88 ± 0.09B	15.010 ± 0.044	–	–	–	13.265 ± 0.150F
180	*C. spinosa*	Old	0.513 ± 0.022	4.63 ± 0.02I	16.177 ± 0.043	1.00 ± 0.82AB	–	–	11.210 ± 0.079J
		Fresh	0.270 ± 0.037	4.65 ± 0.04J	15.390 ± 0.210	0.50 ± 0.18AB	–	–	11.833 ± 0.465I
	C. ovata	Old	0.565 ± 0.019	4.36 ± 0.06K	16.070 ± 0.388	0.50 ± 0.18AB	–	–	12.597 ± 0.127GH
		Fresh	0.278 ± 0.044	4.37 ± 0.02K	15.542 ± 0.183	1.25 ± 0.50AB	–	–	12.488 ± 0.154GH

[a] No growth

more desirable than that of *C. ovata*. The quality of fermented caperberries was maintained when stored in fresh brine with a concentration of 15% NaCl at equilibrium; excessive exposure to air should be avoided to prevent changes of colour during storage. Because of the undesirable odour of caper berries when stored in old brine, and increased microbial contamination, fresh brine containing at least 15% NaCl should be used for the storage of fermented caper berries.

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