

Partial replacement of sodium chloride with other chloride salts for the production of black table olives from cv. Gemlik

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RESEARCH ARTICLE

Abstract

The aim of this study was to investigate the quality of black table olives made from cv. Gemlik by partially replacing sodium chloride with other salts to reduce NaCl in table olives. Five different combinations of chloride salts were used as 10% NaCl (control treatment), 5% NaCl+5% CaCl₂, 5% NaCl+5% KCl, 5% KCl+5% CaCl₂ and 3.3% NaCl+3.3% KCl+3.3% CaCl₂ for table olive production according to the traditional Gemlik method. Fermentations were carried out for 190 days in duplicate. At the end of the fermentations, total acidity values reached from 1.17 to 4.54 g/l and yeast and lactic acid bacteria counts were in the range of 6.51 and 8.26 log cfu/ml, respectively. According to the sensory evaluation, the brines including CaCl₂ were less preferred by the panellists. Combination of KCl and CaCl₂ salts led to bitter taste in the final product. On the other hand, combination of chloride salts as 5% NaCl and 5% KCl resulted in low sodium content olives with good organoleptic characteristics. Result showed that, acceptable end products can be produced by using NaCl and KCl salt mixtures to meet the demands of low sodium intake in the production of table olives.

Keywords: fermentation, processing, cultivar, lactic acid bacteria, sensory properties

1. Introduction

Table olive is an important fermented food product which is produced on industrial scale besides the production at homes. It is made from the fruit of olive tree (*Olea europaea* L.) which is grown especially in Egypt, Spain, Turkey, Algeria and Greece. In 2017, world table olive production was estimated almost as 2.9 million tons and Turkey lies in an important position in the world since it produces 15% of this production (IOC, 2017). Table olives are classified as green olives, turning colour olives and black olives according to the degree of ripeness of the fresh fruits and production method changes depending on the type of the table olive (IOOC, 2004). The main processes used for black olive production in Turkey are fermentation in brine or dry salting. Cv. Gemlik is the most common Turkish variety of black table olives that constitutes half of the olive market in Turkey. Olives from this cultivar are naturally fermented by Gemlik style in brine or dry salt (Erten and Tanguler, 2014; Erten *et al.*, 2016).

Sodium chloride (NaCl) is used as the main ingredient of the vegetable fermentation brines including table olives. In the production of table olives, NaCl plays the major role to ensure the microbiological stability besides enhancing the organoleptic properties by its characteristic flavour (Bautista-Gallego *et al.*, 2010, 2011a; Garrido Fernández *et al.*, 1997; Panagou *et al.*, 2011). The effect of NaCl on the microbiological safety is also important during the packaging and storage of the final product. NaCl is also essential for human body and the physiological need in adults is 184-230 mg/day (Dahl, 1972). However, it was reported that populations around the world are consuming much more sodium than its physiologically necessary (Elliot and Brown, 2007). Lowering dietary intake of sodium is advised by public health and regulatory authorities due to the relationship between high dietary sodium intake and cardiovascular diseases (Panagou *et al.*, 2011; Rodríguez-Gómez *et al.*, 2012; SACN, 2003; WHO, 2003, 2007a). Also salt is important especially for exporting of table olive.

Table 1. The physical characteristics of Gemlik variety olive fruits.

Physical characteristic	Mean
Maturity index (MI)	5.36
Number of olive fruit/kg	232
1000 olive weight (kg)	4.25
Flesh/stone weight ratio	5.87
Mean fruit height (mm)	22.94
Mean fruit width (mm)	18.41
pH	5.24
Colour	
L*	24.43
a*	4.13
b*	1.05
Hue	14.49
ΔC	4.28

World Health Organization (WHO) recommends maximum 2 g sodium/day that is equivalent to 5 g salt/day (WHO, 2003, 2007b). However, salt consumption still remains above such levels all over the world and some plans are implemented by different countries to reduce salt levels in food products. There is also an increasing demand by consumers for low-salt and sodium-reduced food products for health reasons. A diet low in sodium and high in potassium and calcium is effective in lowering blood pressure and protecting against osteoporosis and colon cancer (Bernier *et al.*, 1990; Leiba *et al.*, 2005). Replacement of NaCl with other chloride salts such as potassium chloride (KCl), calcium chloride (CaCl₂) and magnesium chloride (MgCl₂) can overcome the negative effects of high NaCl (Panagou *et al.*, 2011).

Fermented vegetables contribute to high dietary sodium intake. There are studies for NaCl reduction or replacement of NaCl with other salts in vegetable fermentations including olives (Bautista-Gallego *et al.*, 2010, 2011a,b; Panagou *et al.*, 2011; Rodríguez-Gómez *et al.*, 2012; Zinno *et al.*, 2017), sauerkraut (Penas *et al.*, 2010; Viander *et al.*, 2003; Wolkers-Rooijackers *et al.*, 2013), kimchi (Choi *et al.*, 1994), cucumber (Guillou and Floros, 1993; Guillou *et al.*, 1992) and shalgam (Agirman, 2014). Especially black olives are brined at high salt concentrations ranging from 6 to 14% or even higher, depending on processing methods. Different concentrations of chloride salts were studied in brines for the production of table olives to reduce sodium content in table olive fermentations (Bautista-Gallego *et al.*, 2010, 2011a,b; Kanavouras *et al.*, 2005; Mateus *et al.*, 2016; Moreno-Baquero *et al.*, 2013; Mule *et al.*, 2000; Panagou *et al.*, 2011; Rodríguez-Gómez *et al.*, 2012; Tsapatsaris and Kotzekidou, 2004). In the study of Panagou *et al.* (2011), different mixtures of NaCl, KCl, and CaCl₂ as 4% NaCl+4% KCl, 4% KCl+4% CaCl₂, 4% NaCl+4% CaCl₂ and 2.6%

NaCl+2.6% KCl+2.6% CaCl₂ were examined to decrease the sodium content of *Conservolea* natural black olives and the combination 4% NaCl+4% KCl resulted in low sodium content with good organoleptic characteristics. In the work of Bautista-Gallego *et al.* (2011a) on the fermented cracked Aloreña olives, the best overall quality was obtained in the 0.037 kg/l NaCl and 0.073 kg/l KCl mixture. Results show that NaCl can be partially replaced with KCl and CaCl₂ in table olives. However sensory evaluation is also very important from the consumer acceptability point of view besides acceptable analytical results (Bautista-Gallego *et al.*, 2011a). Mule *et al.* (2000) reported the possibility of production green table olives with a low sodium content and good organoleptic characteristics by using brines containing chlorides other than NaCl.

As our knowledge there is no comparative study to evaluate the influence of different mineral salts on olives cv. Gemlik. The aim of the present study was to reduce the sodium content in table olive production and to investigate the effects of different chloride salt mixtures including NaCl, KCl and CaCl₂ at various concentrations on the fermentation and quality of black table olives made from cv. Gemlik.

2. Materials and methods

Samples and experimental design

The olive fruit samples of cv. Gemlik were harvested from Tarsus district of Mersin city in Turkey (36° 54' 59.62' – 34° 53' 42.756') when fresh olives reached harvest maturity for black olives. At the harvest, the olives were fully ripened and the colour of the peel of the olive fruits were black or purple-black. The olive fruit samples were collected and sorted to remove damaged, crushed, soft and different coloured ones which are unsuitable for processing. Then olives were fermented in five different brines that contain different chloride salts at various concentrations as follows; 10% NaCl (Brine A), 5% NaCl+5% CaCl₂ (Brine B), 5% NaCl+5% KCl (Brine C), 5% KCl+5% CaCl₂ (Brine D) and 3.3% NaCl+3.3% KCl+3.3% CaCl₂ (Brine E). Brine A, 10% NaCl treatment, was used as control.

Olive fruits (12 kg) were put into plastic containers (total capacity of 20 l) filled with brine solutions and the brines were covered with food grade perforated disks. Then stones (15% by weight of the olives) were put on the containers to prevent the olives from floating and containers were closed loosely to allow the gas outlet. Fermentation processes were allowed to carry out spontaneously at room temperature in duplicate and the concentrations of the chloride salts in brines were maintained at 10%. Fermentations were followed by monitoring pH and total titratable acidity of the brines.

Physical and chemical analyses

Quality criteria such as maturity index, the number of olive fruit/kg, 1000 olive weight, dimensions of fruit, flesh/stone weight ratio, total dry matter, colour of the fruit, total ash, total acidity, pH and salt levels were determined in the black table olives before and after fermentation. For the determination of the maturity index (MI) randomly selected 100 olive fruits were taken (Arslan and Özcan, 2011; Hermoso *et al.*, 1991). Then the olives were separated into 8 colour categories as green skin (Group A=0), yellow-green skin colour (Group A=1), green skin colour with less than half of the surface is turning red (Group A=2), green skin colour with more than half of the surface is turning red or violet (Group A=3), black skin colour with white flesh (Group A=4), black skin colour with less than half of the flesh is turning purple (Group A=5), black skin colour with more than half of the flesh is turning purple (Group A=6), black skin colour and all of the flesh is purple (Group A=7). The MI was calculated by using the following Equation 1 as shown below and A is the colour category and N is the number of fruits in each category.

$$MI = \frac{\sum(A_i N_i)}{100} \quad (1)$$

The number of olive fruit per kg was determined by counting randomly selected 100 g of olive fruit samples. The result is then multiplied by 10 (Anonymous, 1997). Randomly selected 100 olives were weighed and multiplied by 10 to calculate the 1000 olive weight. Dimensions (width and height) of 10 randomly selected olives for each category were measured by a calipers with 0.1 mm precision (Anonymous, 1997). Randomly selected 100 g of olive fruits were weighed and pitted by hand to determine flesh/stone weight ratio. Colour of olives was characterised by a Konica Minolta chromatometer CR-400 (Tokyo, Japan). Chromatic values as L*, a* and b* were determined. Chroma (ΔC) and hue angle (Hue) values calculated based on the following Equations 2 and 3 as illustrated below:

$$\text{Hue} = \arctan \frac{b^*}{a^*} \quad (2)$$

$$\Delta C = \sqrt{a^{*2} + b^{*2}} \quad (3)$$

Total dry matter of the olive fruits were determined according to Cemeroglu (2010). Ash content was determined in a muffle furnace at 600 °C (Cemeroglu, 2010). The pH of the olive fruits and brines was measured by using a pH meter (WTW-Inolab, Weilheim, Germany) according to the AOAC (1990). Total acidity was determined as lactic acid by titration with 0.1 N NaOH (Anonymous, 1990; Ough and

Amerine, 1988). Salt content was analysed by titration with 0.1 N AgNO₃ solution according to Anonymous (1997).

Microbiological analysis

Microbiological analyses were performed in olive brines and aliquots of olive brines were serially diluted and plated on selective agar plates for microbial enumeration (Kanavouras *et al.*, 2005; Perricone *et al.*, 2010). The media and the conditions were as follows: plate count agar (PCA) incubated at 30 °C for 2-3 days for total mesophilic aerobic bacteria; MRS agar and M17 agars supplemented with 50 mg/l of cycloheximide were incubated at 30 °C for 2-3 days in anaerobic conditions for lactic acid bacteria (LAB); potato-dextrose-agar medium that contains 0.1 g/l oxytetracycline and L-lysine agar incubated at 25 °C for 2-3 days for total and non-*Saccharomyces* yeasts, respectively (Campbell, 1988; Halkman, 2005; Perricone *et al.*, 2010; Servili *et al.*, 2006; Settanni *et al.*, 2011).

Sensory evaluation

For the sensory analysis of black table olives, 11 panellists evaluated the final products for odour, taste, colour and appearance by using 10-point hedonic scale ranging from 1 (dislike extremely) to 10 (like extremely). Also preference ranking test (1-5) was used to determine most preferred table olives among the brines of different chloride salts. Table olive samples were evaluated by panellists and ranked from best to worst (Altug and Elmaci, 2005).

Statistical analysis

Results were subjected to analysis of variance. Duncan's multiple range test was applied for significant differences by using SPSS 18 statistical software (IBM Corporation, Armonk, NY, USA).

3. Results and discussion

Physical and chemical characteristics of raw olive fruits

In present study, different combinations of chloride salts were used for table olive production according to the traditional Gemlik method with cv. Gemlik. The physical characteristics of cv. Gemlik olive fruits are shown in Table 1. The size of olive fruits of cv. Gemlik was larger than the studies reported in other studies (Kumral, 2005; Özay and Borcaklı, 1995; Şahin *et al.*, 2000; Uylaşer *et al.*, 2008). The MI is an important indicator to determine the appropriate harvest time of olive fruits to process and it was 5.36 in the present study. Number of olive fruit/kg was 232. In other studies, number of olive fruit/kg ranged from 272 to 356 for cv. Gemlik which was higher than the present study. Flesh/stone weight ratio was 5.87. Flesh/stone weight ratio was higher than the values in the literature (Kumral, 2005;

Şahin *et al.*, 2000; Uylaşer *et al.*, 2008). The height and width of olive fruits were calculated as 22.94 and 18.41 mm, respectively. In other studies, the height and width of fruits were in the range of 20.40-21.37 mm and 14.40-16.68 mm, respectively (Kumral, 2005; Şahin *et al.*, 2000; Uylaşer *et al.*, 2008). pH of olive fruits was found as 5.24. pH value was similar to the values determined in other studies that were ranged from 5.14 to 5.50 depending on the region for cv. Gemlik (Uylaşer *et al.*, 2008, 2009).

The total acidity of olive fruits was 0.38% as lactic acid in the present study. Total dry matter and ash content (wet weight basis) were 40.43 and 1.12%, respectively. Acidity of the olive fruits was less than reported by Uylaşer *et al.* (2008) in different Gemlik cultivars harvested from three different regions (Gemlik, Nilüfer and Orhangazi) as 0.6-

0.7%. Total dry matter and ash content values of present study were almost same with other studies (Uylaşer *et al.*, 2008, 2009).

Fermentation

The total acidity as lactic acid and pH were used to monitor fermentation of table olives in different brines. Changes in total acidity of brines with different chloride salts during olive fermentations were shown in Figure 1A. Total acidity increased in all brines with different chloride salts throughout fermentation. The total acidity values changed between 0.09-0.27 g/l at the beginning of olive fermentations. Brine B reached the highest total acidity value as 5.8 g/l lactic acid on the 130th day of fermentation and then total acidity decreased reaching 2.9 g/l lactic acid

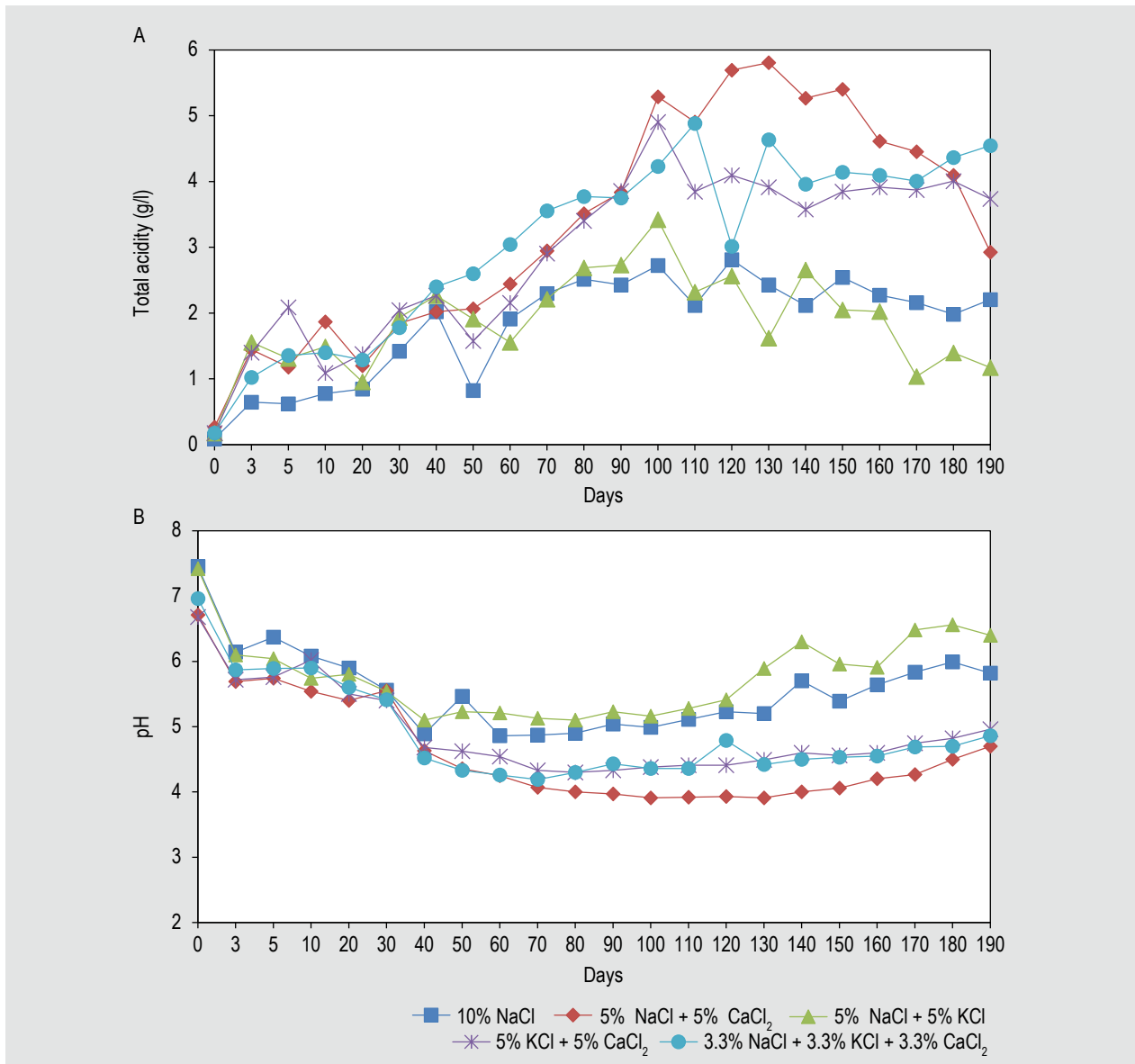


Figure 1. Changes in total acidity (A) and pH (B) during table olive fermentations.

at the end of the fermentation. Brines D and E reached the highest total acidity values on the 100th and 110th day of fermentation and the highest values were determined as 4.9 g/l lactic acid for both of them. Total acidity was lower in the Brines C and A. Total acidity value of Brine C was highest on the 100th day of fermentation as 3.4 g/l lactic acid and it was 1.2 g/l as lactic acid at the end of the fermentation. At the end of the fermentations total acidity values were in the range of 1.17-4.54 g/l. Brine A, in which only NaCl was used as chloride salt, the maximum total acidity was 2.8 g/l as lactic acid on the 120th day of fermentation and reached to 2.2 g/l as lactic acid at the end of the fermentation. Table olive fermentations were conducted 190 days. Final acidity of the fermented table olives was in agreement with previous work of Leventdurur *et al.* (2016). In that work, total acidity value was 2.2 g/l for the fermentation in the 10% NaCl brine at the end of the black olive fermentation for cv. Gemlik of Tarsus district.

Changes in pH of brines with different chloride salts during olive fermentations are shown in Figure 1B. At the end of the fermentations pH values were in the range of 4.7-6.4. In the Brine A, pH value was 5.8 at the end of the fermentation. This result was in agreement with previous study done by Leventdurur *et al.* (2016), since pH value was 5.7 for the brine containing 10% NaCl on the fermentation of cv. Gemlik black olives collected from Tarsus district. In the present fermentations, pH values decreased rapidly in the first 3 days followed by a slow reduction until the 40th day and were stable from that day until the 120th day of fermentation. After the 120th day, pH values of all fermentations increased especially in the Brines A and C. Fluctuations was observed in terms of pH during fermentation. Medium included high amount of fermentable sugars in the beginning. Therefore, the quick fall in pH is caused by the fermentation of those sugars into lactic acid during first 40 days. However, available sugar concentration was decrease with time and LAB started to use proteins instead of sugars. In this case increase in pH values was observed because of releasing of amino acids and ammonia by breakdown of proteins in addition to degradation of lactic acid by LAB and some spoilage microorganisms. In the Brines B, D and E containing CaCl₂, pH was lowest both at the beginning and at the end of the fermentation. In the study of Bautista-Gallego *et al.* (2011b), the presence of CaCl₂ led to lower initial and after-fermentation pH values. They reported that diffusion of alkali in the flesh raises the pH in the solution and a decrease in alkali diffusion into the brine can cause lower pH values due to calcium interaction with pectic acid polymers to form cross-bridges and strengthened the flesh (Bautista-Gallego *et al.*, 2011b; Jiménez *et al.*, 1997; Roy *et al.*, 1994).

Microbial cell densities

Lactic acid bacteria play a fundamental role in table olive fermentations. It was reported that lactic acid bacteria and yeasts compete for the fermentation of olives and lactic acid bacteria are generally responsible for the fermentation of treated olives. On the other hand, yeasts could play a minor role as contributing to the flavour and aroma of table olives (Hurtado *et al.*, 2012). Microbial suspensions were plated on MRS and M17 agar mediums for the mesophilic rod and coccus LAB, respectively (Aponte *et al.*, 2012; Settanni *et al.*, 2011). Number of lactic acid bacteria grown on MRS agar during table olive fermentations is shown in Figure 2A. At the beginning of the olive fermentations, number of LAB on MRS medium ranged from 3.33 to 3.78 log cfu/ml. The lowest and highest LAB counts were observed in Brines C and D, respectively. The samples reached their highest counts on MRS on the 60th days of fermentations of Brines A and E, on the 50th day of fermentation of Brine B, on the 80th day of fermentation of Brine C and on the 40th day of fermentation for Brine D samples. The highest LAB counts were determined as 9.39 log cfu/ml, 9.07 log cfu/ml, 8.89 log cfu/ml, 9.35 log cfu/ml and 8.94 log cfu/ml for Brines A, B, C, D and E, respectively. At the end of fermentation, the values were in the range of 6.51-7.50 log cfu/ml. In the study of Panagou *et al.* (2011), LAB population on MRS medium during the fermentation with different salt mixtures was in the range of 7.2-7.6 log cfu/ml. Number of lactic acid bacteria that was grown on M17 agar during table olive fermentations is shown in Figure 2B. At the beginning of the fermentations, the highest and lowest coccus LAB levels were observed in the Brines A and D as 4.78 and 2.61 log cfu/ml, respectively. In other samples, it was in the range of 3.49-3.83 log cfu/ml. The highest LAB counts on M17 mediums were reported on the 90th day of fermentation for Brine A as 9.09 log cfu/ml. Brines B, C and D reached to their highest counts as 9.08 log cfu/ml on the 60th, 70th and 40th days of fermentations, respectively. The maximum coccus LAB count was 8.99 log cfu/ml on the 40th day of fermentation for Brine E which contain all three chloride salt mixtures. Then LAB counts on M17 medium started to decrease. On the last day of fermentation, LAB grown on M17 medium were in the range of 7.13-8.17 log cfu/ml. Results showed that LAB counts were higher on M17 medium when it was compared with MRS medium at the end of the fermentation. Differences in the counts of LAB on different mediums can be related to the occurrence of different nutrients in two different media. However, number of presumptive coccus LAB can be assumed higher than rod LAB.

Total mesophilic aerobic bacteria count values were in the range of 4.04-4.65 log cfu/ml at the beginning of the olive fermentations as it can be seen from the Figure 2C. The lowest and highest mesophilic aerobic bacteria count values were observed in Brines E and D as 4.04 and 4.65 log cfu/ml,

respectively. The highest mesophilic aerobic bacteria were determined on the 60th day of fermentation for Brine E as 9.28 log cfu/ml, on the 60th day of fermentation for Brine A as 9.22 log cfu/ml, on the 50th day of fermentation for Brine B as 9.13 log cfu/ml, on the 60th day of fermentation for Brine C as 9.23 log cfu/ml and on the 40th day of fermentation for Brine D as 8.96 log cfu/ml. Leventdurur *et al.* (2016) stated that at the end of the fermentation, total mesophilic aerobic bacteria ranged from 7.25 log cfu/ml to 8.35 log cfu/ml that is in agreement with present study.

Yeasts also play an important role in table olive fermentations by acting as desirable or spoilage microorganisms (Arroyo-Lopez *et al.*, 2012; Heperkan, 2013). Number of yeasts that were counted during table olive fermentations is shown in Figure 2D. At the beginning of the fermentations total yeasts were in the range of 3.73 and 4.57 log cfu/ml. The highest yeast counts during the olive fermentations were reported on the 40th day of fermentation for Brine D as 9.21 log cfu/ml, on the 60th day of fermentation for Brine A as 9.20 log cfu/ml, on the 60th day of fermentation for Brine B as 9.06 log cfu/ml, on the 70th day of fermentation for Brine C as 9.17 log cfu/ml and on the 70th day of fermentation for Brine E as 8.96 log cfu/ml. At the end of the fermentation, the highest and lowest yeast counts were 8.26 and 7.25 log cfu/ml in the Brines C and E, respectively. In the previous work of Leventdurur *et al.* (2016), total number of yeasts in NaCl 10% brines of black olive fermentations of cv. Gemlik collected from three different districts were counted as 7.41-7.79 log cfu/ml. In the present study, yeast counts increased until the 40th day of fermentation. After this period, yeast growth decreased but not as low as the values reported in the study of Panagou *et al.* (2011). They reported that yeasts showed a rapid growth within 6-8 days during the olive fermentations. Then, a decline in yeast counts was recorded with populations ranging from 2.5 to 3.2 log cfu/ml. Initial yeast counts of our study were also in agreement with the study of Nisiotou *et al.* (2010) that reports the fermentation of cv. Conservolea natural black olives with different brines. However, the yeast counts at the end of the fermentations were less than our results as a result of the different brine concentration. Their yeast counts were 3-4 log cfu/ml at the beginning of the fermentations and then reached to maximum value as 5-6 log cfu/ml following 5-7 days of the process. Results of the present study showed that yeasts were the predominant microorganisms in the Brines A and C. However, in other samples that contain CaCl₂ in different concentrations, yeasts decreased and LAB started to dominate the fermentation in agreement with previous studies (Bautista-Gallego *et al.*, 2010; Panagou *et al.*, 2011).

Number of non-*Saccharomyces* spp. yeasts in the table olive fermentations is shown in Figure 2E. At the beginning of the olive fermentations, the lowest and highest non-*Saccharomyces* spp. yeast count values were observed in

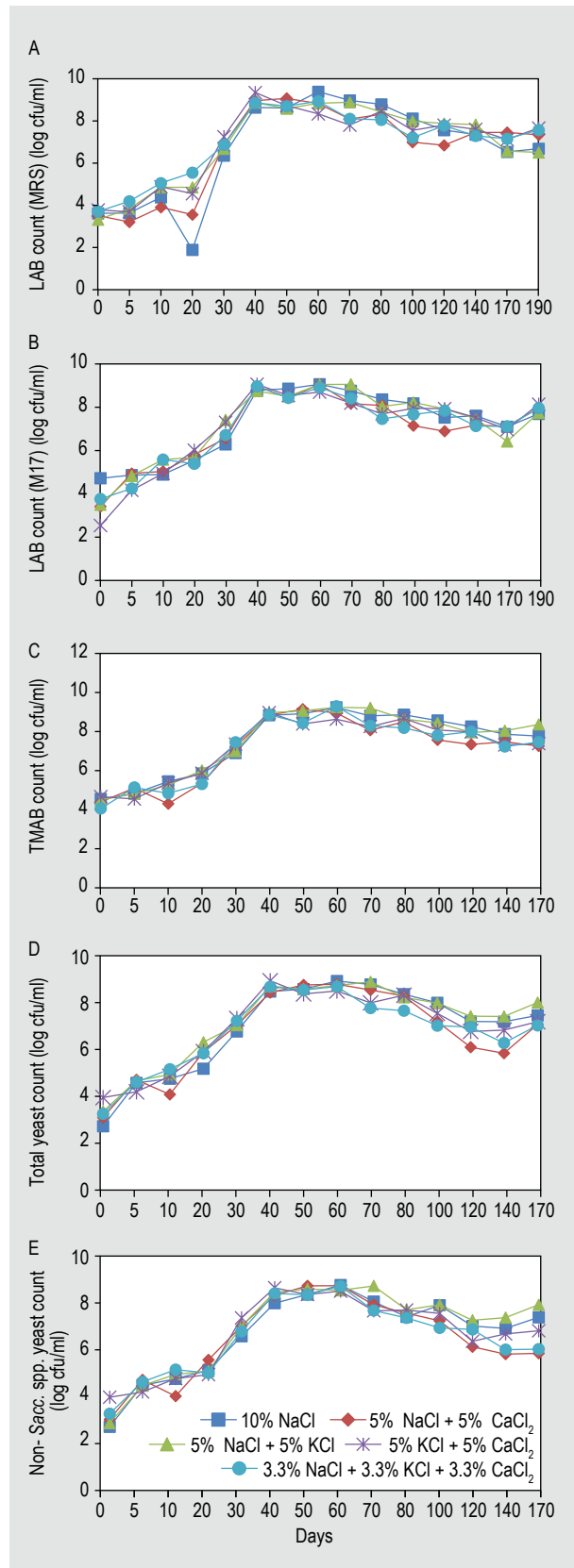


Figure 2. Number of lactic acid bacteria that grown on MRS agar (A) and M17 agar (B), total mesophilic aerobic bacteria (C), total yeasts (D) and non-*Saccharomyces* spp. yeasts (E) during table olive fermentations. LAB = lactic acid bacteria.

Brines A and D as 2.77 and 4.07 log cfu/ml, respectively. The counts of non-*Saccharomyces* spp. yeasts were 3.09, 2.94 and 3.34 log cfu/ml for the Brines B, C and E, respectively. During fermentation, the highest counts were observed on the 60th day of fermentation for Brine A as 8.99 log cfu/ml, on the 60th day of fermentation for Brine B as 8.94 log cfu/ml, on the 70th day of fermentation for Brine C as 8.95 log cfu/ml, on the 40th day of fermentation for Brine D as 8.87 log cfu/ml and on the 60th day of fermentation for Brine E as 8.94 log cfu/ml. At the end of the fermentation, number of non-*Saccharomyces* spp. yeasts were highest in the Brine C as 8.13 log cfu/ml and 7.58, 6.99, 6.17 and 6 log cfu/ml in the Brines A, D, E and B, respectively.

Physical and chemical characteristics of black table olives

The physical characteristics of fermented black table olives are shown in Table 2. Values of number of olives per kg for all samples increased and 1000 olive weight decreased when they were compared to raw olive fruits. The number of olives per kg and 1000 olive values between samples were not significant ($P>0.05$). The flesh/stone weight ratio was decreased in all samples except Brine A in which a slight increase was observed compared to raw olives. Flesh/stone weight ratio was highest and lowest in Brines A and B, respectively. The differences between the flesh/stone weight ratios of treatments were significant at the 5% level ($P<0.05$). Probably, this differences were originated from diverse water binding and water holding capacity of various mineral salts which also influence the texture of the olive flesh. The height and width of olive fruits decreased in all samples. The width of olive fruits was in the range of 16.27-17.28 mm. However, application of different chloride salts was significant at the 5% level importance on the weight of olive fruits. There was not any significant differences between the height of olive fruits ($P>0.05$).

L^* , a^* and b^* parameters were measured and hue angle and chroma values were calculated to define the colour of table olives. Lightness of the colour was defined by L^* parameter which ranges from 0 to 100 indicating an ideal black and white object, respectively (Gould, 1977; Radzevicius *et al.*, 2014; Wojdylo *et al.*, 2009). L^* value of Brines A and C were the lowest and the highest ones, respectively (Table 2). The differences between the values of L^* parameter of samples were not significant ($P>0.05$). Negative and positive a^* values indicate green and red, respectively (Gould, 1977). The highest a^* value was 11.62 for Brine B and lowest a^* value was 6.63 for Brine C. The differences between the a^* values were significant ($P<0.05$). It was observed that L^* and a^* values were found to increase in all samples after fermentation when the results were compared with raw olive fruits. Therefore, it could be stated that redness was increased by fermentation. b^* values of the samples increased after fermentation with the exception of Brine E. Increase of b^* values indicated an increase in yellow colour of the fermented table olives. Negative b^* values indicate blue and positive values indicate yellow (Gould, 1977; Radzevicius *et al.*, 2014). The highest b^* value was determined as 3.74 in Brine C and the lowest b^* value was 0.20 in Brine E. The differences between b^* values were not significant ($P>0.05$). It was reported that the sole analysis of L^* , a^* and b^* parameters are not enough to determine changes in colour. Some researchers stated that the hue angle has the most significant correlation with visual scores and the chroma value gives a good indication of the amount of colour (Abers and Wrolstad, 1979; Wojdylo *et al.*, 2009). Chroma and hue angle values show colour pureness and colour tone, respectively. Hue angle is used as reference, where 0° represents red colour, 90° yellow, 180° green and 360° blue (Jakopic *et al.*, 2007; Veberic *et al.*, 2010). Concerning hue angle values, only an increase was recorded in Brine C. Hue angle was the lowest and the highest in the Brines E and C as 1.21 and 28.3, respectively. It means

Table 2. The physical characteristics of black table olives after fermentation (mean±SD).^{1,2}

Physical characteristic	A (control)	B	C	D	E	
Number of olive fruit/kg	245±7.07	240±14.14	245±7.07	245±7.07	245±7.07	
1000 olive weight (kg)	4.08±0.12	4.15±0.22	4.07±0.10	4.06±0.08	4.05±0.07	
Flesh/stone weight ratio	6.01±0.91 ^a	4.72±0.20 ^b	5.22±0.15 ^{ab}	5.19±0.02 ^{ab}	5.51±0.13 ^a	
Mean fruit height (mm)	22.42±0.3	22.34±0.22	21.91±0.16	21.42±1.1	21.64±0.23	
Mean fruit width (mm)	16.72±0.06 ^{ab}	17.28±0.18 ^a	16.27±0.12 ^b	16.33±0.7 ^b	16.44±0.02 ^{ab}	
Colour	L^*	29.38±14.70	30.52±1.98	33.21±2.76	30.34±1.14	29.68±1.16
	a^*	7.98±2.38 ^c	11.62±2.49 ^a	6.63±1.30 ^c	9.53±1.43 ^{abc}	10.97±1.99 ^{ab}
	b^*	1.97±2.70 ^{ab}	1.43±0.94 ^{ab}	3.74±2.31 ^a	2.38±0.96 ^{ab}	0.20±0.74 ^b
	Hue	13.88±18.85 ^{ab}	7.74±6.06 ^b	28.3±16.77 ^a	14.1±5.67 ^{ab}	1.21±4.67 ^b
	ΔC	6.98±3.66 ^b	11.76±2.38 ^a	7.87±1.29 ^{ab}	8.98±1.99 ^{ab}	10.99±1.96 ^a

¹ A = 10% NaCl; B = 5% NaCl+5% CaCl₂; C = 5% NaCl+5% KCl; D = 5% KCl+5% CaCl₂; E = 3.3% NaCl+3.3% KCl+3.3% CaCl₂.

² Different letters indicate significant difference Duncan ($P<0.05$), within same row.

that redness was highest in Brine E and lowest in Brine C. The differences between the hue angles were significant ($P<0.05$). There weren't any significant differences between hue angles of A and D, B and E brines. Results of the chroma values showed an increase in all samples. Lower chroma value describes the brown colour of the processed fruits (Wojdylo *et al.*, 2009). In present study, the lowest chroma value was observed in Brine A as 6.98 which means A coded brine was the darkest olives. The differences between chroma values were significant ($P<0.05$) and there weren't any significant differences between chroma values of Brines C and D and Brines B and E.

Chemical characteristics of black table olives in different salt mixtures are shown in Table 3. Mean pH of table olives were ranged from 4.19 to 4.87. The differences between the pH values were significant ($P<0.05$). pH values of Brines B and D which had the same CaCl_2 ratio were lowest and there weren't any significant differences between them ($P>0.05$). There was not any significant difference between Brines A and E ($P>0.05$). The highest total acidity as lactic acid was observed in Brine D. The second highest acidity was reported in Brine B. As it was observed in pH, acidity values were highest in Brines B and D which has same CaCl_2 ratio. There was a significant difference between Brines A and E ($P<0.05$). The differences between the acidity values of samples were significant ($P<0.05$). However, there was not any significant difference between Brines A and C ($P<0.05$). Mean salt contents of table olives were in the range of 2.62-3.19%. The most and least salty brines were A and E, respectively. The differences between the salt levels were significant ($P<0.05$). However, there was not any significant difference between Brines B, D and E which have CaCl_2 in their brines. The total dry matter of table olives were in the range of 43.19-43.88% and there was not any significant difference between samples with different brines ($P>0.05$). The difference between the ash contents were significant ($P<0.05$) and the ash content of samples were in the range of 2.30-4.26%. The highest and the lowest ash contents were observed in Brines A and B, respectively.

There wasn't any significant difference between Brines C, D and E which include KCl in their brines.

Sensory evaluation

Results of the preference ranking tests for sensory evaluation are presented by a spider plot in Figure 3.

Panellists ranked each sample from most preferred to least preferred in terms of odour and flavour, bitterness, sourness, saltiness, texture, taste and overall sensory impression. Results show that Brine A was the most preferred in terms of odour and flavour, bitterness, texture and taste by panellists. Brine C was the second most preferred in terms of the odour and flavour and bitterness. Brine C was the most preferred in terms of saltiness by panellists. Brine A was the second after Brine C for the preference in saltiness. The least preferred sample for saltiness was Brine D which does not contain NaCl. Brine C samples were also the most preferred by panellists from sourness and overall sensory impression points of view. Then Brine A samples were the second most preferred for the same characteristics. In terms of texture, Brine A samples were the most preferred and Brine B were the second preferred. Brine D samples, which did not contain any NaCl, were the least preferred. In that context, substitution of NaCl by different proportions of KCl and CaCl_2 in naturally fermented black olives increased the degree of hardness in the texture of final product as judged by the scores assigned by the panellists. This result limits the organoleptic acceptability of the final product. Results of the present study showed that organoleptically acceptable product in terms of texture can be produced by combination of NaCl and CaCl_2 . Since this combination led to improve the sensory score for hardness. As a result, NaCl and KCl could be combined to have an acceptable final product for the production of naturally fermented black table olives of Gemlik cultivar. Alone usage of CaCl_2 salt is not recommended according to sensory analysis results. However, the possible use of this salt just plausible when was

Table 3. The chemical characteristics of black table olives after fermentation (mean \pm SD).^{1,2}

Chemical characteristic	A (control)	B	C	D	E
pH	4.56 \pm 0.05 ^{ab}	4.19 \pm 0.06 ^b	4.87 \pm 0.19 ^a	4.46 \pm 0.25 ^b	4.50 \pm 0.04 ^{ab}
Total acidity ³ (%)	0.62 \pm 0.01 ^b	0.93 \pm 0.01 ^a	0.58 \pm 0.13 ^b	0.96 \pm 0.15 ^a	0.78 \pm 0.01 ^{ab}
Salt ⁴ (%)	3.19 \pm 0.56 ^a	2.76 \pm 0.26 ^b	2.81 \pm 0.12 ^{ab}	2.75 \pm 0.15 ^b	2.62 \pm 0.09 ^b
Total dry matter (%)	43.19 \pm 2.47	43.88 \pm 0.01	43.86 \pm 0.02	43.88 \pm 0.01	43.87 \pm 0.01
Ash content on wet basis (%)	4.26 \pm 0.18 ^a	2.30 \pm 0.39 ^b	3.60 \pm 1.52 ^{ab}	3.42 \pm 0.19 ^{ab}	4.11 \pm 0.6 ^{ab}

¹ A = 10% NaCl; B = 5% NaCl+5% CaCl_2 ; C = 5% NaCl+5% KCl; D = 5% KCl+5% CaCl_2 ; E = 3.3% NaCl+3.3% KCl+3.3% CaCl_2 .

² Different letters indicate significant difference Duncan ($P<0.05$), within same row.

³ Expressed as lactic acid.

⁴ Salt is calculated as NaCl equivalent.

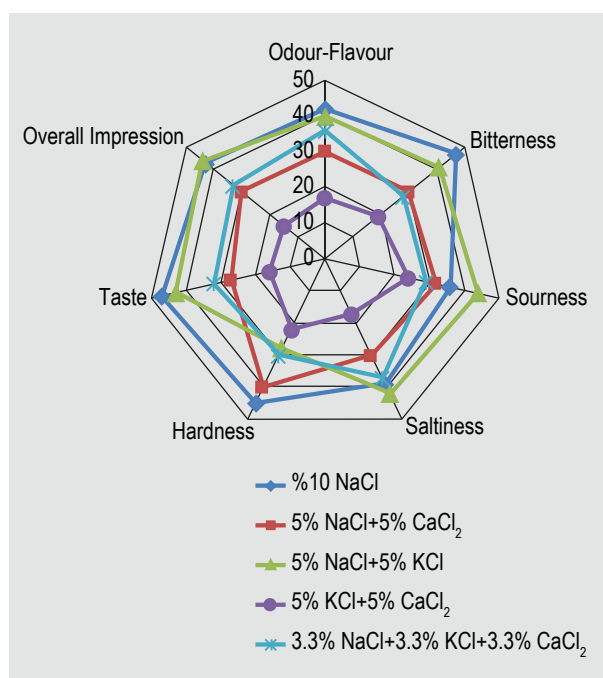


Figure 3. Results of sensory analysis with preference tests belonging black table olives treated with different chloride salts.

combined with NaCl and KCl to have an organoleptically acceptable final product.

The average score of every sensory attributes were calculated to study the effect of the different salt mixtures on the production of table olives and PCA was carried out by XL-Stat 4.06 statistical software (Addinsoft, New York, NY, USA). Table 4 shows the correlation between different sensory attribute variables of PCA. Values more than 0.90 showed strong correlation and values less than 0.90 showed less correlation. There was a strong correlation between overall sensory impression and odour – flavour, bitterness, sourness, saltiness and taste. It means that panellists took into consideration these characteristics to score the overall sensory impression.

Results indicate that inverse correlation was observed between hardness and other characteristics. However, bitterness, odour and flavour, overall sensory impression, saltiness and sourness showed strong correlation with each other. As it is shown in the biplot graph, Brines B, D and E were placed at the negative side of the coordinate system which means that these samples were not preferred by the panellists. Brine A samples were close to texture curve which shows that texture of Brine A was preferred the most. Also it was the most preferred by the panellists in terms of bitterness, taste, odour and flavour. Brine C was preferred the most in terms of saltiness, sourness and overall sensory impression. Brines A and B were preferred in terms of flavour of the brines but Brine C had the best sensory score for that characteristic. Vinegar and soil flavours in Brine A and sauteed mushroom aroma was in Brine C were identified by panellists. Skin colour of the Brines A and B were the most and the least preferred, respectively. On the other hand, Brine B had the best scores for the brightness of skin and colour of the flesh. Scores of the colour of the flesh were almost same in all samples. Thickness of the flesh was similar in all samples but Brine A had the highest score. Brine C had the highest scores in sourness, saltiness and ripeness characteristics. Bitterness of Brine A was preferred the most, followed by Brine C. As it was seen in Brine D, KCl and CaCl₂ caused a negative effect on the bitterness of the fermented end product which was in agreement with the result of Panagou *et al.* (2011). Panagou *et al.* (2011) stated that olive brines with the highest concentration of the combination of KCl and CaCl₂ received the highest scores in bitterness. The lowest scores in bitterness were given in 8% NaCl and 4% NaCl+ 4% KCl brines. As a result, the usage of CaCl₂ caused bitterness in the end product. It was seen that the bitterness induced by the presence of KCl is balanced by NaCl. As a result of that, NaCl could be partially substituted by KCl to have end products with lower sodium content and acceptable organoleptic characteristics. In the study of Panagou *et al.* (2011), 8% NaCl brine received the highest score in saltiness by the panellists and the lowest scores were given in 4% KCl+4% CaCl₂ brine which did not contain any NaCl in the initial brine. This was in good

Table 4. Correlation between different sensory attribute variables.¹

Sensory attribute variables	Odour and flavour	Bitterness	Sourness	Saltiness	Texture	Taste	Overall sensory impression
Odour and flavour	1	0.898	0.786	0.983	0.582	0.963	0.981
Bitterness	0.898	1	0.834	0.835	0.669	0.973	0.937
Sourness	0.786	0.834	1	0.821	0.298	0.836	0.889
Saltiness	0.983	0.835	0.821	1	0.455	0.924	0.972
Texture	0.582	0.669	0.298	0.455	1	0.573	0.547
Taste	0.963	0.973	0.836	0.924	0.573	1	0.977
Overall sensory impression	0.981	0.937	0.889	0.972	0.547	0.977	1

¹ Significant values are written in bold; $\alpha=0.05$.

agreement with the results of present study since Brine D samples, which do not contain NaCl, received the lowest score in saltiness. Brine D samples were not accepted due to the some unacceptable characteristics such as bitter taste, rancid oil and propan gas. Brine C samples get close scores to control treatment and received high scores in terms of juiciness, oily taste and chewiness. Brine D containing CaCl₂ and KCl, was reported as the most rigid by the panellist. They also received the highest score in unwanted characteristic such as astringent and residues aftertaste. Brines A and C received the highest and lowest scores in fibrousness, respectively. Brines A and C were similar to each other in sensory evaluation when they were compared to other chloride salt samples in agreement with reports of Panagou *et al.* (2011) and Marsilio *et al.* (2002) who studied on table olive processing.

4. Conclusions

In conclusion, results of the present study demonstrated that NaCl could be substituted by other chloride salts. Analytical results and some characteristics of the olives produced by combination of NaCl with KCl show similarity to olives produced with NaCl. Sensory evaluation of the final product is very important from the consumer acceptability point of view and this combination was also preferred by the panellists. On the other hand, combination of KCl and CaCl₂ salts caused a bitter taste in the final product and brines including CaCl₂ were less preferred by the panellists. As a result of that CaCl₂ could not be used as only chloride salt in the production of table olives. It could be used with the combination of other chloride salts. However, combination of 5% NaCl and 5% KCl in brines resulted in low sodium content with good organoleptic characteristics. According to the results, acceptable end products can be produced using NaCl and KCl salt mixtures to meet the demands of low sodium intake in the production of table olives. Due to the negative health effects of the NaCl, reduction of salt in fermented foods is very important. Especially plant based fermented foods contain salts at important levels. Therefore further studies on the partial replacement of sodium chloride with different chloride salts need to be done in plant based fermented foods.

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