Comparative evaluation of the effect of the addition of turnip (*Brassica rapa*) on the biogenic amine and volatile flavour compounds of shalgam

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ABSTRACT Shalgam productions done with the addition of turnip at different rates were carried out. Volatiles and biogenic amines were determined before storage and after 6 month storage. A total of thirty seven different volatiles were identified from shalgams. Some of them (such as ethyl-octanoate, ethyl-propionate, 2-ethyl-1-hexanol, 1-octanol, 1-nonanol, (Z)-5-octene-1-ol ,3-Hydroxybutanal, 2-Isopropyl-5-methylhex-2-enal) were isolated for the first time in shalgam. The results indicate that the use of turnip in different ratios has an effect on the percentage and variety of volatiles and, an in-crease in total acidity and biogenic amines. In addition, after storage, an increase also was determined in the amounts of putrechin, cadaverine, histamine, tyramine, spermidine, spermine and total amines. In conclusion, according to the results of microbial, sensory analysis and volatile flavour compounds, it can be stated that the most appropriate amount of turnip is 1 %, however, also ratios of 0.5 % and 2 % can be used.

KEYWORDS Volatile flavour compounds of shalgam; Shalgam quality; Ethyl acetimidate; Storage

1. Introduction

Shalgam (şalgam) is a reddish-coloured, sour-tasting beverage. It is preferred especially because it complements foods (pita, fish, meatballs) in terms of taste. The production amount of shalgam has increased due to the rapid spread of its consumption in recent years, and small plants have been replaced by very large facilities. The shalgam market, which has grown throughout the country, especially due to its unique sensory properties, signals that it will gain an international character soon.

Although shalgam gets its name from the turnip used in its production, there is no standard ratio in the recipe. There are significant differences in terms of quality between shalgams produced in enterprises, the number of which is increasing day by day in the sector (Utus, 2008; Erten et al., 2008; Agirman, 2014; Tanguler et al., 2017; Cankaya, 2018). One of the most important ways to eliminate this negativity is to determine the standard amount for the turnip used in the recipe. On the other hand, it is not known what effect the turnip used has, especially during storage on volatile flavour substances. Turnip is claimed to contain phenolic compounds, protein, vitamins and mineral substances, as well as glucose, fructose, and sucrose (Rodríguez-Sevilla et al., 1999).

Although the number of national and international studies on shalgam has increased recently, there are limited publications on the biogenic amine and flavour substances of shalgam and, as far as is known, there is no publication on the effect of different amounts of turnip.

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This study aims to determine the effects of turnip, which gives its name to shalgam but can be used at different rates by each producer, on fermentation, biogenic amine content and volatile flavour compounds (VFC) before and after storage.

2. Methods

Purple carrot, turnip and bulgur flour were supplied by AYRIS Agriculture Food Industry. Other raw materials were obtained from the market.

2.1 Production of shalgam

Shalgam production was carried out according to the traditional method reported by Erten et al. (2008) and Tanguler et al. (2017). The course of fermentation was monitored by determining the total acidity. Trials done with the addition of turnip at different rates were carried out in two parallel and were coded as T0 (control, 0 %), T1 (0.5 %), T2 (1.0 %), T3 (2.0 %) and A4 (4.0 %). Total acidity and pH analyses were carried out in two parallels during the fermentation of shalgam. Since shalgam is a coloured product, the analysis was carried out using a pH meter and the titration was terminated when the pH value of the samples was 8.1 (Cemeroglu, 2007). The pH value in the samples was measured using a pH meter. To determine the number of lactic acid bacteria (LAB), dilutions were made with 0.85 % brine by taking 1 mL sample under aseptic conditions and spread on de Man Rogosa and Sharpe Agar. total mesophilic aerobic bacteria (TMAB), coliform bacteria, yeast and non-Saccharomyces yeasts (NSY) counts were also determined (Harrigan and McCance, 1990; Halkman, 2005; Carbó et al., 2020).

2.2 Analyses performed in shalgam after fermentation

Analysis of VFC in shalgams obtained at the end of fermentation and stored for six months was carried out according to the method reported by Kıvançlı and Elmacı (2016) with some modifications. 5 mL sample was put in a 20 mL vial. The equilibration, extraction, and injection processes were performed by an automatic injection module (GC Injector80). The agitator on/off times was 5/2 s, and vial fibre exposure was 22 mm. Extraction time and temperature were selected at 45 min and 60 °C, respectively. Speed of agitation was varied between 250 and 750/min. The fibre of Divinylbenzene/Carboxen/ Polydimethylsiloxane (DVB/CAR/PDMS, 50/30 μm, Sigma) was selected and used to trap the headspace VFC during extraction. The VFC of samples isolated by fibres were thermally desorbed in the injector port of a GC (7890A-GC, Agilent) at 250 °C with a septum purge flow rate of 3.0 mL/min in splitless mode. The above values were made according to these values as the best results obtained in the fibre used as a result of the optimization study were obtained at this temperature and time.

DB-Wax column (60 m×0.25 mm×0.4 μm) was used in the separation of volatiles with helium as the carrier gas at a flow rate of 1.5 mL/min. The oven temperature program was started at 60 °C for 3 min, pursued by a 2 °C/min increase to 220 °C, followed by 3 °C/min increase to 245 °C and finished by holding the oven temperature at 245 °C for 20 min. The detection was simultaneously done by a mass spectrometer (5975BVL-MSD, Agilent) on the total ion current obtained by electron impact at 70 eV. The mass range acquisition was m/z 29–350. The identification of the peaks of volatile compounds in shalgam was performed by comparing their mass spectra and retention indices with the Wiley 7.0, NIST 98 and Flavor 2L libraries, and also validation was performed with the help of external standards. Peaks determined outside of existing external standards were tentatively identified with the help of their RIs and library databases in a comparative manner. Compounds without reference standards were determined approximately with standards with the same functional group and/or similar amounts of carbon atoms (Kesen, 2020). Percentage values for each identified compound were calculated over the total areas of all flavours identified. The standards used for this research were obtained from (Sigma-Aldrich, Merck and Supelco®, Germany).

Biogenic amine analysis of shalgams was carried according to the HPLC method suggested by Eerola et al (1993). Simply, 5 mL of sample was diluted up to 50 mL with perchloric acid solution (0.4 M) and mixed adequately. The diluted sample (1 mL) was transferred into the teflon tube and added 200 μL NaOH (2 N), 300 μL saturated $NaHCO_3$ and finally 2 mL dansyl chloride solution (10 mg/mL). The tube was sealed hermetically and incubated at 40 °C in water bath included shaker for 45 min. After that, the derivation process was completed via addition of 100 μL ammonia solution (25 %), and the volume was fulfilled up to 5 mL with acetonitrile. After centrifugation (6000 rpm, 5 min, 4 °C), the supernatant was passed through PTFE membrane filter (0.45 μm) and finally injected (20 μL) to the HPLC system (Shimadzu, Japan) including pump (LC-20AT), column oven (CTO-10AS), PDA detector (SPD-M20A), degasser (DGU-20A5), auto sample (SIL-20A). The column (Nucleodur 100-5 C18) was kept at 30 °C with 1 mL/min flow rate and eluted with gradient flow (A: 0.1 M ammonium acetate and B: Acetonitrile; 0 min 50 % A + 50 % B; 30 min 10 % A + 90 % B). The detector was set at 254 nm. Identification and quantification of the peaks were carried out using certified high purity standard substances (Sigma-Aldrich). For the quantification of the peaks, the calibration curves fit for the individual standard substances were used. The coefficient of determination (R^2) values of the curves were determined between 0.9981-0.9995. The analysis was repeated two times.

The sensorial test was carried out according to a 10-point scale indicating colour, odour, taste, acidity (sourness), swallowing character and finally general acceptability by 13 semi-trained panellists. Statistical analysis was performed by applying a one-way analysis of variance (ANOVA) to the results obtained regarding aroma in the produced shalgam. Duncan's test was applied to the differences found to be significant as a result of the statistical analysis using the Windows SPSS 10.0 package program. Moreover, within the scope of the study, principal component (PC) analysis of VFC of shalgams samples obtained by adding different amounts of turnip radish was performed using Minitab 17 (Minitab Inc., USA) program. In this way, the classification model of the produced shalgams was obtained.

3. Results

This study was conducted because there was no comparative research on the addition of turnip at different amounts in shalgam production before. All fermentation trials carried out lasted 12 days. Gunes (2008) and Cankaya (2018) reported that carrot fermentation varies between 8-14 days. On the contrary, Cirak (2016) stated that carrot fermentation takes 22 days. The findings are consistent with Gunes (2008) and Cankaya (2018).

3.1 pH and total acidity during the fermentation

At the beginning of the fermentation, the total acidity amounts ranged between 0.86 (T0)–1.35 (T3) g/L, while the pH values were determined between 4.09 (T2)–4.13 (T1). As expected, the total acidity in all samples increased rapidly with the onset of fermentation and was found between 7.61 (T0) and 7.83 (T4) g/L at the end of fermentation and, the pH values are between 3.40 and 3.43. In addition, increasing turnip addition caused a slight increase in the total acidity values of the shalgams (Fig. 1). In previous studies on the different properties of shalgam, it has been reported that the total acidity values at the beginning of fermentation are between 0.2-0.82 g/L and the pH values are between 4.72 and 6.58.

In addition, at the end of the fermentation, these values were reported to be between 4.88-8.71 g/L and 3.26-3.89, respectively (Gunes, 2008; Utus, 2008; Agirman, 2014; Cirak, 2016; Cankaya, 2018). In the present study carried out, the total acidity data determined at the beginning of the fermentation were found to be higher than the previous studies, while the pH values were found lower. On the

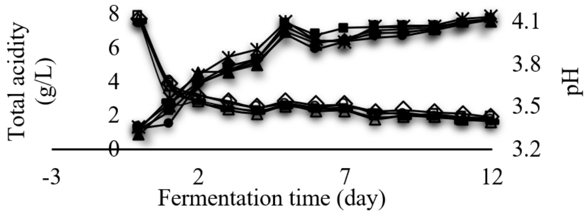

Figure 1: The total amount of acidity in terms of lactic acid and the change in pH value during the carrot fermentation. T0: Addition of 0.0 % turnip, T1: Addition of 0.5 % turnip, T2: Addition of 1.0 % turnip, T3: Addition of 2.0 % turnip, T4: Addition of 4.0 % turnip. Total acidity (–▲–: T0, –■–: T1, –●–: T2, –♦–: T3, –*–: T4), pH (–△–: T0-pH, –□–: T1-pH, –○–: T2-pH, –◇–: T3-pH, ——: T4-pH).

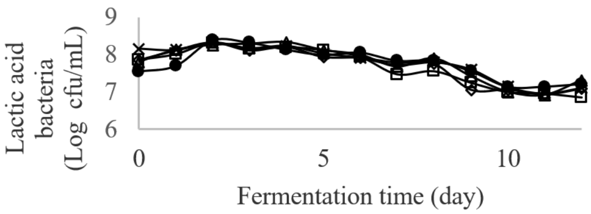

Figure 2: The change of LAB throughout carrot fermentation. –□–: T0, –◇–: T1, –△–: T2, –x–: T3, –●–: T4.

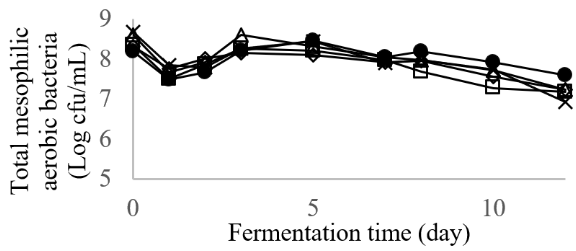

Figure 3: Change in the number of TMAB throughout the carrot fermentation.
–□–: T0, –◇–: T1, –△–: T2, –x–: T3, –●–: T4.

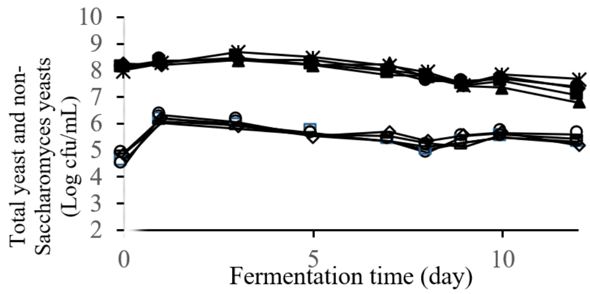

Figure 4: Change in the total yeast and NSY throughout the carrot fermentation. Total yeast (–▲–: T0, –■–: T1, –●–: T2, –♦–: T3, –*–: T4), NSY (–△–: T0-NSY, –□–: T1-NSY, –○–: T2-NSY, –◇–: T3-NSY, ——: T4-NSY).

other hand, the data obtained at the end of fermentation are consistent with previous studies.

3.2 Microbial analyses

During the experiments, LAB, TMAB, yeast and NSY were counted in the samples taken throughout fermentation and the results are given in Figs. 2, 3 and 4. With the start of fermentation, a rapid increase in the number of LAB was observed, and the numbers reached the maximum until the 2nd day of fermentation in all experiments except the T2 trial. In the following days, LAB counts partially entered the stationary phase and at the end of fermentation, it was determined between 6.85 log cfu/mL (T0) and 7.31 log cfu/mL (T2). In the studies carried out by Cankaya (2018), Cirak (2016) and Utus (2008), LAB numbers were reported to be between 6.57-7.49 log cfu/mL at the beginning of fermentation, while Agirman (2014) reported between 8.69-9.19 log cfu/mL. The data obtained at the beginning of fermentation is higher than the data reported by Utus (2008), Cirak (2016) and Cankaya (2018), but lower than the values reported by Agirman (2014).

The number of TMAB was found to be between 8.19 log cfu/mL and 8.66 log cfu/mL at the beginning of fermentation. With the start of fermentation, their numbers increased on the 3rd day in the T0, T1 and T2 trials, and on the 5th day in the T3 and T4 trials. In the following days, a decrease occurred in all trials and at the end of carrot fermentation, TMAB counts were determined between 6.92 and 7.59 log cfu/mL. While the number of TMAB was determined between 6.35-9.5 log cfu/mL in various studies on shalgam before fermentation, it was reported to be between 3.48-8.1 log cfu/mL at the end of fermentation (Gunes, 2008; Agirman, 2014; Cirak, 2016). According to the shalgam standard TS 11149 (TSE, 2003), the number of TMAB in ready-to-drink shalgam should be between 1.0×10^4 (4.0 log cfu/mL) - 1.0×10^5 (5.0 log cfu/mL) (TSE, 2003). While the data obtained in the conducted study were lower than the values reported by Agirman (2014) before fermentation and higher than the values reported by TSE (2003) at the end of fermentation, it is generally consistent with other studies. The most important reasons for that differences may be the microbial load of the raw materials used in production, inadequate sanitary conditions during processing or user error.

As can be seen from Fig. 4, the total number of yeast present in the medium at the beginning of the carrot fermentation ranged from 8.01 log cfu/mL (T4) to 8.25 log cfu/mL (T3), while the number of NSY was between 4.41 (T2) and 4.91 log cfu/mL (T0). In all experiments carried out with the start of fermentation, both total yeast and NSY started to increase rapidly and the maximum values were reached on the 3rd and 1st day of fermentation, respectively. However, after their numbers reached the maximum, a decrease was observed in all trials and the total yeast count at the end of fermentation ranged between 6.80 (T0) and 7.68 log cfu/mL (T4), while NSY counts were between 5.18 (T3) and 5.60 log cfu/mL (T0). In studies on shalgam, the total yeast count at the beginning of fermentation was found to be between 7.15-7.91 log cfu/mL, while the number of NSY was found to be between 6.97-7.89 log cfu/mL (Gunes, 2008; Agirman, 2014; Cirak, 2016; Cankaya, 2018). However, Utus (2008) reported that the number of NSY was between 4.48-5.54 log cfu/mL. Therefore, the total yeast numbers obtained at the beginning of fermentation were found to be higher than in previous studies. However, NSY counts are lower than the values reported by Agirman (2014) and Cirak (2016) but are consistent with the values reported by Utus (2008). In addition, Utus (2008) and Agirman (2014) reported that the yeast count at the end of fermentation in shalgam was between 6.89-7.60 log cfu/mL, while the number of NSY was between 6.02-7.07 log cfu/mL. While the total yeast numbers stated by the researchers are consistent with the data obtained, the NSY numbers are high than the data.

At the beginning of the fermentation, the number of coliform bacteria in the medium was between 3.16 and 3.58 log cfu/mL. The number of coliform bacteria decreased due to the start of fermentation and therefore the increasing total acidity and decreasing pH values, and they could not be isolated from the medium after the second day of fermentation. However, Ozturk (2009) reported that coliform bacteria was found (215-1541 cfu/mL) in four of the shalgams ready for consumption in his study, in which he examined the shalgams of 20 different companies. That difference may be due to insufficient fermentation or inadequate sanitation conditions.

3.3 GC–MS analysis and effect of the addition of different amounts of turnip on volatile flavour compounds

As far as is known, there are limited studies on VFC found in ready-to-consume shalgams (Tanguler et al., 2017). Moreover, there is also a study on VFC of shalgams stored for 90 days, both pasteurized and unpasteurized (Kirlangic et al., 2021). Therefore, it can be said that there is no study on the effect of adding different amounts of turnip radish on the VFC in shalgams. The effect of different amounts of turnip addition and six months storage on the VFC of shalgams are given in Table 1.

A total of 37 VFC from different groups such as esters (11), terpenes (6), high alcohols (7), volatile phenols (5), carbonyl compounds (4) and volatile acids (4) were determined in shalgams by GC-FID and MS analysis (Table 1). With the addition of increasing amounts of turnip changes in the total area percentage of the compounds were observed. However, it was observed that the VFC determined in the shalgams obtained after fermentation, in general, was similar but differed in their percentages. However, in the negative result it is R&D and expresses what we should not do. Some of the identified VFC were also identified in different varieties of purple carrots (Keskin et al., 2021) and shalgams (Tanguler et al., 2017; Kirlangic et al., 2021). Compared with the VFC found in purple carrots (Daucus carota L.) stated by Keskin et al. (2021), different esters (Ethyl-acetate, isoamyl-acetate, ethyl-decanoate, diethyl-succinate etc), higher alcohols (2-butanol, 1-butanol, 3-methyl-,1-octanol etc), terpenes (2-carene, linalool, α-terpineol, borneol etc) and carbonyl compounds (Heptanal, decanal, pentanal etc) were isolated in shalgam. As reasons for this, raw materials other than purple carrot used in production, lactic acid fermentation and ethyl alcohol fermentation can be shown.

In addition to the 37 VFC, ethyl decanoate, (Z)-5-octen-1-ol, pentanal, γ-terpinene, 2-carene, α-bergamotene and myrtenol were isolated in shalgam samples at the beginning of storage (after fer-mentation), could not be detected in 6 months stored sample. In contrast, 3-decyn-2-ol and linalool oxide, which were undetectable before storage, were detected in the stored samples.

Esters, higher alcohols and terpenes formed a significant part of the VFC in shalgams and these were found to be the dominant groups before storage. Similarly, esters and higher alcohols were again determined as dominant compounds after storage. However, a significant reduction in terpenes occurred with storage. In contrast, Kirlangic et al. (2021) reported that terpenes, which usually cause a bitter and pungent taste in carrots, predominate in shalgam at the end of storage.

Eleven ester were determined in shalgam produced without turnip added. Ethyl acetimidate, an ester not previously reported in shalgam, was determined by the addition of turnip. Generally increased with the addition of increased turnip, and the highest percentage value was determined in the T3 trial. Therefore, it can be said that this compound is an ester compound that passes from turnip to the product. In addition, the effect of storage on the amount of ethyl-acetimidate was found to be significant ($p < 0.001$) (Table 1).

Ethyl-acetate and isoamyl-acetate are the most abundant esters detected in shalgams, their percentage varying between 5.85 and 7.58. The effect of storage or turnip addition on ethyl acetate was found to be significant. The amounts of ethyl propionate, ethyl hexanoate and ethyl octanoate increased until the T2 trial and then decreased. While ethyl acetate (Kirlangic et al., 2021), diethyl-succinate and isoamyl-acetate (Tanguler et al., 2017) have been previously reported in shalgam, some ester compounds (such as ethyl-octanoate, ethyl-propionate) obtained in the present study are reported for the first time. Taveira et al. (2009) previously reported that ethyl esters such as ethyl-hexanoate and ethyl-octanoate, Maifreni et al. (2004) n-propyl-acetate are found in turnip. On the other hand, many ester compounds were identified that were not reported or identified before. Moreover, Keskin et al. (2021) reported that various ester compounds (such as isobornyl-acetate) can be found in purple carrots. Therefore, it can be said that these compounds come from other raw materials and/or emerge during the fermentation process by the acting of LAB and yeasts. Various researchers have reported that esters can be synthesized from glycerides by some of their LAB as well as enzymatically synthesized by yeast during ethanol fermentation (Molina et al., 2007).

With the increasing addition of turnip, the total ester amounts also increased compared to the control sample and the highest value was determined in the T2 sample. However, while the effect of increasing turnip amount on the relative and total ester values was generally insignificant, the effect of the storage process was found to be

Table 1: The effect of different amounts of turnip radish addition and six months storage on the volatile flavour compounds of shalgams.

LRI	Volatile flavor compound****	Odor description*****	Peak area percentage (%) ± standard deviation								
				Storage			Shalgams produced with the addition of different turnip radish				
			Sig*	0th month	6th month	Sig*	T0	T1	T2	T3	T4
Esters (%)		*Odour description*									
890	Ethyl acetate	*Nail polish remover, fruity*[e]	***	5.29 ± 0.95^{b}	8.25 ± 0.98^{a}	*	7.58 ± 1.2^{a}	7.14 ± 2.2^{ab}	7.11 ± 2.2^{ab}	5.95 ± 1.7^{b}	6.1 ± 1.8^{b}
953	Propanoic acid, ethyl ester	*Fruity, pear, apple, sweet*[e]	**	0.95 ± 0.34^{b}	3.13 ± 1.81^{a}	ns	1.75 ± 0.9	1.67 ± 1.2	3.42 ± 3.3	1.55 ± 0.9	1.83 ± 0.9
968	n-Propyl acetate	*Solvent, sweet fruity*[d]	***	0.26 ± 0.1^{b}	3.03 ± 1.13^{a}	ns	1.62 ± 1.5	1.78 ± 2.2	1.45 ± 1.5	2.05 ± 2.3	1.3 ± 1.3
1608	Acetamide, N-ethyl-	*nd*	***	0.91 ± 0.6^{b}	6.9 ± 1.6^{a}	ns	3.45 ± 4	4.27 ± 4.4	3.45 ± 2.9	4.71 ± 3.9	3.66 ± 2.8
1122	Isoamyl acetate	*Fruity, banana, solvent*[g]	***	2.53 ± 0.5^{b}	10.02 ± 1.1^{a}	ns	6.4 ± 3.6	5.98 ± 4.4	6.08 ± 4.5	7.05 ± 5	5.85 ± 4.2
1242	Ethyl hexanoate	*Fruity, sweet*[g]	***	1.2 ± 0.2^{a}	0.27 ± 0.02^{b}	ns	0.67 ± 0.5	0.75 ± 0.6	0.78 ± 0.6	0.78 ± 0.6	0.69 ± 0.5
1341	Ethyl lactate	*Sharp fruity, butterscotch*[d]	**	3.02 ± 0.4^{a}	2.4 ± 0.4^{b}	ns	2.66 ± 0.5	2.44 ± 0.6	2.48 ± 0.6	2.7 ± 0.6	3.14 ± 0.4
1435	Ethyl octanoate	*Fruity, pineapple, pear*[e]	***	6.21 ± 1.3^{a}	0.49 ± 0.3^{b}	ns	2.95 ± 2.4	3.51 ± 3	4.26 ± 4	3.02 ± 3	3.03 ± 3
1553	Isobornyl acetate	*Green*	**	1.06 ± 0.3^{a}	0.7 ± 0.2^{b}	ns	1.11 ± 0.3	0.8 ± 0.2	0.85 ± 0.2	0.77 ± 0.2	0.9 ± 0.3
1695	Diethyl succinate	*Pungent, cheese, old*[g]	***	$0.35\pm0.1a$	0.22 ± 0.1^{b}	**	0.43 ± 0.1^{a}	0.35 ± 0.1^{a}	0.24 ± 0.1^{b}	0.2 ± 0.1^{b}	0.22 ± 0.1^{b}
1824	Phenethyl acetate	*Roses, floral*[g]	***	0.66 ± 0.1^{b}	0.88 ± 0.2^{a}	**	1 ± 0.1^{a}	0.68 ± 0.2^{b}	0.63 ± 0.2^{b}	0.78 ± 0.2^{b}	0.75 ± 0.1^{b}
	Total esters		***	25.03 ± 2.2^{b}	36.24 ± 3.7^{a}	ns	29.9 ± 7.5	31.4 ± 7.2	32.7 ± 7	30.9 ± 7.5	28.3 ± 6.1
Higher alcohols (%)											
996	2-Butanol	*Fruity*[d]	ns	1.8 ± 0.4	1.84 ± 0.3	*	2.2 ± 0.2^{a}	2.04 ± 0.3^{ab}	1.7 ± 0.3^{bc}	1.69 ± 0.3^{bc}	1.49 ± 0.2^{c}
1825	3-Methyl-1-butanol	*Balsamic, whisky, malt, pungent, onion, cheese*[f]	ns	11.72 ± 2.02	10.25 ± 1.5	ns	12.4 ± 2.8	10.77 ± 2.3	10.42 ± 1.4	10.24 ± 1.7	11.09 ± 1
1484	2-Ethyl-1-hexanol	*Citrus, floral oily sweet*[d]	ns	0.45 ± 0.28	0.49 ± 0.39	***	1.1 ± 0.2^{a}	0.38 ± 0.1^{b}	0.38 ± 0.1^{b}	0.29 ± 0.1^{b}	0.27 ± 0.1^{b}
1527	2-Nonanol	*Waxy, creamy, citrus*[d]	***	0.26 ± 0.1^{b}	0.68 ± 0.3^{a}	**	0.44 ± 0.2^{bc}	0.65 ± 0.5^{a}	0.32 ± 0.1^{c}	0.42 ± 0.1^{bc}	0.51 ± 0.3^{ab}
1556	1-Octanol	*Fatty, toasted, chemical*[f]	***	$0.75\pm0.1b$	2.14 ± 0.8^{a}	ns	1.69 ± 0.9	1.41 ± 0.8	1.07 ± 1.2	1.65 ± 1	1.39 ± 0.9
1665	1-Nonanol	*Honey, sweet*[g]	**	0.8 ± 0.1^{a}	0.57 ± 0.2^{b}	ns	0.79 ± 0.1	0.61 ± 0.2	0.7 ± 0.2	0.7 ± 0.2	0.62 ± 0.3
1922	Phenylethyl alcohol	*Roses*[e]	ns	8.42 ± 1.1	8.08 ± 0.8	ns	8.67 ± 1.5	7.91 ± 0.9	7.78 ± 1	8.33 ± 0.7	8.55 ± 0.4
	Total higher alcohols		ns	25.11 ± 3.7	24.28 ± 2.6	ns	27.89 ± 3.5	24.3 ± 3.5	22.94 ± 3.5	23.9 ± 2.7	24.46 ± 0.9
Carbonyl compounds (%)											
1184	Heptanal	*Fatty, rancid, citrus, green*[f]	**	0.22 ± 0.2^{b}	0.31 ± 0.01^{a}	**	0.27 ± 0.1^{ab}	0.17 ± 0.2^{c}	0.23 ± 0.1^{bc}	0.34 ± 0.1^{a}	0.33 ± 0.1^{a}
2580	3-Hydroxybutanal	*nd*	***	0.3 ± 0.08^{b}	0.65 ± 0.1^{a}	ns	0.51 ± 0.3	0.44 ± 0.2	0.54 ± 0.2	0.45 ± 0.2	0.45 ± 0.2
1498	Decanal	*Green, metallic*[i]	ns	1.17 ± 0.8	1.09 ± 0.5	ns	0.8 ± 0.3	1.08 ± 0.3	1.76 ± 1.01	1.28 ± 0.7	0.72 ± 0.2
1373	2-Isopropyl-5-methylhex-2-enal	*Herbal*[d]	*	0.87 ± 0.3^{a}	0.61 ± 0.2^{b}	*	0.72 ± 0.2^{b}	0.65 ± 0.2^{b}	0.49 ± 0.1^{b}	1.15 ± 0.4^{a}	0.7 ± 0.3^{b}
	Total carbonyl compounds		ns	3.0 ± 0.9	2.66 ± 0.5	ns	2.53 ± 0.3	2.56 ± 0.4	3.31 ± 0.9	3.39 ± 0.7	2.37 ± 0.4
Terpenes (%)											
1549	Linalool	*Citrus, sweet floral*[d]	**	0.89 ± 0.4^{a}	0.57 ± 0.2^{b}	**	1.1 ± 0.4^{a}	0.82 ± 0.3^{ab}	0.55 ± 0.3^{b}	0.62 ± 0.2^{b}	0.54 ± 0.2^{b}
1635	Terpinen-4-ol	*Solventy, musty*[i]	ns	0.29 ± 0.1	0.25 ± 0.1	ns	0.32 ± 0.1	0.27 ± 0.05	0.19 ± 0.1	0.26 ± 0.07	0.31 ± 0.1
1626	Iso pinocarveol	*Woody, warm, balsamic*[d]	***	0.7 ± 0.2^{a}	0.35 ± 0.1^{b}	ns	0.63 ± 0.3	0.64 ± 0.3	0.40 ± 0.2	0.46 ± 0.2	0.47 ± 0.3
1692	α-Terpineol	*Terpenic, citrus*[d]	*	4.17 ± 0.9^{a}	3.36 ± 0.7^{b}	*	4.36 ± 0.2^{a}	4.32 ± 1^{a}	2.94 ± 0.5^{b}	3.52 ± 0.9^{ab}	3.69 ± 1^{ab}
1700	Borneol (Isoborneol)	*Balsamic*[d]	ns	1.98 ± 0.6	2.07 ± 0.9	ns	1.54 ± 0.5	2.72 ± 1.3	1.85 ± 0.3	2.08 ± 0.5	1.95 ± 0.8
1861	Geraniol	*Floral, green*	***	1.83 ± 0.6^{a}	0.68 ± 0.3^{b}	ns	1.72 ± 1.2	1.24 ± 0.8	1.06 ± 0.5	1.07 ± 0.5	1.19 ± 0.5
	Total terpenes		***	21.58 ± 5.57^{a}	7.52 ± 1.5^{b}	ns	12.81 ± 5.9	17.44 ± 10.1	16.3 ± 12	12.96 ± 7.9	13.25 ± 7.6

significant ($p < 0.01$).

Seven different higher alcohols were determined in shalgams and 3-methyl-1-butanol was the most abundant higher alcohol in the samples, followed by phenyl-ethanol. Not only 3-methyl-1-butanol, but also many higher alcohol compounds decreased with increasing turnip addition. Similarly, the total higher alcohol content decreased from the T0 trial to the T2 trial with increasing turnip addition. 3-Methyl-1-butanol (isoamyl alcohol) and phenylethyl alcohol have been reported previously in turnip radish (Maifreni et al., 2004). However, in this study, it was determined that this compound decreased with the increasing addition of turnip radish. This may be due to the interactions that take place during lactic acid and ethyl alcohol fermentation in the production of shalgam. While the effect of turnip addition on 2-butanol, 2-ethyl-1-hexanol and 2-nonanol was significant, the effect of storage on 2-nonanol, 1-octanol and 1-nonanol were significant ($p < 0.05$). 2-butanol, 3-methyl-1-butanol and phenylethyl alcohol are higher alcohols previously reported in shalgam, 2-ethyl-1-hexanol, 1-octanol, 1-nonanol and (Z)-5-octene-1-ol has not been previously reported in the studies of Tanguler et al. (2017) and (Kirlangic et al., 2021).

Four different carbonyl compounds were determined in shalgams. Decanal and 2-isopropenyl-5-methylhex-4-enal are the carbonyl compounds with the dominant. Total carbonyl compounds increased with increasing turnip addition until the T3 trial and then decreased. Heptanal and decanal in turnip (Taveira et al., 2009) and heptanal in purple carrot and shalgam (Tanguler et al., 2017; Kebede et al., 2014) have been reported in previous studies. However, other carbonyl compounds that have not been reported in shalgam before, have been reported for the first time. Interestingly, although an aliphatic aldehyde, heptanal, was found in turnip radish and control samples, it was determined in lower amounts in samples T2 and T3 than in the control. This may be due to interactions between microorganisms during fermentation or analyzer error. In addition, the effects of turnip and storage on heptanal and 2-isopropyl-5-methylhex-2-enal were found to be statistically significant.

The aroma of FTB mostly comes from the raw material used, and the purple carrot, which is the main raw material used in production, plays an important role in this (Tanguler et al., 2017). Terpenes are compounds that usually cause a bitter and pungent taste sensation. They qualitatively expressed an important group of VFC in the FTBs (Tanguler et al., 2017; Kirlangic et al., 2021). α-Terpineol was determined as the terpene with the highest percentage. While the highest percentage in total terpene was obtained as 17.44 % in the T1 trial, the lowest value was found as 12.81 % in the T0 trial. Kebede et al. (2014) reported that the characteristic flavour of carrots with different colours is mostly due to terpenes. Moreover, there was a significant reduction in relative and total terpenes with storage. The effect of storage or turnip addition on α-terpineol and linalool were found to be significant at least a 5 % significance level. Similarly, previous studies have been determined α-bergamoten and γ-terpinene

Table 1. The effect of different amounts of turnip radish addition and six months storage on the volatile flavour compounds of shalgams (*cont.*).

Volatile phenols (%)											
1956	Creosol	*Medicine, disinfectant*	ns	1.38±0.2	1.08±0.4	ns	1.2±0.6	1.12±0.4	1.21±0.2	1.31±0.2	1.31±0.06
2011	Methyl eugenol	*Spicy, cinnamon, musty, vegetatived*	ns	0.27±0.1	0.25±0.09	ns	0.27±0.07	0.23±0.08	0.23±0.1	0.34±0.2	0.23±0.04
2036	4-Ethyl-2-methoxy-phenol, (4-ethyl guaiacol)	*Spicy and clove-like with medicinal, woodyd*	ns	6.18±1.36	5.29±0.8	ns	6.22±1.05	5.19±1.43	5.78±1.93	6.14±0.81	5.36±0.35
2167	2-Methoxy-4-(2-propenyl)-phenol	*nd*	ns	0.95±0.18	0.86±0.16	ns	0.97±0.11	1.02±0.11	0.81±0.12	0.86±0.1	0.87±0.16
2068	2-Ethyl phenol	*Phenolicd*	ns	0.39±0.07	0.35±0.03	ns	0.39±0.02	0.34±0.06	0.32±0.05	0.38±0.04	0.41±0.06
	Total Volatile phenols		ns	9.17±1.7	7.83±1.29	ns	9.05±1.8	7.89±2.3	8.34±2.29	9.04±1.19	8.18±0.58
Acids (%)											
1452	Ethylic acid	*Vinegare*	**	7.29±2.73^{b}	10.81±2^{a}	ns	8.81±1.66	10.4±3.4	9.24±3.6	8.45±4.3	8.36±2.35
1528	Propanoic acid	*nd*	*	2.64±2.6^{b}	4.19±1.7^{a}	*	2.86±0.3^{b}	2.48±2.4^{b}	2.26±0.5^{b}	3.41±1.8^{b}	6.05±1.3^{a}
2086	Caprylic acid	*nd*	ns	2.62±0.61	2.59±1.33	ns	3.54±1.7	1.8±0.38	2.07±0.35	2.76±0.56	2.85±0.62
2171	Pelargonic acid	*Floral, ripe fruitg*	ns	3.56±1.5	3.89±3.2	**	2.56±1.7^{b}	1.77±1.2^{b}	2.84±0.2^{b}	5.19±1.2^{a}	6.24±3.4^{a}
	Total acids (%)		**	16.1±4.58^{b}	21.47±3.11^{a}	ns	17.78±3.9	16.46±4.41	16.4±3.75	19.8±5.23	23.5±4.12

Sig: Significance. ***, ** and * display the significance at 0.1 %, 1 % and 5 % by LSD, respectively. a–c Values not sharing the same superscript letter within the horizontal line are different according to the Duncan test. ns: not significant.
****Reliability of the identification process: The VFC were considered to be tentative (by comparing their mass spectra and retention indices with the Wiley 7.0, NIST 98 and Flavor 2L libraries, and also validation was performed with the help of external standards);
**** Odor description: d: Anonymous (2022), e: Molina et al. (2009), f: Bonneau et al. (2016), g: Welke et al. (2022), nd: Odor description could not determine in the literature.

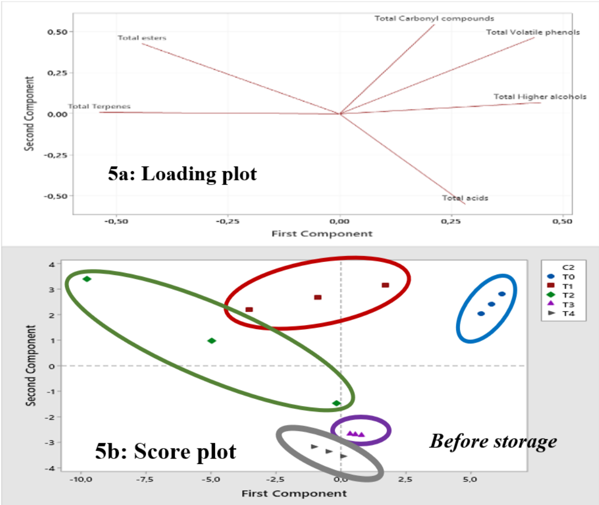

Figure 5: The PC Analysis plots expressing the distribution of volatile flavour compounds in the shalgam beverages before storage, a: Loading plot of total VFC, b: Score plot of relative VFC.

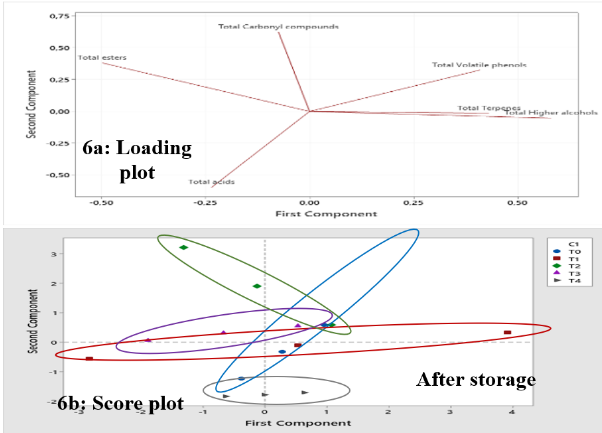

Figure 6: The PC Analysis plots expressing the distribution of volatile flavour compounds in the shalgam beverages after storage, a: Loading plot of total VFC, b: Score plot of relative VFC.

in purple carrot, γ-terpinene, linalool, terpinen-4-ol, borneol, myrtenol and geraniol in shalgam, and α-terpineol in stored shalgam (Tanguler et al., 2017; Keskin et al., 2021; Kirlangic et al., 2021).

In addition, five different volatile phenols and 4 different volatile acids compound were determined in shalgams. The effect of turnip addition and storage on relative and total volatile phenols was statistically insignificant ($p > 0.05$). In the study performed, it was determined that the dominant volatile acid was ethylic acid (between 8.36-10.4 %). While Keskin et al. (2021) reported that there was no ethylic acid in purple carrot, Tanguler et al. (2017) and Kirlangic et al. (2021) reported that there was ethylic acid in shalgams.

When we look at the total volatiles in general, an increase was determined until the T2 trial with increasing turnip addition, and then a decrease was observed. To evaluate the difference between the shalgams of addition of the different amounts of turnip and the relationship between variables, PC analysis was applied to relative and total volatile compounds. In terms of total VFC, the eigenvalues of the first two PCs were found to be greater than one both at the beginning and at the end of storage, thus according to the Kaiser criterion being significant.

Before storage, PC1 showed about 55.4 % of data variation and differentiate the shalgam samples according to the percentage of total ester, total higher alcohol and total terpene (Fig. 5a). However, after storage, PC1 retained about 39.2 % of total variation and differentiate to the samples according to the percentage of total ester, total higher alcohol, total volatile phenol and total terpene (Fig. 6a). Before storage, total ester and total terpene had a negative effect on PC1, while the others had a positive effect. In addition, the variables that correlate the most with the first PC are total higher alcohol and total volatile phenol. The first PC is positively correlated with these two variables. Therefore, an increase in the percentage of these variables increases the value of the PC1 or vice versa. As can be seen from Table 1, increasing turnip addition decreased the percentage value of these compounds and thus the PC1 value. At the end of storage, there was a positive correlation between PC1 and total terpene-total higher alcohol, whereas there was a negative correlation with total ester. So, while these two compounds act together, the total ester acts in the opposite direction. As seen in Table 1, while these two compounds decreased with increasing turnip addition, the total ester increased.

According to the relative volatiles before storage, the control sample (T0) and T3 have similar scores for PC1, but they are separated for PC2. In addition, T0 and T1 samples have similar scores for PC2, but they are different scores than T3 and T4. Furthermore, in terms of relative flavours before storage, there was no good separation in control, T3 and T4 samples, whereas good separation was observed in the T2 sample (Fig. 5b). After storage, the control sample has different scores from the T3 and T4 samples for PC1, as well as the T2 sample for PC2. However, in terms of relative VFC after storage, a very good distinction was seen in the T1 sample, while a good distinction was seen in the control, T2 and T3 samples (Fig. 6b).

3.4 Biogenic amines

Biogenic amines and their concentrations in shalgams produced by adding different amounts of turnip and stored for six months are given in Table 2.

Biogenic amine compounds and total biogenic amine amounts in shalgams generally increased with the addition of increasing turnip until the T3 trial (2.0 % turnip addition), and then a decrease was observed. The lowest was 63.2 mg/L (control) and the highest value was 77.7 mg/L in the T3 trial. Before storage, the lowest amounts of tryptamine (8.52 mg/L), putrechin (25.9 mg/L), cadaverine (7.1 mg/L) and histamine (6.55 mg/L) were obtained from turnip without added (T0) was determined in the experiment, the highest values were determined in the experiment performed with the addition of 2.0 % turnip

Table 2: Biogenic amines in shalgams produced by adding turnip at different rates and stored for six months (mg/L).

	T0	T1	T2	T3	T4	S*
	Before storage					
Tryptamine	8.519±1.033	8.609±1.012	8.989±0.319	9.035±0.387	8.733±0.715	ns
2-Phenylethylamine	0.219±0.1	0.28±0.113	0.294±0.108	0.335±0.2	0.42±0.124	ns
Putrescine	25.906^{b}±2.922	26.22b±1.549	32.035^{ab}±5.146	36.737^{a}±6.047	31.183^{ab}±1.206	*
Cadaverine	7.096±0.396	7.614±0.825	7.086±0.298	7.76±0.486	7.545±0.31	ns
Histamine	6.548±0.823	6.607±0.065	6.705±0.203	7.416±0.13	6.924±0.15	ns
Tyramine	9.701c±0.41	11.675^{ab}±0.83	11.149^{b}±0.34	12.093^{ab}±0.48	12.366^{a}±0.21	***
Spermidine	2.403±0.21	2.566±0.11	2.651±0.57	2.534±0.16	2.48±0.21	ns
Spermine	2.814a±0.43	2.052b±0.19	1.733^{b}±0.2	1.74^{b}±0.16	2.141^{b}±0.23	**
TOTAL	63.206b±5.53	65.623b±3.99	70.642^{ab}±4.62	77.65^{a}±7.16	71.79^{ab}±1.14	*
	After storage					
Tryptamine	8.40±0.48	7.02±0.59	7.28±0.75	8.22±1.03	8.55±1.17	ns
2-Phenylethylamine	0.15^{c}±0.03	0.19^{bc}±0.04	0.19bc±0.01	0.37^{b}±0.21	0.63^{a}±0.01	***
Putrescine	32.55^{bc}±1.67	29.66^{c}±0.39	32.54^{bc}±0.08	40.91^{a}±9.15	40.16^{ab}±1.36	*
Cadaverine	7.27±0.11	7.68±0.77	7.30±0.33	8.21±0.63	9.19±2.16	ns
Histamine	7.72^{c}±0.54	7.73^{b}±0.15	7.98^{bc}±0.33	9.32^{a}±0.14	8.38^{b}±0.08	***
Tyramine	10.03^{b}±0.62	11.33^{ab}±1.72	11.31^{ab}±0.55	11.73^{ab}±0.01	13.01^{a}±0.66	*
Spermidine	3.03±0.26	3.16±0.4	3.42±0.45	2.86±0.19	2.79±0.16	ns
Spermine	2.86^{a}±0.31	2.54^{a}±0.02	2.45^{a}±0.62	1.76^{b}±0.07	1.51^{b}±0.06	**
TOTAL	72.00^{b}±2.76	69.31^{b}±2.96	72.47^{b}±1.65	83.37^{a}±10.47	84.21^{a}±3.47	*

Sig: Significance. ***, ** and * display the significance at 0.1 %, 1 % and 5 % by LSD, respectively. a–c Values not sharing the same superscript letter within the horizontal line are different according to the Duncan test. ns: not significant.

(T3) as 9.04 mg/L, 36.7 mg/L, 7.76 mg/L and 7.42 mg/L, respectively. The effect of turnip on putrescine ($P < 0.05$), tyramine ($P < 0.001$), spermine ($P < 0.01$), which are biogenic amines, was significant. The amounts of putrescine, histamine, tyramine and tryptamine that we determined in this study are compatible with Özdestan and Üren (2010).

While a decrease was observed in the amount of tryptamine in shalgams after storage, an increase was observed in the amount of putrescine, cadaverine, histamine, tyramine, spermidine, spermine and total biogenic amines. It was determined that there was an increase in the total amount of biogenic amines at the end of storage with the addition of turnip, and total biogenic amine amounts were between 63 mg/L (T0) and 72 mg/L (T4). According to the analysis of variance, the effect of turnip on 2-phenylethylamine, putrescine, histamine, tramine and spermine in stored shalgams was found to be statistically significant (Table 2).

No study has been found on the exchange of biogenic amines related to the storage of shalgam. Similarly, Anli et al. (2006) and Torres et al. (2002) reported that temperature, time and pH are important factors affecting the biogenic amine content during storage of beers or Chilean mackerel, and that biogenic amine formation increases at high storage temperature. On the other hand, Colak and Ugur (2002) found in their study that the amount of biogenic amines increased with ripening in sausages, and that the amount of biogenic amines in sausages stored at room conditions was higher than in samples kept in the refrigerator.

It can be said that the relative and total biogenic amines determined in shalgams generally increase with the addition of increasing turnip, and that biogenic amines may be formed as a result of the activities of microorganisms in the environment, and may have passed into shalgam from the added turnip.

3.5 Sensorial analysis

As can be seen from the spider web diagram (Fig. 7), while the T0 trial received the highest appreciation (score) in terms of colour, the least liked samples were T1 and T4. It may be due to the white colour of the turnip used. While the most liked samples in terms of smell were T3 and T2, the least liked samples were T0 and T1. In addition, while the most liked sample in terms of taste was T2, the least liked samples were T0 and T4. In terms of acidity, the most liked sample was T3, while the least liked sample was T1. While the samples that were liked in terms of swallowing character were close to each other, the least

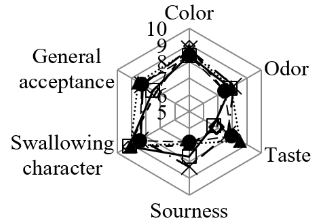

Figure 7: The spider web diagram of shalgam samples. –◇–: T0, —○—: T1, ...▲...: T2, –.–X–.–: T3, –□–: T4.

liked samples were T3 and T1. In terms of general acceptance, the most liked example was T2, while the least liked example was T0. Therefore, it can be said that the addition of turnip to a certain extent increases the appreciation of the consumers, but as the amount increases, the appreciation of the consumers decreases.

4. Conclusions

In summary, this study revealed the effects of turnip radish, which gives its name to shalgam but is sometimes used, sometimes not, and/or used at different rates, on microbial change and total acidity during the fermentation, and volatile flavours of shalgam at the end of fermentation. The total acidity, which is important in shalgam and desired by many consumers in high amounts, generally increased with the addition of increased turnip radish. However, an increase was observed in the amount of total and relative biogenic amines, which cause adverse effects when taken into the body at high concentrations. In addition, an increase also was observed after six months of storage (except tyramine). The interaction of turnip addition and storage was investigated and the effect of storage and turnip addition on the total amount of biogenic amine in shalgams was found to be significant.

Twenty-seven compounds, some of which were previously reported in turnip or purple carrot, but were unreported in shalgams, were reported for the first time in shalgam. The results indicate that the use of turnip in different ratios has an effect on the percentage and variety of VFC and a slight increase in total acidity. The first two PCs, both pre-storage and post-storage, account for a significant portion (> 82 %) of the total variance. Pre-storage, PC1 explained 55 % of the total variance, while post-storage explained less. Also, the total ester, which had a negative effect on PC1 before storage, was obtained as positive after storage. Moreover, the control sample was separated from other samples in terms of relative VFC with storage.

In conclusion, according to the results of microbial, sensory analysis and VFC, it can be stated that the most appropriate amount of turnip is 1 %, however, also ratios of 0.5 % and 2 % can be used. This information will be especially useful for producers to produce better quality and standard shalgam. However, further studies should be carried out in shalgam for more information about the sensory properties, general composition and even the effects at the end of storage, as well as testing the added turnip in wider limits.

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References

Agirman, B. (2014). *Reducing sodium chloride amount by using different chloride salts in shalgam juice production.* Cukurova University, Turkey.

Anli, R. E., Vural, N., Demiray, S., and Mert, B. (2006). Biogenic amine content of beers consumed in Turkey and influence of storage conditions on biogenic amine formation. *J. Inst. Brewing*, 112(3):267–274.

Anonymous (2022). *The good scents company information system.* (accessed February 17, 2022).

Bonneau, A., Boulanger, R., Lebrun, M., Maraval, I., and Gunata, Z. (2016). Aroma compounds in fresh and dried mango fruit (Mangifera indica L. cv. Kent): Impact of drying on volatile composition. *Int. J. Food Sci. Tech.*, 51(3):789–800.

Cankaya, A. (2018). *The effect of different fermentation temperature and production method on antioxidant activity, anthocyanin and phenolic compounds of shalgam juice*. Niğde University, Turkey.

Carbó, R., Gordún, E., Fernández, A., and Ginovart, M. (2020). Elaboration of a spontaneous gluten-free sourdough with a mixture of amaranth, buckwheat, and quinoa flours analyzing microbial load, acidity, and pH. *Food Sci. Tech. Int.*, 26(4):344–352.

Cemeroglu, B. (2007). *Food Analyses. No 34*. Food Technology Association Publications, Ankara Turkey.

Cirak, M. (2016). *The effect of different fermentation temperature application on quality of shalgam production*. Cukurova University, Turkey.

Colak, H. and Ugur, M. (2002). The effect of different temperature and time in storage on the formation of biogenic amines in fermented sucuks. *Turkish J. Vet. Anim. Sci.*, 26:779–784.

Erten, H., Tanguler, H., and Canbaş, A. (2008). A traditional Turkish lactic acid fermented beverage: Shalgam (Salgam). *Food Rev. Int.*, 24(3):352–359.

Gunes, G. (2008). *Research on the determination of the most appropriate black carrot amount in shalgam juice production*. Cukurova University, Turkey.

Halkman, A. (2005). *Food Microbiology Applications*. MERCK, Basak Matbaacılık ve Tanıtım Hizmetleri Ltd, Ankara, Turkey.

Harrigan, W. and McCance, M. (1990). *Laboratory Methods in Food and Dairy Microbiology (8th ed)*. Academic Press, London, UK.

Kebede, B. T., Grauwet, T., Palmers, S., Vervoort, L., Carle, R., Hendrickx, M., and Van Loey, A. (2014). Effect of high pressure high temperature processing on the volatile fraction of differently coloured carrots. *Food Chem.*, 153:340–352.

Keskin, M., Guclu, G., Sekerli, Y. E., Soysal, Y., Selli, S., and Kelebek, H. (2021). Comparative assessment of volatile and phenolic profiles of fresh black carrot (Daucus carota L.) and powders prepared by three drying methods. *Scientia Horticulturae*, 287:110256.

Kirlangic, O., Ilgaz, C., and Kadiroglu, P. (2021). Influence of pasteurization and storage conditions on microbiological quality and aroma profiles of shalgam. *Food Biosci.*, 44(101350).

Kıvançlı, J. and Elmacı, Y. (2016). Characterization of Turkish-style coffee aroma by gas chromatography and mass spectrometry and descriptive analysis techniques. *Int. J. Food Prop.*, 19(8):1671–1686.

Maifreni, M., Marino, M., and Conte, L. (2004). Lactic acid fermentation of Brassica rapa: Chemical and microbial evaluation of a typical Italian product (brovada). *Euro. Food Res. Tech.*, 218(5):469–473.

Molina, A. M., Guadalupe, V., Varela, C., Swiegers, J. H., Pretorius, I. S., and Agosin, E. (2009). Differential synthesis of fermentative aroma compounds of two related commercial wine yeast strains. *Food Chem.*, 117(2):189–195.

Molina, A. M., Swiegers, J. H., Varela, C., Pretorius, I. S., and Agosin, E. (2007). Influence of wine fermentation temperature on the synthesis of yeast-derived volatile aroma compounds. *Appl. Microbio. Biotech.*, 77(3):675–687.

Özdestan, Ö. and Üren, A. (2010). Biogenic amine content of Shalgam (Şalgam): A traditional lactic acid fermented Turkish beverage. *J. Agric. Food Chem.*, 58(4):2602–2608.

Ozturk, O. (2009). *Research on the composition of shalgam beverages obtained from Adana Market*. Cukurova University, Turkey.

Rodríguez-Sevilla, M. D., Villanueva-Suárez, M., and Redondo-Cuenca, A. (1999). Effects of processing conditions on soluble sugars content of carrot, beetroot and turnip. *Food Chem.*, 66(1):81–85.

Tanguler, H., Selli, S., Sen, K., Cabaroglu, T., and Erten, H. (2017). Aroma composition of shalgam: a traditional Turkish lactic acid fermented beverage. *J. Food Sci. Tech.*, 54(7):2011–2019.

Taveira, M., Fernandes, F., Guedes de Pinho, P., Andrade, P. B., Pereira, J. A., and Valentão, P. (2009). Evolution of Brassica rapa var. rapa L. volatile composition by HS-SPME and GC/IT-MS. *Microchem. J.*, 93(2):140–146.

Torres, S., Roeckel, M., and Marti, M. (2002). Histamine formation by Morganella morganii iso-lated from Trachurus murphyii (Chilean mackerel). *Lat. Am. Appl. Res.*, 32(2):209–214.

TSE (2003). *TS 11149 Standard of Shalgam Beverage*. Turkish Standards Institute, TSE, Ankara, Turkey.

Utus, D. (2008). *The effect of black carrot (Daucus carota) size used on the quality of shalgam production*. Cukurova University, Turkey.

Welke, J. E., Nicolli, K. P., Hernandes, K. C., Biasoto, A. C. T., and Zini, C. A. (2022). Adaptation of an olfactometric system in a GC-FID in combination with GCxGC/MS to evaluate odor-active compounds of wine. *Food Chem.*, 370:131004.