Food Bioscience 41 (2021) 100973



Contents lists available at ScienceDirect

Food Bioscience

journal homepage: www.elsevier.com/locate/fbio





Effect of temperature and production method on some quality parameters of fermented carrot juice (*Shalgam*)

Hasan Tanguler [a], Akkiz Cankaya [a,1], Erdal Agcam [b], Hasan Uslu [a,*]

[a] Department of Food Engineering, Faculty of Engineering, Nigde Omer Halisdemir University, 51245, Nigde, Turkey
[b] Department of Food Engineering, Faculty of Agriculture, Cukurova University, 01330, Adana, Turkey

ARTICLE INFO

Keywords:
Fermentation temperatures
Production methods
3D molecular demonstration of lactic acid
Phenolic contents
Pseudo second order model
Shalgam

ABSTRACT

This study is a paper in which compared the effect of fermentation temperature on antioxidant activity, anthocyanin profiles and phenolic compounds of *Shalgam* were investigated. 3D-molecular demonstration of lactic acid, which is the main molecule in *Shalgam*, was realized. As the fermentation temperature increased, titration acidity increased faster, and thus the fermentation time was shortened. Total phenolic content and anthocyanin profiles were higher in *Shalgams* produced by traditional method, while antioxidant activity was found to be lower. Moreover, for total phenolics, anthocyanin profiles and antioxidant activity, and minimum scores for sensory analysis, the lowest values were generally determined in *Shalgams* produced by both methods at 10 °C. It could be said that *Shalgam* fermented higher than 10 °C was more acceptable for consumers. This study is important in terms of showing that *Shalgam* can be produced in a shorter time in accordance with the standards. Experimental fermentation procedure, the production rate of the fermentation was studied as a kinetic character. Pseudo first order and Pseudo second order models were applied. PSO was fitted well to fermentation production rate.

1. Introduction

Fermentation is one of the oldest, most practical and economical food conservation methods (Erten et al., 2008). It improves nutritional characteristics of the products by increasing mineral bioavailability and the digestibility of carbohydrate and proteins. In addition, it enhances sensorial characteristics and shelf life of fresh vegetables such as cucumber, cabbage, and olive. On the other hand, consumers' tendency towards natural (minimally processed food or without preservatives), nutritious, health-promoting and aroma-rich products has increased the interest in fermentation and fermented products (Altay et al., 2013). One of these products is the *Shalgam* (salgam) beverage obtained by lactic-acid fermentation (Tanguler et al., 2017). *Shalgam* beverage, a reddish colored, cloudy appearance, and sour beverage, is a traditional product specific to the south of Turkey (Erten et al., 2008). Lately, it has begun to be sold in the other parts of Turkey and also in some European countries' capitals (Tanguler et al., 2017).

The main raw material is a purple carrot (*Daucus carota* ssp. *sativus* var. *atrorubens* Alef.) which should be used at least 15% ratio. Bulgur flour (bran) is a minor raw material. Bulgur is acquired by boiling drying, grinding and sieving of wheat (especially *Triticum aestivum* or *Triticum durum*). It is used as the nutrient source for microorganisms in *Shalgam* beverage production at the ratio of 3%. Unrefined rock salt and sourdough (or baker's yeast, *Saccharomyces cerevisiae*) also used. And if the available, root of turnip (*Brassica rapa* L.) is also used in the production (Erten et al., 2008). In recent years, the amount of this beverage production has reached quite high dimensions. Home or home-scale businesses have been replaced by large industrial plants. However, there is still no standard manufacturing technique in the industry. The processing method, raw materials and their amounts vary from one manufacturer to another. However, basically two methods are used in production. These are "traditional method, *TM*" and "direct method, *DM*", which are used industrially (Erten et al., 2008; Tanguler & Erten, 2012b).

The parameters influencing the quality of fermented beverages are the raw materials, autochthonous microorganisms, the interaction of microorganisms and the fermentation temperature (Torija et al., 2003). One of the most important parameters is fermentation temperature (Wasnin et al., 2014). It influences the biochemical reactions, growth, and metabolism of the microorganisms found in the medium. Hence, the

* Corresponding author.
E-mail address: hasanuslu@ohu.edu.tr (H. Uslu).
[1] Prepared from master thesis of Akkız CANKAYA.

https://doi.org/10.1016/j.fbio.2021.100973
Received 28 January 2021; Received in revised form 4 March 2021; Accepted 5 March 2021
Available online 11 March 2021
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diversity in the formation and amount of primary and secondary metabolites occurs, and this change determines the chemical and sensorial characteristics of the fermented products (Torija et al., 2003). Some researches published the suitability of distinct fermentation temperature in the production of fermented products to obtain desired sensorial characteristics (Wasnin et al., 2014) indicated that the range of fermentation temperature in the production of sauerkraut must be between 15 and 20 °C. Another study, Wasnin et al. (2014) examined the affects of fermentation temperature on some physicochemical characteristics and flavor components by storing fresh durian pulp for 10 days at different temperatures. They indicated that the product fermented at 27 °C was more appreciated by consumers than at 40 °C.

Shalgam is usually produced at ambient temperature in 10–35 °C according to the season and this affects the duration of fermentation (Erten et al., 2008). That difference leads to the presence of *Shalgam* beverages with different composition and sensory characteristics in the market. This study describes the effect of fermentation temperatures (10 °C, 22 °C and 35 °C) on antioxidant activity (AA), anthocyanin profiles, total phenolic content (TPC) and total flavonoid content (TFC) of *Shalgam* beverage. At the same time, in this present research, two different production methods which are used commonly in the industry were investigated. In addition, production rate of the fermentation was studied as kinetic study.

2. Materials and methods

The main raw material (purple carrot) and bulgur flour (setik) were provided by Doganay Food Company (Adana, Turkey). Other raw materials were supplied from the market (Nigde, Turkey).

2.1. The production of Shalgam beverage

Shalgam beverages were manufactured at the Fermentation Laboratory of Faculty of Engineering by two different methods; "traditional method" and "direct method".

The production by TM and DM method were performed according to Canbaş and Deryaoğlu (1993) and Erten et al. (2008). TM carried out in two distinct stages; "Dough fermentation" and "Carrot fermentation". The dough fermentation is carried out for the enhancing the count of microorganisms. Sourdough (0.2%) was mixed and kneaded with the bulgur flour (3%), salt (0.2%) and tap water. Later on, the dough obtained was allowed for the first fermentation at 25 °C for 3 days. After that time, the fermented mixture is extracted with tap water four times by blending well and the extract is obtained. That extract containing sourdough flora was combined with cleaned, chopped and cut in 2–3 cm diameter size purple carrots (18%), sliced turnip (1%), and salt (1%) in a 3 L in a closed glass jar to perform the carrot fermentation (lactic acid and ethanol fermentation).

In direct method, the first fermentation is not carried out. Purple carrots were cleaned, sorted and then cut in 2–3 cm diameter size. The cut purple carrots (18%), bulgur flour (3%), rock-salt (1.2%), sorted and sliced turnip (1%), sourdough (0.2%) and tap water were transferred into a closed glass jar to perform the carrot fermentation.

The lactic acid and ethanol fermentations in both methods (*TM* and *DM*) were carried out at 10°C, 22°C and 35°C in duplicate and followed by measuring pH and titration acidity (TA) as lactic acid. The amount of TA specified in the TSI (Turkish Standardization Institute) must be at least 6 g/L in *Shalgam* (Anonymous, 2016). For this reason, the fermentation was terminated when the minimum amount of TA (6 g/L) needed to be found in the *Shalgam* samples was reached. Following fermentation, the *Shalgams* were stored for 1 day at + 4 °C, removed from the sediment and bottled. *Shalgam* beverages were stated as T1 (10 °C), T2 (22 °C), T3 (35 °C) in the *TM* and D1 (10 °C), D2 (22 °C) and D3 (35 °C) in the *DM*.

Main molecules in the fermentation media have been shown in Fig. 1 and these molecules were designed with the jmol (Java viewer for chemical structures in 3D) program. This demonstration gives information about interaction of solute-solvent. Red, grey and white medias relate oxygen atoms, carbon atoms and hydrogen atoms, respectively.

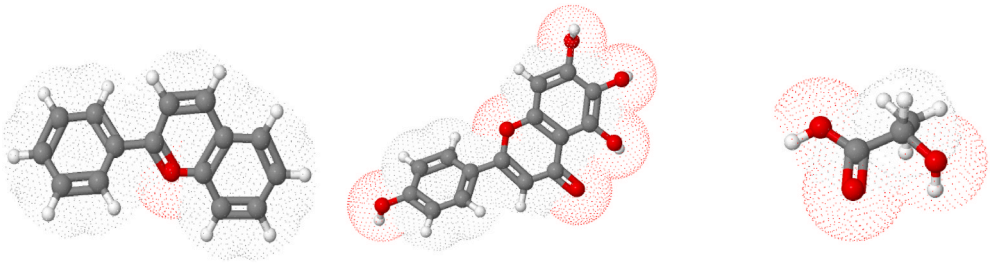
2.1.1. Analysis

pH value was defined directly by using a pH meter (VWR International Ltd., Ireland). TA values were determined by titrating *Shalgam* beverages up to pH 8.1 with 0.1 N NaOH. They were expressed as g lactic acid/L (Tanguler & Erten, 2012b). The amount of sugar remaining in *Shalgam* was measured by means of the phenol-sulphuric acid method (Amrane & Prigent, 1996). The dry solid and ash were determined according to AOAC (1990). Direct measurements of absorbance at 420 nm, 520 nm, and 620 nm were performed using a spectrophotometer (Thermo Scientific, Evolution 300 UV-VIS) with a 1 cm quartz tub. Colour intensity (CI) values were determined as the sum of optic density, OD, (CI = 420 nm + 520 nm + 620 nm). Tint values were determined as (OD_{420}/OD_{520}) (Ribéreau-Gayon et al., 2006, p. 404). Colors of *Shalgams* were evaluated with a Minolta CR-400 Chroma Meter (Konika Minolta Optics Inc., Japan). The device is standardized against the white ceramic plate prior to each use. L* gives the brightness value (lightness and darkness). a* and b* are the chromaticity coordinates. All analytical determinations were performed in duplicate, however, colour parameters triplicate and then the results were averaged.

Antioxidant activity (AA) was determined by DPPH method as described by Klimczak et al. (2007), but some modifications have been made. 100 μL of centrifuged *Shalgam* was added to 3000 μL of 1,1-diphenyl-2-picrylhydrazyl radical (DPPH*; 0,1 g/100 mL in 80% methanol) and mixed by vortex for 3 min. It was then kept in the dark for an hour to allow the reaction to equilibrate. At the end of that time, each of sample absorbance was determined at 515 nm in the spectrophotometer (PerkinElmer Lambda, USA). The AA values of the samples were determined as % inhibition of DPPH using the following equation. *Ac* and *As* indicate the absorbance of the control and the *Shalgam*, respectively.

$$AA\ (\%) = \frac{A_C - A_S}{A_C} x100$$

TPC and TFC analyses were carried out by the methods described



(a) (b) (c)

Fig. 1. 3D molecular demonstration of main molecules in fermentation media. (a) flavonoid (b) anthocyanin (c) lactic acid.

Abdullakasim et al. (2007) and Zhishen et al. (1999), respectively. The *Shalgam* sample and methanol (80%) were mixed in equal amounts (5:5 mL), centrifuged (6000 rpm, 10 min, +4 °C). Following centrifugation, a 1 mL of clear liquid was taken, mixed with 4 mL of distilled water and 0.3 mL of 5% $NaNO_2$ solution. The mixture was incubated for 5 min. A 0.3 mL 10% $AlCl_3{\cdot}6H_2O$ solution was added. Then, 2 mL NaOH (1 M) was mixed with the solution. The absorbance values were measured at 510 nm against distilled water immediately. Calibration curve created using certified quercetin standard for total flavonoid analysis and expressed as mg quercetin equivalents/L.

Anthocyanin profiles were measured using HPLC with method described by Justesen et al. (1997). Firstly, the sample and methanol (80%) were mixed in equal amounts, centrifuged (4000 rpm, 10 min, + 4 °C) and passed through 0.45 μm Teflon membrane filters. After extraction, it was injected into HPLC (Schimadzu LC-20AT, Japan, 2006) system consisting of a quaternary pump, a column temperature control oven (CTO-10AS), an auto sampler unit (SIL-20A), a degasser module (DGU-20A_5) and a photodiode array detector (SPD-M20A). The separation in HPLC took place in a photodiode array (PDA) detector set at 520 nm and an XTerra RP18 (Waters, Ireland) column (5 μm, 4.6 × 250 mm). The following solvents with a flow rate of 1 mL/min and 20 μL injection volume were used for spectral measurement; as a mobile phase solvent A, formic acid 5% (v/v) and solvent B, acetonitrile/solvent A (80/20). The flow rate was set at 1.0 mL/min with the gradient condition as followed: 100% A and 0% B at 0.01 min, 95% A and 5% B at 10 min, 90% A and 10% B at 25 min, 80% A and 20% B at 55 min, 55% A and 45% B at 70 min, 0% A and 100% B at 90 min, 100% A and 0% B at 95 min, and 100% A and 0% B at 100 min.

2.1.2. Sensory evaluation

The beverages obtained by two ways were evaluated by use of a descriptive and ranking test at ambient temperature according to Altug (1993). The taste panel consisted of 11 assessors. Results were calculated for statistical significance by one-way analysis of variance (ANOVA). Duncan multiple comparison tests was applied to significant differences using the software SPSS 10.0 for Windows.

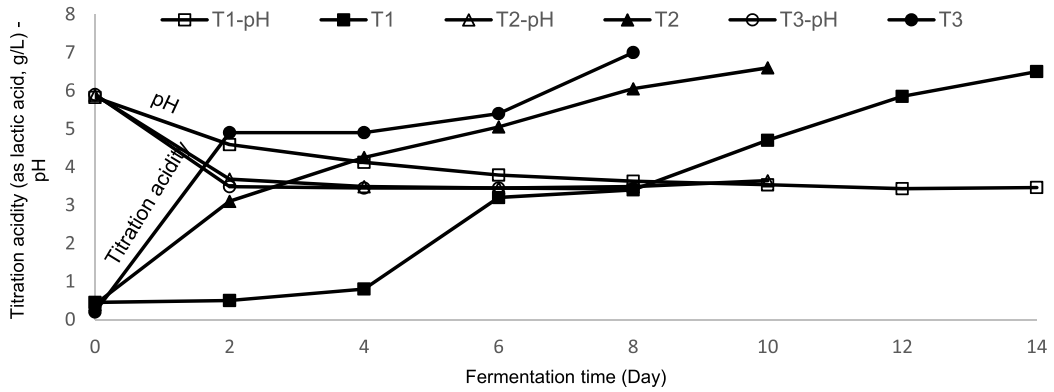
3. Results and discussion

In this research, *Shalgam* beverages were produced by *TM* and *DM* at different temperatures. Fermentation trials were followed with pH values and TA amounts. Figs. 2 and 3 show the results of pH and TA determinations during fermentations. The fermentation temperature influenced the time to reach the desired TA in both methods. Longest fermentations were carried out at 10 °C.

The primary end product of carrot fermentation in the production of *Shalgam* is lactic acid, which gives the sour soft taste of *Shalgam* and accounts for the majority of TA. It is produced by mostly homo-fermentative and hetero-fermentative lactic acid bacteria (LAB) using sugar during fermentation (Tanguler & Erten, 2012b). One of the most significant features affecting consumers' preferences in *Shalgam* beverage is the amount of TA (Agirman, 2014). According to the revised Turkish standards (Standard of Shalgam Beverage, 2016), TA in ready-to-serve *Shalgam* should be at least 6.0 g/L, and the pH should be a maximum of 3.8. Therefore, it was terminated when the amount of TA reached 6 g/L in this study (the lowest amount specified in the standard).

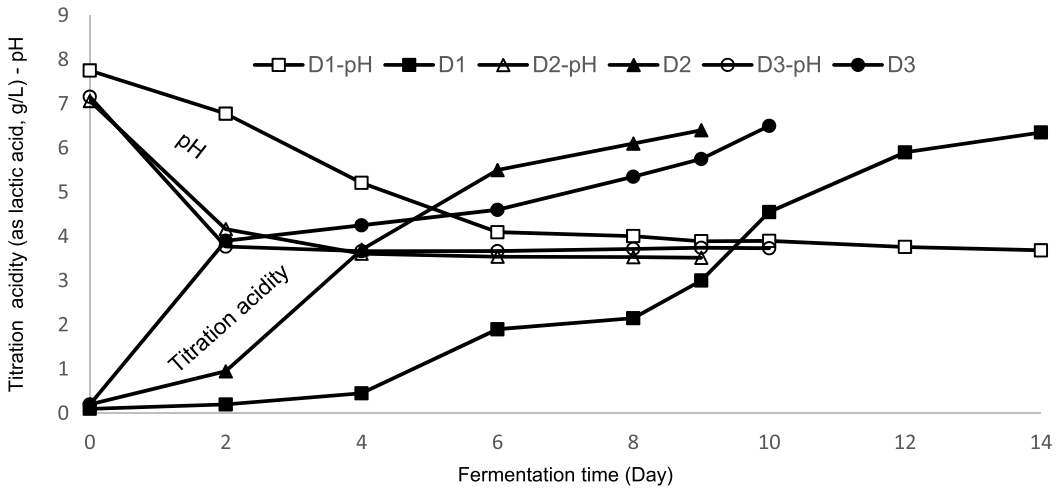
Fig. 2 gives the pH and the amounts of TA changes during the carrot fermentation of *Shalgam* beverages carried out by *TM*. The levels of pH and TA were between 5.82 – 5.90 and 0.2–0.45 g/L as a lactic acid at the beginning of fermentation, respectively. Whereas in *DM*, pH and the amounts of TA varied from 7.06 to 7.75 and 0.1–0.2 g/L, respectively (Fig. 3). The TA amounts were found to be lower than *TM* and the pH values were found higher. Considering that the lowest TA and the highest pH values were found when used *DM*, it can be said that dough fermentation used in *TM* contribute to the formation of lactic acid by increasing counts of LAB. In the fermentations carried out at 22 °C and 35 °C by both methods, TA increased quickly from the beginning. This is usually due to the fact that LAB forms organic acids using sugars. On the other hand, in the experiments (T1 and D1), there was no significant increase in the first four days, followed by a rapid increase in TA. For this reason, the obligatory value of TA was reached or surpassed after 14 days in the trials of D1 and T1. However, fermentations carried out at *TM* and *DM* were terminated earlier at increasing temperatures. For example, in the T2 and D2 trials, the fermentation was completed in 10 and 9 days, respectively, and the T3 trial performed at 35 °C was completed in 8 days. Interestingly, the D3 trial performed by the direct method at 35 °C last a little longer and was completed in 10 days. This may be due to the fact that the fermentation was terminated before it was completed (after achieving the lowest amount of total acidity specified in the standard), as well as the low starting number and therefore the LAB number in the D3 trial during the fermentation (results not given).

At the end of fermentation, the amounts of TA were found between 6.50 and 7.0 g/L and 6.35–6.50 g/L and pH levels varied between 3.43 – 3.64 and 3.52–3.73 in the *TM* and *DM*, respectively. TA increased with increasing temperature in both methods and highest values at each temperature were obtained at samples produced by the *TM*.



T1 (10°C), T2 (22°C), T3 (35°C), Titration acidity (--■--: T1, --▲--: T2, --●--: T3), pH (--□--: T1, --Δ--: T2, --○--: T3)

Fig. 2. The development of TA and pH during carrot fermentations carried out by the *TM*.



D1 (10°C), D2 (22°C), D3 (35°C), Titration acidity (--■--: D1, --▲--: D2, --●--: D3), pH (--□--: D1, --Δ--: D2, --○--: D3)

Fig. 3. The development of TA and pH during carrot fermentations carried out by the *DM*.

In previous study (Tanguler & Erten, 2012b), it is determined that the levels of pH were found between 3.36 and 3.46, and TA as lactic acid 6.83–7.25 g/L in samples produced by the *DM*. On the other hand, TA amounts were found in the range of 5.98–8.71 g/L in *Shalgam* beverages produced by the *TM* by Canbaş and Deryaoğlu (1993), Agirman (2014) and Tanguler et al. (2014). Findings in present work for TA and pH in *Shalgam* beverages produced by *TM* and *DM* are generally in good accordance with the revised Turkish standards (Anonymous, 2016). However, the results slightly lower than previous studies in *Shalgam* beverages produced with the method *TM* and in *Shalgam* produced with the method *DM* (Agirman, 2014; Canbaş & Deryaoğlu, 1993; Tanguler & Erten, 2012b; Tanguler et al., 2014). The most important reason is probably the termination of the process before completely end of fermentation. However, despite the early termination of fermentation, *Shalgam* beverages with TA and pH values appropriate to the standards were obtained at relatively shorter times.

3.1. *Effect of the temperature and methods on general composition of Shalgam*

Tables 1 and 2 show the general composition of *Shalgam* beverages produced by *TM* and *DM*, respectively.

Purple carrots are rich in sugars (especially sucrose, and in smaller quantities fructose and glucose) (Tanguler, 2010). During fermentation of *Shalgam*, most of sugars are converted into mainly lactic acid by LAB. Moreover, CO_2, ethyl alcohol and also other end products are produced by yeasts and LAB in the fermentation medium (Okcu et al., 2016). Total sugar generally decreased with increasing temperature in both methods, and the amounts obtained in this study indicates that lactic acid fermentation was not completed. Their amounts were determined between 4.85 and 5.76 g/L. Neither different temperatures nor production methods had a significantly effect on total sugar amounts. These values are higher than previous reports given by many scientist (Agirman, 2014; Gok, 2017; Gunes, 2008; Tanguler & Erten, 2012a; Tanguler et al, 2014, 2015). One of the most important reasons for these higher values is probably the termination of the fermentation process immediately after reaching the total acidity value specified in the standard.

The difference in colour parameters is reflected in the Hunter L*, a*, b* values. In 3D coordinate system, the L* value indicates the path from darkness to lightness on the vertical axis (Agirman, 2014). The minimum and maximum L*, a* and b* values ranged between 13.3 and 14.3, 3.0–5.6 and −0.4 – 1.17, respectively (Tables 1 and 2). In all produced *Shalgam* beverages, a* colour is red and b* colour is blue or close to blue. Therefore, it can be said that there is a blue colour in redness. Compared with literature reports, the levels of L*, a* and b* values in *Shalgam* beverages produced in our study were generally found

Table 1
General composition of shalgams produced by *TM*.

	T1	T2	T3	Sig.
TA as lactic acid (g/L)	$6.5^{b} \pm 0.1$	$6.6^{b} \pm 0$	$7.0^{a} \pm 0$	**
pH	3.46 ± 0.2	3.64 ± 0.01	3.43 ± 0.1	ns
Total sugar (g/L)	5.26 ± 0.1	5.76 ± 1.4	4.85 ± 0.7	ns
Total solid (%)	2.45 ± 0.2	2.33 ± 0.3	1.83 ± 0.1	ns
Colour properties				
Tint	$0.55^{b} \pm 0.01$	$0.73^{a} \pm 0.03$	$0.71^{a} \pm 0.03$	*
Colour intensity	$1.18^{b} \pm 0.1$	$2.14^{a} \pm 0.2$	$2.30^{a} \pm 0.11$	*
Colour composition % OY_{420}	$31.10^{b} \pm 0.1$	$33.61^{a} \pm 0.2$	$34.21^{a} \pm 0.8$	*
$\%OY_{520}$	55.77 ± 1.3	46.21 ± 1.2	48.23 ± 1.8	ns
$\%OY_{620}$	13.12 ± 1	19.74 ± 0.1	17.53 ± 3.4	ns
L*	13.91 ± 0.47	13.78 ± 0.31	14.25 ± 0.06	ns
a*	5.03 ± 1.52	4.74 ± 0.54	5.2 ± 0.87	ns
b*	−0.35 ± 0.32	−0.33 ± 0.09	−0.12 ± 0.27	ns
TPC (mg GA/L)	$259.77^{b} \pm 6$	$382.10^{a} \pm 15$	$362.10^{a} \pm 24$	*
Total flavonoid (mg quercetin/L)	$166.38^{b} \pm 8$	$278.22^{a} \pm 18$	$269.51^{a} \pm 15$	*
Antioxidant activity (%)	43.45 ± 5	38.94 ± 2	38.48 ± 7	ns
Anthocyanin profiles (mg/L)				
Cya-3-xyl-glc-gal	3.58 ± 1.14	5.74 ± 0.34	5.11 ± 0.29	ns
Cya-3-xyl-gal	13.77 ± 1.25	12.87 ± 0.22	12.25 ± 0.31	ns
Cya-3-xylglc-gal, acylated-sin	11.20 ± 0.94	14.06 ± 1.76	13.34 ± 0.66	ns
Cya-3-xylglc-gal, acylated-fer	88.97 ± 13.95	135.01 ± 9.77	119 ± 3.42	ns
Cya-3-xylglc-gal, acylated-coum	7.36 ± 1.52	8.54 ± 0.11	8.45 ± 0.51	ns
Total anthocyanin	124.91 ± 17.88	176.24 ± 13.02	158.17 ± 5.11	ns

GA: Gallic acid, Sig: Significance, ns: not significant. D1 (10 °C), D2 (22 °C), D3 (35 °C).

Table 2
General composition of shalgams produced by *DM*.

	D1	D2	D3	S Sig.
TA as lactic acid (g/L)	6.35 ± 0.1	6.4 ± 0.2	6.5 ± 0	ns
pH	3.68 ± 0.1	3.52 ± 0.1	3.72 ± 0.1	ns
Total sugar (g/L)	5.64 ± 0.1	5.07 ± 0.2	4.85 ± 0.1	ns
Total solid (%)	1.73 ± 0.2	2.65 ± 0.2	2.25 ± 0.3	ns
Colour properties				
Tint	0.65 ± 0.1	0.63 ± 0.1	0.69 ± 0.1	ns
Colour intensity	2.01 ± 0.2	2.00 ± 0.4	2.01 ± 0.1	ns
Colour composition $\%OY_{420}$	32.94 ± 2.6	32.13 ± 0.2	32.26 ± 0.2	ns
$\%OY_{520}$	51.34 ± 1.2	50.97 ± 3.3	49.51 ± 6.1	ns
$\%OY_{620}$	15.62 ± 4.2	16.87 ± 1.1	16.20 ± 0.6	ns
L*	13.27 ± 0.1	14.23 ± 0.87	13.38 ± 0.04	ns
a*	3.16 ± 0.55	5.58 ± 2.08	2.95 ± 0.31	ns
b*	0.93 ± 0.1	0.16 ± 0.06	1.17 ± 0.28	ns
TPC (Total Phenolic Acid Content) (mg GA/L)	185.93 ± 57.2	229.74 ± 5.6	257.10 ± 19.3	ns
TFC (Total flavonoid content) (mg quercetin/L)	116.01 ± 45.2	160.00 ± 1.2	166.65 ± 10.1	ns
Antioxidant activity (%)	45.72 ± 0.1	46.77 ± 0.3	47.13 ± 0.7	ns
Anthocyanin profiles (mg/L)				
Cya-3-xyl-glc-gal	3.92 ± 0.27	3.24 ± 0.19	3.10 ± 1.66	ns
Cya-3-xyl-gal	12.28 ± 0.92	8.47 ± 5.27	12.21 ± 1.21	ns
Cya-3-xylglc-gal, acylated-sin	7.14 ± 0.64	9.77 ± 1.11	7.56 ± 1.47	ns
Cya-3-xylglc-gal, acylated-fer	60.84 ± 9.45	72.70 ± 1.29	67.23 ± 1.92	ns
Cya-3-xylglc-gal, acylated-coum	4.42 ± 1.54	4.95 ± 0.33	4.55 ± 0.86	ns
Total anthocyanin	88.68 ± 28.59	99.16 ± 2.40	94.67 ± 0.9	ns

GA: Gallic acid, Sig: Significance, ns: not significant. D1 (10 °C), D2 (22 °C), D3 (35 °C).

lower than the results given by some researchers (Agirman, 2014; Tanguler et al., 2014). They reported their levels between 18.8 and 24.8, 50.4–56.5 and 32.1–42.3, respectively. The most important reason may be the fermentation time as previously mentioned. In this study, pH values were generally determined proportional to b* values, while inversely proportional to a* values. Similarly, Steed and Truong (2008) stated that the higher pH was cause darker purple and blue colors.

3.1.1. *Antioxidant activity, total phenolic, flavonoid and anthocyanin contents*

The phenolic compounds or polyphenols one of the largest and most widely distributed groups in the plant world such as fruits and vegetables are secondary plant metabolites (Nizamoglu & Nas, 2010; Toktaş et al., 2018). Chemically, they are divided into two groups; non-flavonoid (hydroxycinnamic, hydroxybenzoic acid and derivatives, phenolic alcohols) and flavonoids (anthocyanins, flavon-3-ol monomers and polymers, flavonols and proanthocyanidins) (Akalin, 2011, p. 57; Hosseini, 2017; Ribéreau-Gayon et al., 2006, p. 404). Flavonoids are found in the large class of phytochemicals. They are thoroughly distributed in the plant leaves and the skin of fruits (Toktaş et al., 2018). These compounds are the source of bitterness and sourness in foods (Okcu et al., 2016; Toktaş et al., 2018). Therewith, they contribute to the colour, taste and flavor of the fruit, vegetables and fermented products (Nizamoglu & Nas, 2010). They are also known to have important positive effects on human health (prevention of diseases such as cardiovascular diseases, some types of cancers such as colon cancer, reducing the risk of diabetes and some other degenerative diseases) due to their natural antioxidant activities, anti-inflammatory, and antimicrobial impacts (Hosseini, 2017; Nizamoglu & Nas, 2010; Toktaş et al., 2018). For these reasons, various studies have been carried out on phenolic in various materials in recent years. Cranberry, grape, tea, red wine, cabbage, onion, sorghum, peas and legumes contain high amounts of phenolic compound (Okcu et al., 2016). On the other hand, purple carrot or juice also contains a significant amount (1878–4920 mg GA/kg) of phenolic substances (Algarra et al., 2014; Ekinci et al., 2016). However, Toktas et al. (2018) reported that there is much lower TPC (113 mg GA/kg) in purple carrots. These compounds pass through to the *Shalgam* beverage during fermentation. Therefore, the most of phenolic content of *Shalgam* is generally related to purple carrot (Gunes, 2008; Okcu et al., 2016). However, in *Shalgam* beverages, there are lower amounts of TPC than purple carrots (Ribéreau-Gayon et al., 2006, p. 404).

The most important factors affecting the concentration of TPC and TFC in fermented products are; production technology, maceration time, pressure, conversions during ripening (Akalin, 2011, p. 57) and lactic strains (Okcu et al., 2016). In addition to these factors, raw material and fermentation temperature also effects concentration (Akalin, 2011, p. 57). The amounts of TPC and TFC were found higher in the *Shalgam* beverages produced by *TM*. On the other hand, results indicate that the amount of these substances not only was affected than the method used in the production but also temperature. TPC and TFC amounts in *Shalgam* beverages usually increased with the increasing temperature in both *TM* and *DM* (Except T3). They obtained between 186 (D1) - 382 mg GA/L (T2) and 116 (D1) - 278 mg quercetin/L (T2), respectively. The data obtained for TFC in *Shalgam* beverages produced by *TM* are in good agreement with the results reported by Toktas et al. (2018) who found between 197 and 252 mg rutin/L in *Shalgam* beverages produced in laboratory and commercial. This wide distinction in TPC is generally due to the anthocyanin amounts that passing from purple carrot to *Shalgam*. The results were higher than results reported by Toktas et al. (2018) (62.71–81.5 mg GA/L). On the contrary, the amounts were lower than the results of Agirman (2014) and Ekinci et al. (2016) who determined that the amounts of TPC to be in the range of 517–749 mg GA/L. The most important reason could be the termination of the process before the complete end of fermentation (after reaching the total acidity value specified in the standard). It is known that quantities of TPCs rose in the course of Shalgam fermentation (Agirman, 2014; Gunes, 2008).

Anthocyanins are water-soluble natural phenolic compounds, which give to the fruit, vegetable and some beverages their unique red, blue and purple colors according to the pH level and their structural properties (Algarra et al., 2014). In addition, there may be also some positive benefits on human health. For example, reduced risk of coronary heart disease, stroke risk, cataract, hypertension, anticancer, antitumor and antiinflammatory effects (Algarra et al., 2014; Jing, 2006; Kamiloglu et al., 2015). Purple carrot is a product that has gained great importance recently due to its high anthocyanin content (<1750 mg/kg) (Kamiloglu et al., 2015). During the fermentation process performed in the production of *Shalgam*, the anthocyanins passing through the purple carrot give red colour to *Shalgam*. Therefore, *Shalgam* is a rich source of anthocyanin (Erten et al., 2008). Okcu et al. (2016) stated that anthocyanins in *Shalgams* are mainly related to purple carrot.

A total of five anthocyanin profiles were identified and quantified in *Shalgam* samples produced in present study. These were acylated (first two of them) and non-acylated anthocyanins. were cyanidin-3-xylosyl-glucosyl-galactoside (Cya-3-xyl-glc-gal), cyanidin-3-xylosyl-galactoside (Cya-3-xyl-gal), cyanidin-3-xylosyl-glucosyl-galactoside acylated with sinapic acid (Cya-3-xylglc-gal, acylated-sin), cyanidin-3-xylosyl-glucosyl-galactoside acylated with ferulic acid (Cya-3-xylglc-gal, acylated-fer) and cyanidin-3-xylosyl-glucosyl-galactoside acylated with coumaric acid (Cya-3-xylglc-gal, acylated-coum) (Tables 1 and 2). Similarly, some researchers have reported that purple carrot (Kamiloglu et al., 2015; Türkyilmaz et al., 2012) and *Shalgam* (Okcu et al., 2016; Tanguler, 2010; Turker et al., 2007) contain significant amounts of cyanidin based

anthocyanins especially acylated forms (Algarra et al., 2014). These are Cya-3-xyl-gal, Cya-3-xyl-glc-gal and their monoacylated forms with ferulic, sinapic and *p*-coumaric acids. However, Ekinci et al. (2016) stated that 6 individual anthocyanins including Cya-3-gal, Cya-3-glu, Cya-3-arabinoside, peonidin (peo)-3-gal, peo-3-glu, and peo-3-arabinoside were determined in the *Shalgam* using LC–MS/MS.

While the highest values for individual anthocyanins (especially acylated anthocyanins) and total anthocyanins in the *Shalgam* beverages produced by both methods were generally determined in the experiments performed at 22 °C (T2 and D2), the lowest values were generally T1 and D1. A decrease in both individual and total anthocyanin levels in both production methods was observed in *Shalgam* beverages fermented above 22 °C. Similarly, Lee et al. (2007) reported that the amount of anthocyanins in the production of fermented black bean kojis increased till a certain temperature (30 °C) and then decreased at 35 °C. Wang and Stretch (2001) conducted in a study on the storage of blueberries at different temperatures (0 °C, 5 °C, 10 °C, 15 °C and 20 °C). They reported that the amount of anthocyanin was increased up to 15 °C, but the values decreased at 20 °C. Some researchers stated that temperature is one of the most important factors among the all factors (light, presence of other phenolic compounds, enzymes, metal ions, sugars, ascorbic acid, and oxygen etc) affecting the stability of anthocyanins (Jing, 2006) in purple carrots (Kamiloglu et al., 2015) and *Shalgam* beverages (Turker et al., 2007). In fermentations carried out at temperatures above 22 °C, anthocyanins may be degraded and this may also have led to a decrease in final product.

The anthocyanins containing five cyanidin derivatives were observed both methods; however, it is important that the amounts of the individual constituents vary depending on the TM and DM (Tables 1 and 2). In addition, individual and total anthocyanin values in *Shalgam* beverages produced by *TM* were higher than *Shalgam* beverages produced by *DM*. Increased microbial flora in the dough fermentation performed by *TM* can be said to cause an increase of total and individual anthocyanins passing from purple carrot to *Shalgam*. The highest total anthocyanins in *Shalgam* beverages produced by different methods at 10 °C, 22 °C and 35 °C were obtained as 124.9 mg/L (T1), 176.2 mg/L (T2) and 158.2 mg/L (T3), respectively. Therefore, the differences in the total and individual anthocyanins amounts in the *Shalgam* can be explained by the differences in production methods and temperatures. No studies have been found on the directly comparison of anthocyanin amounts in *Shalgam* beverages produced by these two methods. However, some researchers stated that total anthocyanin amounts in *Shalgam* beverages were between 67.5 and 222 mg/L as Cya-3-glucoside (Agirman, 2014; Gunes, 2008; Tanguler, 2010). These extensive ranges can be attributed on to the complex interaction between microbial flora (LAB and yeasts) and phenols that are effective during fermentation, as well as to the production method and raw materials used in the production.

The major individual anthocyanin in the *Shalgam* beverages produced at different temperatures by both production methods was Cya-3-xylglc-gal acylated-fer, and their amounts between 60.8 and 135 mg/L were determined. In addition, minor individual anthocyanins were found as Cya-3-xyl-glc-gal. These are also supported with the literatures by Türkyilmaz et al. (2012). The difference among *Shalgam* samples produced in increasing temperatures in terms of total and individual anthocyanin was statistically insignificant in both methods ($P > 0.05$). However, the difference between the methods for individual anthocyanins (especially Cya-3-xyl-glc-gal, Cya-3-xylglc-gal, acylated-fer and Cya-3-xylglc-gal, acylated-coum) and total anthocyanins were found significant ($P < 0.05$).

One of the most significant features of anthocyanins is that they have antioxidant properties like most phenolics (Lee et al., 2007). Products with antioxidant capacity are important in terms of having health-promoting properties. Moreover, its protective effects against diseases such as cancer and cardiovascular diseases are also remarkable.

TPC and anthocyanin, which are present in significant amounts in purple carrots, have powerful antioxidant capacity (Hosseini, 2017; Tanguler, 2010). Antioxidant capacity of purple carrots are higher than tomato, apple, orange, red grapes, black cherry, pineapple juice and ginger. In addition, *Shalgam* is a product rich in anthocyanin's from purple carrot and LAB which are well known for their antioxidant properties and beneficial effects on health. Okcu et al. (2016) stated that phenolic compounds which could enhancement AA were affected by distinct LAB strains during fermentation of *Shalgam*. Moreover, antioxidant capacity of purple carrots may vary depending on processing and extraction methods (Hosseini, 2017). But, increasing temperatures in both methods had no statistically significant effect at $P > 0.05$ on AA in the present study. However, the difference between the methods in terms of temperatures (10 °C, 22 °C and 35 °C) were found significant ($P < 0,05$). The AA values of all tested temperatures were found between 38.5 and 47%. Therefore, it can be said that *Shalgam* beverages have a significant potential in terms of AA. Moreover, higher values were determined in *Shalgam* beverages produced by the *DM* and the highest value was obtained in sample D3. On the other hand, the antioxidant activity decreased with increasing temperature in *Shalgam* beverages produced by *TM*, and increased in the *Shalgam* beverages produced by *DM*. Similarly, Lee et al. (2007) reported that decreased AA with increased temperature in the production of fermented koji.

In addition, AA increased with increasing TPC in *Shalgam* beverages produced by *DM* and, decreased with decreasing phenolic compounds in *Shalgam* beverages produced by *TM* (except T1). Similar relations were also observed between anthocyanin amounts and antioxidant capacity. Some researchers stated that the antioxidant capacity is generally related to amount of TPC and anthocyanin found in products (Chu et al., 2002; Li et al., 2012). In a study conducted with different wine-making technologies, Baiano et al. (2009) also reported that the AA determined by DPPH* method has increased with the increase of TPC in all of the 1-year wines. Hanay (2011) performed phenolic and antioxidant determination by applying two different extraction temperatures (90 °C and 100 °C) to tea samples. He found that the amount of the TPC and AA was higher at 100 °C in tea extracts.

Although there is a positive correlation between AA and TPC in *Shalgam* samples observed in this study, there was also exception (T1). Interestingly, the AA decreased with the increased phenolic substance in sample T1. Similarly, Hosseini (2017) also reported that the amount of anthocyanin decreased as the fermentation time and black grape pomace ratio increased, whereas the AA increased. Baiano et al. (2009) stated that the AA depends not only on the TPC, but also on the specific chemical structure of each phenolic matter. On the contrary to many researchers (Baiano et al., 2009; Chu et al., 2002; Lee et al., 2007; Li et al., 2012) reported no strong relationship between TPC and AA. Moreover, Jing (2006) stated that statistical analyses could not well clarify the relationship between TPCs and their AAs. For this reason, more detailed studies on the relationship between AA with phenolic compounds, and/or anthocyanins are required.

3.1.2. Sensorial analysis

Eleven panelists carried out sensorial properties of *Shalgam* beverages produced by different methods and different temperatures presented in Table 3. Whole meal bread and water were given to the panellists to neutralize the taste between the sample evaluations. Colour, smell, taste and overall impression values in *Shalgam* beverages produced by *TM* ranged between 5.10 and 7.55, 4.72–7.18, 4.18–7.63 and 5.55–7.54, respectively. And their statistical evaluations showed that there is significant difference for colour ($P < 0.05$), smell ($P < 0.01$), taste ($P < 0.001$) and overall impression ($P < 0.001$). The scores given by panelists increased with increasing temperature and the highest scores were found in sample T3 (35 °C). On the other hand, their values in *Shalgam* beverages produced by *DM* have been changed between 5.45 and 8.73 ($P < 0.001$), 5.65–7.45 ($P < 0.01$), 4.63–7.91 ($P < 0.001$) and 4.91–7.91 ($P < 0.001$), respectively. The lowest values in *Shalgam* beverages produced by both methods were generally achieved in

Table 3
Sensory composition results.

	Traditional method				Direct method			
	T1	T2	T3	Sig	D1	D2	D3	Sig
Colour	5.10[b]	7.19[a]	7.55[a]	*	5.45[c]	8.73[a]	6.45[b]	***
Smell	4.72[c]	5.55[b]	7.18[a]	**	7.10[a]	7.45[a]	5.65[b]	**
Taste	4.18[c]	6.36[b]	7.63[a]	***	4.63[c]	7.91[a]	5.81[b]	***
Overall impression	5.55[b]	5.73[b]	7.54[a]	***	4.91[c]	7.91[a]	6.09[b]	***

T1 (10 °C), T2 (22 °C), T3 (35 °C), D1 (10 °C), D2 (22 °C), D3 (35 °C), Sig: Significance, Expressions given with different letters on the same line were found statistically significant (*: 5% significance level, **: 1% significance level, ***: 0.1% significance level) according to Duncan test.

Shalgam beverages produced at 22 °C. In contrast to the *Shalgam* beverages produced by *TM*, D2 (22 °C) was the most popular example of *Shalgam* produced by *DM*. However, the highest scores were generally obtained in *Shalgam* beverages produced by *DM*. In contrast, Tanguler et al. (2015) stated that scores of colour, taste, smell and overall impression of *Shalgam* produced by *TM* were higher than *Shalgam* produced by *DM*. The most important reasons are the temperature of the fermentation used and the incomplete fermentation. According to the sensorial analyses, the least preferred samples were determined as beverages T1 and D1. This suggests that the fermentation temperatures must be higher than 10 °C.

3.1.3. Kinetic study

Although many kinetic models exist, the main known kinetic models are adapted to the fermentation production rate for this study. For this reason, Pseudo first order model was used (Datta & Uslu, 2017; Rajoriya et al., 2007). Pseudo first order model;

$$\frac{dq_t}{dt} = k_f(qe - qt) \quad (1)$$

Q_t is the amount of acid at time t (mg/g); q_e is the initial material at equilibrium; k_f is the pseudo first order rate coefficient (day^{-1}); and t is the contact time (day).

The integration of Eq. (1) when $q_t = 0$ at $t = 0$

$$Log_{(qe-qt)} = \log q_e - \frac{k_f}{2.303}t \quad (2)$$

The values of k_f and q_e can be found from a plot of log (qe -qt) versus t. The pseudo first-order parameters are shown in Table 4, and the model plots for each temperature studied are shown in Fig. 4.

Another model, the pseudo-second-order model (Rajoriya et al., 2007) is given by Eq. (3). The rate law for this system can be expressed as below.

$$\frac{dQ}{dt} = k_S(Q_e - Q)^2 \quad (3)$$

where, k_S and Q are the pseudo-second-order rate coefficient (mg/g/day) and amount of acid production at any time (mg/g), respectively. Eq. (3) can be integrated with the boundary situations $t = 0$ to $t = t$ and $Q = Q$ to give Eq. (4)

$$\frac{1}{Q_e - Q} = \frac{1}{Q_e} + k_S t \quad (4)$$

The linear form of Eq. (4) is written as follows:

$$\frac{t}{Q} = \frac{1}{k_S Q_e^2} + \left(\frac{1}{Q_e}\right).t \quad (5)$$

A plot can be drawn between (t/Q) versus t which gives a straight line. The amount of acid after production at equilibrium (Q_e) and pseudo-second-order rate coefficient (k_S) can be determined from intercept and slope of the straight line, respectively. The result was shown in Table 4. As seen from Fig. 5 PSO model are good fitted to adopted fermentation data.

Table 4
Results of rate models for fermentation production of lactic acids.

Temperature (°C)	Pseudo-first-order model			Pseudo-second-order model		
	Q_e (mg g^{-1})	k_f (mg g^{-1} day^{-1})	R^2	Q_e (mg g^{-1})	k_S (mg g^{-1} day^{-1})	R^2
10	2.274	0.3407	0.6713	3.224	0.2822	0.9975
22	2.403	0.4530	0.6733	3.187	0.2845	0.9983
35	6.909	0.1922	0.9734	3.177	0.5029	0.9969

4. Conclusions

Recently, consumer's preferences are changing. There is an increase in the consumer's preference of fermented products, especially due to its unique properties such as high nutritional content and positive effects on health. *Shalgam* is a traditional Turkish sour soft beverage which is fermented by mainly LAB and also yeast. There are mainly two different methods in industry for *Shalgam* production. In addition, one of the most important parameters influencing the quality of fermented beverages is fermentation temperature. This study carried out for this purpose compares the effect of fermentation temperature and production methods on antioxidant activity, anthocyanin profiles and phenolic compounds of *Shalgam* beverage. There is no study related with the effect of different temperatures on *Shalgam* fermentation and its characteristics. The results revealed that temperature and production method affected the general composition of *Shalgam* beverages.

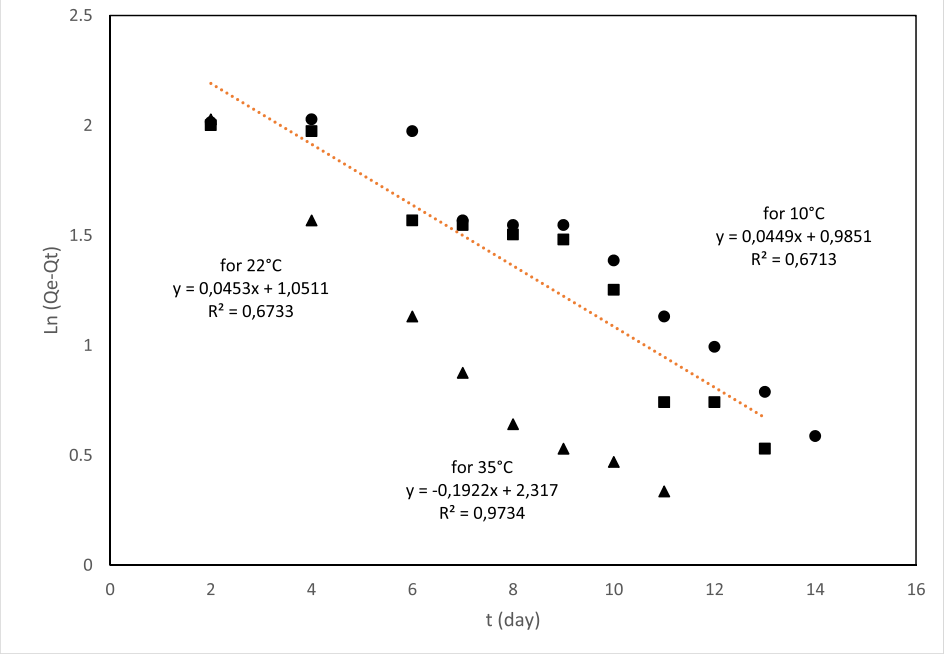
TA, phenolic compound, flavanoid, individual and total anthocyanin amounts were found generally higher in *Shalgam* produced by traditional method. However, samples produced with direct method scored higher in terms of colour, taste, smell and overall impression in the sensory analyzes. Our results for TA, pH, L*, a* and b* values were determined slightly lower and total sugar higher than previous reports. The reason for this is that, according to Turkish standards, the fermentation trials were terminated early, taking into account the least TA value in *Shalgam* beverages as mentioned before. However, this study shows that since the determined values are in accordance with the standard, the fermentation can be terminated in a shorter time and *Shalgam* ready for consumption can be produced in a shorter time.

Funding details

This work was supported by the [Nigde Omer Halisdemir University, Scientific Research Projects Unit] under Project [FEB 2017/25-BAGEP].

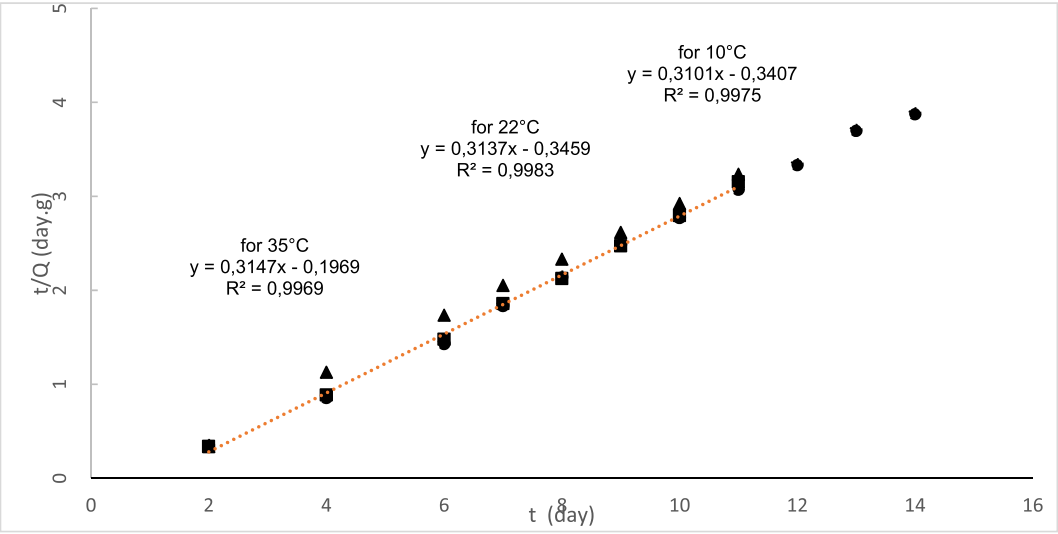
Author statement

Hasan TANGULER: Conceptualization, Supervision, Funding acquisition, Writing - Original Draft.
Akkiz CANKAYA: Visualization, Writing - Original Draft.
Erdal AGCAM: Investigation and some analysis.
Hasan USLU: Formal analysis.



(● : 10°C; ■ : 22°C; ▲ : 35°C)

Fig. 4. PFO plot for the fermentation production rate at different temperatures.



(● : 10°C; ■ : 22°C; ▲ : 35°C)

Fig. 5. PSO plot for the fermentation production rate at different temperatures.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Acknowledgements

We would like to thank Nigde Omer Halisdemir University, Scientific Research Projects Unit (Project no: FEB 2017/25-BAGEP) for its support and Doganay Gida for its raw material support.

References

Abdullakasim, P., Songchitsomboon, S., Techagumpuch, M., Balee, N., Swatsitang, P., & Sungpuag, P. (2007). Antioxidant capacity, total phenolics and sugar content of selected Thai health beverages. *International Journal of Food Sciences & Nutrition, 58*, 77–85. https://doi.org/10.1080/09637480601140946

Agirman, B. (2014). *Reduction of sodium chloride content by using different chloride salts in Shalgam juice production.* Adana, Turkey: Cukurova University.

Akalin, A. C. (2011). *Determination of antioxidant phenolic compounds in pomegranate wine.* Master thesis Ankara University (in Turkish).

Algarra, M., Fernandes, A., Mateus, N., de Freitas, V., Esteves da Silva, J. C. G., & Casado, J. (2014). Anthocyanin profile and antioxidant capacity of black carrots (*Daucus carota* L. ssp. *sativus* var. *atrorubens* Alef.) from Cuevas Bajas, Spain. *Journal*

of Food Composition and Analysis, 33, 71–76. https://doi.org/10.1016/j.jfca.2013.11.005

Altay, F., Karbancioglu-Güler, F., Daskaya-Dikmen, C., & Heperkan, D. (2013). A review on traditional Turkish fermented non-alcoholic beverages: Microbiota, fermentation process and quality characteristics. *International Journal of Food Microbiology, 167*, 44–56. https://doi.org/10.1016/j.ijfoodmicro.2013.06.016

Altug, T. (1993). *Sensory test techniques*. İzmir: Course Books. Publication (in Turkish).

Amrane, A., & Prigent, Y. (1996). Behaviour of the yeast *Kluyveromyces marxianus* var. *marxianus* during its autolysis. *Antonie Van Leeuwenhoek, 69*(3), 267–272.

Anonymous. (2016). *TSE (Turkish standardization Institute), TS11149 standard of shalgam beverage*. Ankara: TSE.

Aoac. (1990). In K. Helrich (Ed.). *Official methods of analysis of the association of official analytical chemists* (15th ed., Vols. 1 & 2) Arlington, Virginia.

Baiano, A., Terracone, C., Gambacorta, G., & La Notte, E. (2009). Phenolic content and antioxidant activity of primitivo wine: Comparison among winemaking technologies. *Journal of Food Science, 74*(3), C258–C267. https://doi.org/10.1111/j.1750-3841.2009.01101.x

Canbaş, A., & Deryaoğlu, A. (1993). A research on the production technique and composition of Shalgam juice. *Doga-Turkish Journal of Agricultural Forestry, 17*, 119–129.

Chu, Y. F., Sun, J., Wu, X., & Liu, R. H. (2002). Antioxidant and antiproliferative activities of common vegetables. *Journal of Agricultural and Food Chemistry, 50*, 6910–6916. https://doi.org/10.1021/jf020665f

Datta, D., & Uslu, H. (2017). Adsorption of levulinic acid from aqueous solution by Amberlite XAD-4. *Journal of Molecular Liquids, 234*, 330–334. https://doi.org/10.1016/j.molliq.2017.03.084

Ekinci, F. Y., Baser, G. M., Özcan, E., Üstündağ, Ö. G., Korachi, M., Sofu, A., Blumberg, J. B., & Chen, C. Y. O. (2016). Characterization of chemical, biological, and antiproliferative properties of fermented black carrot juice, shalgam. *European Food Research and Technology, 242*, 1355–1368. https://doi.org/10.1007/s00217-016-2639-7

Erten, H., Tanguler, H., & Canbaş, A. (2008). A traditional Turkish lactic acid fermented beverage: Shalgam (Salgam). *Food Reviews International, 24*, 352–359. https://doi.org/10.1080/87559120802089324

Gok, S. (2017). *Determining the qualification properties and suitability to the Turkish food codex of salgam that sold packaged or unpacked in adana province*. Kahramanmaras, Turkey: MSc, Kahramanmaras Sutcu Imam University (in Turkish with an abstract in English).

Gunes, G. (2008). *A study on the determination of the most suitable quantity of black carrot (Daucus carota) for the production of Shalgam*. Adana, Turkey: MSc, Cukurova University.

Hanay, N. (2011). *Effects of different extraction time and temperature on infusion amount of phenolics and alkaloids*. Antalya, Turkey: MSc, Mediterranean University.

Hosseini, S. R. (2017). *The effect of different eksikara grape pomace ratios on the anthocyanin profiles, monomeric anthocyanin content and antioxidant activity of Shalgam juice*. Konya, Turkey: MSc, Selcuk University (in Turkish with an abstract in English).

Jing, P. (2006). *Purple corn anthocyanins: Chemical structure, chemoprotective activity and structure/function relationships*. USA: PhD, Ohio State University.

Justesen, U., Kunthsen, P., & Leth, T. (1997). Quantitative analysis of flavonols, flavones and flavones in fruits, vegetables and beverages by HPLC with photo-diode array and mass spectrometric detection. *Journal of Food Chromatography, A799*, 101–110. https://doi.org/10.1016/S0021-9673(97)01061-3

Kamiloglu, S., Pasli, A. A., Ozcelik, B., Van Camp, J., & Capanoglu, E. (2015). Colour retention, anthocyanin stability and antioxidant capacity in black carrot (*Daucus carota*) jams and marmalades: Effect of processing, storage conditions and in vitro gastrointestinal digestion. *Journal of Functional Foods, 13*, 1–10. https://doi.org/10.1016/j.jff.2014.12.021

Klimczak, I., Małecka, M., Szlachta, M., & Gliszczyńska-Świgło, A. (2007). Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juices. *Journal of Food Composition and Analysis, 20*, 313–322. https://doi.org/10.1016/j.jfca.2006.02.012

Lee, I. H., Hung, Y. H., & Chou, C. C. (2007). Total phenolic and anthocyanin contents, as well as antioxidant activity, of black bean koji fermented by *Aspergillus awamori* under different culture conditions. *Food Chemistry, 104*, 936–942. https://doi.org/10.1016/j.foodchem.2006.12.049

Li, H., Deng, Z., Zhu, H., Hu, C., Liu, R., Young, J. C., & Tsao, R. (2012). Highly pigmented vegetables: Anthocyanin compositions and their role in antioxidant activities. *Food Research International, 46*, 250–259. https://doi.org/10.1016/j.foodres.2011.12.014

Nizamoglu, N. M., & Nas, S. (2010). The phenolic compounds found in vegetables and fruit; their structure and importance. *Electronic Journal of Food Technology, 5*, 20–25 (in Turkish with an abstract in English).

Okcu, G., Ayhan, K., Gunes Altuntas, E., Vural, N., & Poyrazoglu, E. S. (2016). Determination of phenolic acid decarboxylase produced by lactic acid bacteria isolated from shalgam (şalgam) juice using green analytical chemistry method. *Lebensmittel-Wissenschaft und -Technologie- Food Science and Technology, 6*, 615–621. https://doi.org/10.1016/j.lwt.2015.10.072

Rajoriya, R. K., Prasad, B., Mishra, I. M., & Wasewar, K. L. (2007). Adsorption of benzaldehyde on granular activated carbon: Kinetics, equilibrium, and thermodynamic. *Chemical and Biochemical Engineering Quarterly, 21*(3), 219–226.

Ribéreau-Gayon, P., Glories, Y., Maujean, A., & Dubourdieu, D. (2006). *Handbook of Enology Volume 2 the chemistry of of wine stabilisation and treatments*. Chichester, England: John Wiley and Sons, Ltd.

Steed, L. E., & Truong, V. D. (2008). Anthocyanin content, antioxidant activity, and selected physical properties of flowable purple-fleshed sweetpotato purees. *Journal of Food Science, 73*, S215–S221. https://doi.org/10.1111/j.1750-3841.2008.00774.x

Tanguler, H. (2010). *Identification of predominant lactic acid bacteria isolated from Shalgam beverage and improvement of its production technique*. PhD. Adana, Turkey: Cukurova University (in Turkish with an abstract in English).

Tanguler, H., & Erten, H. (2012a). Chemical and microbiological characteristics of shalgam (salgam): A traditional Turkish lactic acid fermented beverage. *Journal of Food Quality, 35*, 298–306. https://doi.org/10.1111/j.1745-4557.2012.00447.x

Tanguler, H., & Erten, H. (2012b). Occurrence and growth of lactic acid bacteria species during the fermentation of shalgam (salgam), a traditional Turkish fermented beverage. *LWT-Food Science and Technology, 46*, 36–41. https://doi.org/10.1016/j.lwt.2011.10.026

Tanguler, H., Saris, P. E. J., & Erten, H. (2015). Microbial, chemical and sensory properties of shalgams made using different production methods. *Journal of the Science of Food and Agriculture, 95*, 10–1015. https://doi.org/10.1002/jsfa.6781

Tanguler, H., Selli, S., Sen, K., Cabaroglu, T., & Erten, H. (2017). Aroma composition of shalgam: A traditional Turkish lactic acid fermented beverage. *Journal of Food Science & Technology, 54*. https://doi.org/10.1007/s13197-017-2637-1, 2011–2019.

Tanguler, H., Utus, D., & Erten, H. (2014). Effect of black carrot size usage on the quality of shalgam (salgam): A traditional Turkish lactic acid fermented beverage. *Indian Journal of Traditional Knowledge, 13*, 647–653.

Toktaş, B., Bildik, F., & Özçelik, B. (2018). Effect of fermentation on anthocyanin stability and in vitro bioaccessibility during shalgam (şalgam) beverage production. *Journal of the Science of Food and Agriculture, 98*, 3066–3075. https://doi.org/10.1002/jsfa.8806

Torija, M. J., Rozès, N., Poblet, M., Guillamón, J. M., & Mas, A. (2003). Effects of fermentation temperature on the strain population of *Saccharomyces cerevisiae*. *International Journal of Food Microbiology, 80*, 47–53. https://doi.org/10.1016/S0168-1605(02)00144-7

Turker, N., Aksay, S., Istanbullu, O., & Artuvan, E. (2007). A study on the relation between anthocyanin content and product quality: Shalgam as a model beverage. *Journal of Food Quality, 30*, 953–969. https://doi.org/10.1111/j.1745-4557.2007.00171.x

Türkyilmaz, M., Yemi, O., & Özkan, M. (2012). Clarification and pasteurisation effects on monomeric anthocyanins and percent polymeric colour of black carrot (*Daucus carota* L.) juice. *Food Chemistry, 134*, 1052–1058. https://doi.org/10.1016/j.foodchem.2012.03.013

Wang, S. Y., & Stretch, A. W. (2001). Antioxidant capacity in cranberry is influenced by cultivar and storage temperature. *Journal of Agricultural and Food Chemistry, 49*, 969–974. https://doi.org/10.1021/jf001206m

Wasnin, R. M., Karim, M. S. A., & Ghazali, H. M. (2014). Effect of temperature-controlled fermentation on physico-chemical properties and lactic acid bacterial count of durian (*Durio zibethinus* Murr.) pulp. *Journal of Food Science & Technology, 51*, 2977–2989. https://doi.org/10.1007/s13197-012-0869-7

Zhishen, J., Mengcheng, T., & Jianming, W. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chemistry, 64*, 555–559. https://doi.org/10.1016/S0308-8146(98)00102-2