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Research Article

Characterization of Volatile Compounds of Bulgur (Antep Type) Produced from Durum Wheat

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Bulgur is enjoyed and rediscovered by many people as a stable food because of its color, flavor, aroma, texture, and nutritional and economical values. There is more than one type of bulgur overall the world according to production techniques and raw materials. The volatile compounds of bulgur have not been explored yet. In this study, Headspace Solid Phase Microextraction (HS-SPME) and Gas Chromatography–Mass Spectroscopy (GS-MS) methods were used to determine the volatile flavor compounds of bulgur (Antep type, produced from Durum wheat). Approaching studies were used and the results were optimized to determine the ideal conditions for the extraction and distinguish the compounds responsible for the flavor of bulgur. Approximately, 47 and 37 important volatile compounds were determined for Durum wheat and bulgur, respectively. The study showed that there was a great diversity of volatiles in bulgur produced using Durum wheat and Antep type production method. These can lead to a better understanding of the combination of compounds that give a unique flavor with more researches.

1. Introduction

Bulgur is a cleaned, cooked, dried, tempered, debranned, milled, optionally polished, and finally size-classified. Bulgur is a national food in most of the Middle East countries. Today, it is an international delicious wheat product (USA, Europe, Australia, Japan, China, and Russia). Recently, the scientific studies related to bulgur have been increasing. Additionally, its production and consumption are increased due to its low cost, long shelf life, ease of preparation, taste, and high nutritional and economic values.

Bulgur production technique is specified and shortly described as "bulguration" [1]. In bulguration, the combination of cooking and drying operations affects the important properties of wheat, and this combination (cooking + drying) is unique in food processing.

General composition of bulgur is 9–13% water, 10–16% protein, 1.2–1.5% fat, 76–78% carbohydrate, 1.2–1.4% ash, and 1.1–1.3% fiber. Protein, calcium, iron, vitamin B1, and niacin contents of bulgur are higher than other cereal products like bread and pasta. Many nutrients leach out of wheat, but nutrients are absorbed back into the grain during the cooking operation. Losses of nutrients that are soluble in water like vitamins are prevented. Bulgur digestibility increases due to the coagulation of protein and gelatinization of starch. The excess nitrogenous substances are caused by the hard structure of starch fused with protein. This is a desirable feature in bulgur because of its resistance to insect, mites, and microorganisms and long shelf life [2, 3]. Additionally, bulgur is a natural food because there are no uses of chemicals or additives during processing.

Recently, the bulgur industry has changed overall the world. According to the report published by the International Grain Council [4], the production amount is around 1 million tons. As mentioned in the report, the bulgur production of Turkey, which was 722 thousand tons in 1984, was increased to 856,000 tons in 1992. It is estimated that bulgur industry in Turkey has developed rapidly and has obtained the production of 1 million tons in the last 10 years. According to the data of the Turkish Grain Board, there are 99 big bulgur factories in Turkey by 2014. While installed capacity of these factories is around 1,595,421 tons/year, the actual capacity is about 900,544 tons/year. The numbers of bulgur plants were around 500, 30–40 years ago. Today, the number decreased to around 100, but the bulgur production capacity of each plant is increased dramatically.

Aroma compounds stimulate much more qualities and therefore are mainly responsible for the characteristic flavor of foods. These substances are one of the most significant factors, which shape the quality and affect consumer behaviors [5]. Aroma and flavor characteristics of various cereals such as corn, rye, triticale, wheat, roasted barley, malted barley, or rice were investigated, based on volatile compounds, composition standpoint, that mainly use laborious and expensive solvent extraction techniques [6]. The solvent-free, fast, and inexpensive method is called Solid Phase Microextraction (SPME) method, which is based on the absorption of volatile compounds onto a coated fused silica fiber. SPME offers the possibility of detecting compounds at the utterance level. As most cereal grains are characterized by a very low concentration of flavor. SPME has opened up new avenues allowing interested researchers to study cereal flavor. The SPME method for headspace analysis of volatile compounds was successfully applied for the identification of volatiles in processed oats [7], distiller's grains [8], and bread crumbs [9].

Overall the world, there are two bulgur production techniques such as Antep and Karaman (Mut), industrially [10]. Additionally, village and sun-dried type bulgur are available. Antep type bulgur is geographically indicated (certificated) by Gaziantep Commodity Exchange in 2017 via Turkish Patent Institute to protect its taste, technique, and specification.

There are a lot of unproved stories (urban legend) about bulgur taste and flavors depending on the production methods and raw materials. Traditional consumers prefer sun-dried bulgur. Some consumers prefer Antep bulgur due to its taste. Some consumers prefer Karaman (Mut) bulgur due to its color. All consumers have different comments about bulgur taste and flavor. New bulgur plant investors are confused regarding the best production method and raw material. Additionally, producers, academia, consumers, and quality controllers do not know the differences between both bulgur based on flavor and raw material. Therefore, this study focused on this issue to clarify the taste and flavor of bulgur depending on the raw material and production technique. In the literature, there is no information about volatile flavor compounds that deal with the flavor of Durum wheat and bulgur. The objective of this study is to identify and quantify the volatile flavor compounds of Antep type bulgur by using SPME/GC-MS as a new adapted method.

2. Materials and Methods

2.1. Bulgur Production. In general, different wheat varieties are used during the commercial bulgur production. Additionally, each plant uses different processing parameters in its equipment (different motor powers, different water properties, different water ratios, etc.). These differences in the parameters and varieties would cause the significant fluctuation in the results. In order to prevent uncontrollable error in the results and to obtain standard bulgur for the analysis in the study, the samples were produced in laboratory by using commercial Antep type bulgur production technique. Also, in order to follow the changes in the volatile flavor compounds starting from raw material (wheat) to the finished product (bulgur), the samples were produced in the laboratory.

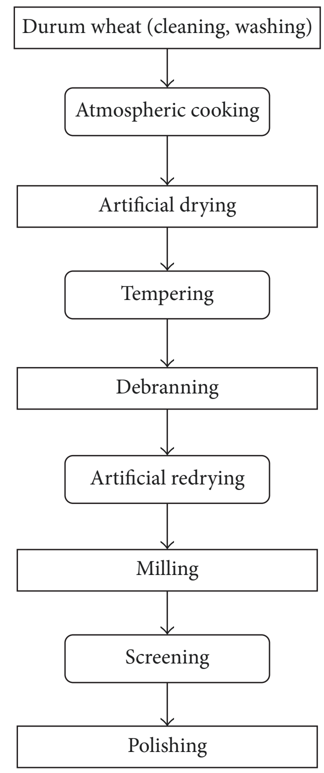

Figure 1: Production flow chart of Antep type bulgur.

In the study, Durum wheat *(Zivego)* was obtained from Simaş bulgur factory (Gaziantep, Turkey) and stored at 8°C in a dark place. Bulgur was produced using Antep method, which is shown in Figure 1. In commercial Antep type production method, Durum wheat is generally used and it is firstly cleaned. Then, it is washed before cooking very rapidly. Cooking is made under atmospheric conditions until all starch is gelatinized. After cooking, drying is made and then short tempering (15–30 mins) by adding water, debranning (by using emery type debranner), and milling are made. Then, polishing is optionally made. As final stage, size classification is made.

In this study, according to Antep bulgur production method explained above, the cleaned Durum wheat was rapidly washed. Then, atmospheric cooking was made to cook wheat. After that, an artificial dryer (MK II, Sherwood Scientific, UK) was used to dry product. After the drying operation, tempering, debranning, redrying, milling, screening, and polishing were made (Figure 1). The details of each stage were explained as follows.

2.1.1. Cleaning and Washing of Wheat. Raw material (Durum wheat) was screened by using 3.2 mm screen to separate the small and foreign materials. Then, wheat was aspirated to separate dust and light foreign particles by using an aspiration system (Merba Co., Mersin, Turkey). After that, the samples were stored in a refrigerator at 8°C for further experiments. Before each experiment, the sample was rapidly washed with distilled water for 30 sec to remove dust and foreign materials from the surface of wheat kernels.

2.1.2. Atmospheric Cooking. According to Antep production method (Figure 1) distilled water was boiled (96°C, according to the altitude of laboratory that made the experiment), and then wheat was added to the boiling water. The cooking operation was continued until all found starch in wheat gelatinized. The gelatinization and cooking time were determined by using the method explained by Bayram [2]. The wheat kernels during cooking were collected and cut periodically by a blade to control the center of wheat kernel. When all starch in the endosperm of wheat kernel seems translucent (as the loss of opaqueness), this appearance shows gelatinized starch, and the cooking was stopped. The cooking time was determined as nearly 50 min and this cooking time was used during the experiments.

During cooking, the ratio of wheat to water was 1/1.75. After cooking, the moisture content of wheat was 54.48% (d.b.). Traditionally, the cooked wheat is called "hedik."

2.1.3. Drying. After the cooking operation, the cooked samples were dried as soon as possible. Drying was made by using a packed bed dryer (MK II, Sherwood Scientific, UK). Drying air temperature and velocity were 40°C and 2.5 m/s, respectively. Drying column diameter was 150 mm. Drying was continued until the moisture content reached 12% (d.b.). Traditionally, the dried and cooked wheat is called "diri bulgur."

2.1.4. Tempering. The main difference of the production method of Antep bulgur from the other technique is short (15 mins) and low moisture (17%, d.b.) tempering operation. Before the debranning operation, the moisture content of cooked and dried wheat was increased by tempering to 17% (d.b.) to help the removing bran from the surface of wheat kernel. A hand spray pump was used to obtain homogenous distribution of distilled water on the surface of the wheat kernels. During spraying, the wheat kernels were mixed. After the tempering [11], the samples were left for 15 min (tempering time).

2.1.5. Debranning. In order to partially remove the bran of tempered wheat, a modified vertical emery type debranner (Lab. Scale, Merba Co., Mersin, Turkey) was used [12, 13].

2.1.6. Redrying. After the debranning operation, the moisture content was decreased to 14% (d.b.) by using a packed bed dryer (MK II, Sherwood Scientific, UK) at 40°C.

2.1.7. Milling. The debranned and redried samples were milled by using a disc mill (Model 4E, Quaker City Mill, Philadelphia, USA) at 178 ± 2 rpm.

2.1.8. Screening. After the milling operation, the different particle sizes of bulgur were classified using 2.8, 1.60, and 1.0 mm screens (ASTM E11, Aramtest Trade Co. Ltd., Turkey). The sample obtained from the screens between 2.8 and 1.0 mm were used for further analysis.

2.1.9. Polishing. As an optional operation in the production method of Antep bulgur, a polishing step is recently started to be used in industry to obtain polish and yellow bulgur. In this study, as a parallel to industrial application, the polishing operation was used.

According to Balci and Bayram [11], a mechanical polishing system was used (Lab. Scale Mechanical/Kneading/polisher, Biltek Eng., Gaziantep/Turkey). Before polishing, a small amount of distilled water was added to obtain 17% (d.b.) moisture to supply gentle polishing on the surface of the kernels.

After all operations, the product was called Antep bulgur. The moisture content of bulgur was around 12% (d.b.). The bulgur samples were stored in a refrigerator at 8 ± 1°C for the analysis.

2.2. Physical and Chemical Analysis of Raw Material (Durum Wheat) and Bulgur. Wheat and bulgur samples were analyzed in triplicate for moisture (Method 44-19-10.) [14], protein (Method 46-12.01) [15], and ash (Method 08-01) [16] contents using approved standard methods [3]. The color of wheat and bulgur samples was determined by measuring the CIE L^* (100: white; 0: black), a^* (+: red; −: green), b^* (+: yellow; −: blue), and YI (Yellowness Index) values at D65/10 by using HunterLab, ColorFlex (Model No. 45/0, USA).

Starch (Ewers method) [17] and fat contents (30-25.01) [18] of Durum wheat were measured. pH's were measured by using a pH meter (Jenway, 3010, UK) at 20°C [17]. Wet gluten (d.b., %) (Method 38-12.02) [19], dry gluten (d.b., %) (Method 38-12.02) [19], gluten index (Method 38-12.02) [19], sedimentation (cm), delayed sedimentation (cm) (Method 56-62.01) [20], falling number (FN, sec), fungal falling number (FFN, sec) [21], and Alveoconsistograph values [22] of Durum wheat were measured.

All chemicals used in the experiments were bought from Sigma-Aldrich (Sigma Co. Steinheim, Germany).

2.2.1. Extraction of the Volatile Compounds. Solid Phase Microextraction (SPME) (Model 57330-U, Supelco, USA) apparatus was used for extraction of volatile compounds by Divinylbenzene-Carboxen-Polydimethylsiloxane (DVP/CAR-PDMS) (GRAY) (Model 57328-U, Supelco, USA) fiber with 50/30 μm thickness from Supelco (Bellefonte, USA), as absorbent. This method was used to extract volatile compounds of another cereals by some researchers [23, 24]. The fiber was conditioned before use and thermally cleaned after each analysis at 250°C at the injector port of Gas Chromatography.

For the extraction of volatile compounds, the bulgur sample (6 g) was ground and placed in a 30-ml vial. Then, the vial was sealed with a silicon septum and the needle of SPME device (Supelco, Bellefonte, USA) was inserted into the vial. The vial was placed in a water bath and the fiber was pushed out of the hosting to absorb volatile compounds from the headspace of the vial. The best combination of heat and time for the extraction of volatile compounds in bulgur was determined as the temperature of 70°C for 120 min by preexperiments and trials. Two hours later, the fiber was pulled into needle housing again and SPME was removed from the vial. After that SPME device was inserted into GC-MS injection port, and the fiber was taken out of the needle housing and left for 5 min at 250°C for thermal desorption [25].

2.2.2. GC-MS Analysis for Volatile Compounds. Gas Chromatography–Mass Spectroscopy (GC-MS) (Perkin Elmer-Clarus 500 Model, USA) was used for the analyses. The separation of volatile compounds was carried out in Supelcowax 10 capillary column (30 m length × 0.25 ID × 0.25 μm film thickness) (N316551, Perkin Elmer, USA). Carrier gas was helium with a flow rate of 1.5 ml/min. The oven temperature was programmed in the beginning with 40°C, held for 4 min at that temperature, then increased to 90°C with a rate of 3°C/min, then increased to 130°C with a rate of 4°C/min, held for 4 min at that temperature, finally increased to 240°C with a rate of 5°C/min, and held for 8 min at that temperature. The injection port was operated in the splitless mode at 250°C. The electron energy of MS was 70 eV and operated in EI^+ mode. The source temperature was 180°C with mass range from 30 to 350°C. Wiley and NIST/EPA/NIH libraries (May 2005, Perkin Elmer, USA) were used for the identification of peaks. After the identification, the concentrations of volatile compounds were calculated as percentage.

2.3. Statistical Analysis. The results were analyzed by using one-way ANOVA at $p \leq 0.05$ significant level. Standard deviations were calculated. Multiple Range Test (Duncan) was carried out to determine difference and homogenous group by using SPSS Statistical Software (version 20) (IBM Co., Chicago, Illinois, United States). The experiments were triplicated.

3. Results and Discussion

3.1. Physical and Chemical Analysis of Raw Material (Durum Wheat) and Bulgur. The moisture, ash, and protein contents as well as L^*, a^*, b^*, and YI values of Durum wheat and Antep bulgur are given in Table 1.

The moisture, ash, and protein contents of wheat as average values were found to be 6.13, 1.39, and 12.32 (%, d.b.), respectively. The average values of the color values (L^*, a^*, b^* and YI) of Durum wheat were determined as 52.70, 7.88, 23.39, and 69.61, respectively. The other properties of Durum wheat (starch content, fat content, pH, wet gluten, dry gluten, gluten index, sedimentation (cm), delayed sedimentation, falling number, fungal falling number, Alveoconsistograph resistance, and elasticity values) were measured to specify the most important properties of Durum wheat (Table 2).

According to the results (Table 1), the overall average of moisture content of bulgur increased to double due to the cooking operation. According to the Bulgur Codex [26],

Table 1: Physical and chemical properties of Durum wheat and bulgur.

Properties	Samples	
	Durum wheat	Bulgur
m.c.% (d.b.)	6.13 ± 0.20	12.99 ± 0.11
Ash content, % (d.b.)	1.39 ± 0.16	1.20 ± 0.06
Protein content, % (d.b.)	12.32 ± 0.21	11.97 ± 0.77
L^*	52.70 ± 1.15	61.09 ± 1.47
a^*	7.88 ± 1.24	6.61 ± 0.28
b^*	23.39 ± 1.42	29.61 ± 0.43
YI	69.61 ± 3.45	72.06 ± 1.13

d.b.: dry base.

the obtained experimental results are suitable. The ash contents of Durum wheat and bulgur were found as 1.39 and 1.20, respectively. The ash content of bulgur is related to bran content, which is generally affected by the debranning, milling, and polishing operations.

The protein content of bulgur is related to protein content of raw material and processing yield. The protein content of bulgur reduced by about 0.5 point due to the leaching of protein into water during cooking. It is an important result that shows the protein loss occurs during cooking. In the study, the protein content of Antep bulgur was between 11.92 and 12.01% (d.b.), which is similar to the study of Toufeili et al. [27]. In addition, Singh et al. [28] found significantly ($p \leq 0.05$) different protein contents for different wheat varieties.

L^*, a^*, b^*, and YI values of bulgur were determined as 59.94–62.10, 6.57–6.85, 29.70–30.10, and 71.51–77.78, respectively. The color values are similar to the results of the study of Balci [29].

3.2. Volatile Compounds of Durum Wheat and Antep Bulgur. As a result of the increase in the consumer' demands for bulgur, the volatile compounds started to gain importance. The most important characteristics of bulgur that are of interest to consumers are flavor and color.

There is no study about volatile flavor compounds of bulgur. In this study, the method used is simple, easy, rapid, and economic does not use excess amount of chemical (no solvent). Volatile flavor compounds found in Durum wheat are also not available in the literature. Therefore, this study additionally presents the information about the compositions of the volatile flavor compounds of Durum wheat by using this new simple method.

Typical GC-MS Chromatograms of Durum wheat and Antep bulgur are given in Figures 2 and 3, respectively. The detected volatile flavor compositions of Durum wheat and Antep type bulgur are given in Table 3. The molecular weight (g/mol) and retention time (min) for each component were determined. Table 3 indicates that there is more than one compound that can be responsible for the flavor of Durum wheat and Antep bulgur. The results are expressed as the mean of GC-MS analysis of triplicated experiments.

Table 2: Properties of raw material (Durum wheat).

Properties	Unit	Values
Starch content (d.b.)	g/100 g	44.882
Fat content (d.b.)	g/100 g	1.404
pH		6.79
Wet gluten (d.b., %)	g/100 g	32
Dry gluten (d.b., %)	g/100 g	11.2
Gluten index	g/100 g	62
Sedimentation	cm	13
Delayed sedimentation	cm	20
Falling number (Fn)	sec	400
Fungal falling number (Ffn)	sec	99
Alveoconsistograph values*		
T	mm H_2O	99
A	mm	70
Ex		18.6
Fb	$(10E-4\,J)$	213
T/A		1.42
Iec	%	41.9
Fb (40)	$(10E-4\,J)$	156
HYD2200	(% b 15)	55.3

*The moisture contents of the samples were adjusted to 16.5% for the experiments.

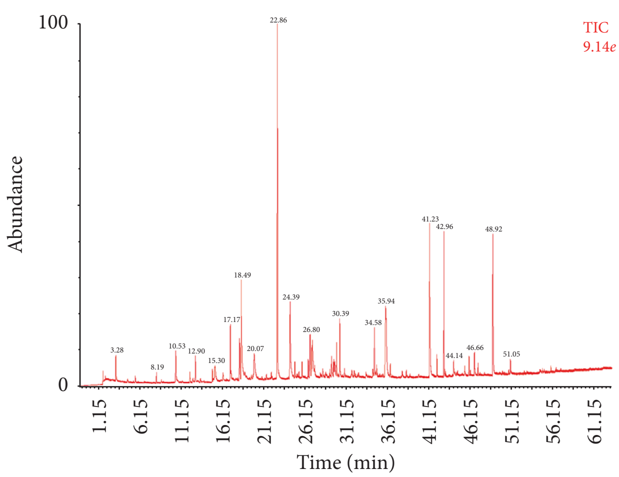

Figure 2: A typical GC-MS Chromatogram obtained from Durum wheat.

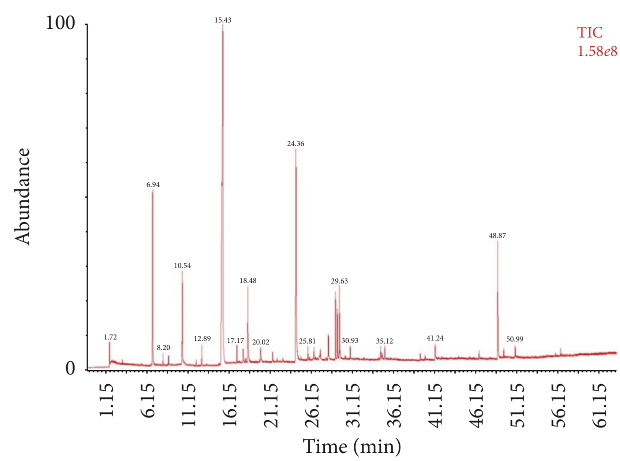

Figure 3: A typical GC-MS Chromatogram obtained from bulgur.

Approximately, 47 volatile components were detected in Durum wheat. 1-Hexanol, styrene, hexanoic acid, heptadecane, and dodecane were found to have the highest concentrations at a rate of 17.82, 7.06, 5.96, 5.83, and 5.72%, respectively. Relative to the other compounds detected, this might be one of the reasons that supply the sweet floral taste mixed with the flavor of grass, which could be felt while eating cooked wheat. In addition, these volatile flavor compounds are critical and important for the formation of flavors of pasta, spaghetti, Durum bread, semolina, sweets, couscous, and related Durum wheat products. The results can also be used for the studies related to these products.

Thirty-seven volatile flavor compounds for bulgur were detected (Table 3). The compounds such as dodecane, nonanal, styrene, decane, and nonanoic acid had the highest concentrations: 32.81, 13.74, 7.20, 6.44, and 4.86%, respectively. Relative to the other compounds detected, this might be one of the reasons that supported sweetie rose, orange, and floral taste mixed with the aroma of fatty grass, which could be felt while eating Antep bulgur.

When volatile compounds found in Durum wheat and Antep bulgur (Table 3) were compared, a lot of differences were found between the results. There were 16 volatile compounds missing from Durum wheat during processing to produce bulgur. These lost compounds were acetic

Table 3: Volatile flavor compounds of Durum wheat and Antep type bulgur.

RT (min)	Compounds	MW (g/mol)	Average percent ratio (%)		Odor*
			Wheat	Bulgur	
	Carboxylic acids				
27.27	Acetic acid	60	2.90 ± 0.14	n.a.	Vinegar
41.23	Hexanoic acid	116	5.96 ± 1.52	1.84 ± 1.03	Unpleasant
46.65	Octanoic acid	144	0.83 ± 0.15	0.49 ± 0.17	Fruity acid
48.92	Nonanoic acid	158	4.88 ± 1.3	4.86 ± 0.81	Fatty
51.04	Decanoic acid	172	0.59 ± 0.14	0.98 ± 0.5	Rancid
54.85	Benzoic acid	122	n.a.	1.51 ± 0.31	Odorless
	Aldehydes				
10.55	Hexanal	100	2.36 ± 0.79	4.49 ± 0.8	Grassy
21.52	2-Heptenal	112	n.a.	0.60 ± 0.12	Pungent green vegetable fresh fatty
24.39	Nonanal	142	1.52 ± 1.21	13.47 ± 2.37	Rose-orange
25.83	Octanal	128	1.42 ± 0.56	0.76 ± 0.33	Fruity
27.32	Furfural	96	n.a.	0.98 ± 0.14	Almond-like
28.29	Decanal	156	n.a.	2.32 ± 0.58	Pleasant
29.39	Benzaldehyde	106	0.79 ± 0.18	2.31 ± 0.28	Bitter almond
29.65	2-Nonenal	140	0.66 ± 0.24	2.71 ± 0.89	Rose-orange
34.56	1-Nonenal	144	2.68 ± 0.76	n.a.	Rose-orange
34.83	2-Octenal	182	0.65 ± 0.33	0.92 ± 0.60	Fatty green herbal
56.58	Vanillin	152	0.10 ± 0.05	0.34 ± 0.03	Pleasant aromatic, vanilla
	Alcohols				
12.28	Ethylbenzene	106	0.48 ± 0.11	0.21 ± 0.07	Pungent
16.28	1-Butanol	146	0.70 ± 0.49	n.a.	Mildly alcoholic odor
18.27	Pentanol	88	2.38 ± 0.07	0.25 ± 0.19	Mild to moderately strong
22.84	Hexanol	102	17.82 ± 1.26	0.46 ± 0.39	Sweet alcohol, pleasant
26.57	1-Octen-3-ol	128	1.11 ± 0.49	0.69 ± 0.23	Alcohols
28.32	4-Ethylcyclohexanol	128	1.07 ± 0.42	n.a.	Magnolia muguet floral lily
30.39	1-Octanol	130	2.35 ± 0.28	0.26 ± 0.13	Fresh orange rose
42.11	Benzene methanol	108	0.66 ± 0.16	0.38 ± 0.05	Almond-like
	Phenols				
42.95	2,6-Bis(1,1-dimethylethyl)-4-methyl phenol	220	3.47 ± 1.58	n.a.	Phenolic
45.48	Phenol	94	0.63 ± 0.09	0.66 ± 0.05	Sweet, tarry
49.62	2-Methoxy-4-vinylphenol	150	n.a.	0.34 ± 0.07	Dry woody
	Esters				
27.00	2-Pentyl ester	184	2.14 ± 1.04	n.a.	Weak odor of bananas
	Furans				
17.18	2-Pentyl furan	138	2.80 ± 0.64	0.75 ± 0.12	Ethereal
	Hydrocarbons				
6.94	Decane	142	n.a.	6.44 ± 2.88	
8.23	Chloroform	118	0.38 ± 0.04	0.25 ± 0.16	Pleasant
8.82	4-Methylcyclopentene	92	0.45 ± 0.27	n.a.	Hydrocarbon odor
12.94	O-xylene	106	1.28 ± 0.23	0.50 ± 0.33	Sweet
14.97	Benzene	106	0.51 ± 0.05	n.a.	Gasoline-like
15.43	Dodecane	170	5.72 ± 2.28	32.81 ± 0.65	Mild aliphatic hydrocarbon
17.92	Heptacosane	380	n.a.	1.18 ± 0.01	
18.50	Styrene	104	7.06 ± 1.04	7.20 ± 1.42	Sweet, floral
19.70	Hexadecane	282	1.81 ± 0.97	1.19 ± 0.19	Odorless
20.07	Heptadecane	296	5.83 ± 2.78	n.a.	Fuel-like
26.78	1-Octene	112	3.45 ± 0.99	n.a.	Gasoline

Table 3: Continued.

RT (min)	Compounds	MW (g/mol)	Average percent ratio (%)		Odor*
			Wheat	Bulgur	
	Ketones				
3.32	Propanone	58	1.22 ± 0.48	2.37 ± 0.48	Sweetish
4.72	2-Butanone	72	0.20 ± 0.08	n.a.	Acetone-like
22.12	6-Methyl-5-hepten-2-one	126	0.62 ± 0.48	0.27 ± 0.16	Powerful, fatty, green
24.96	3-Octen-2-one	126	0.76 ± 0.13	n.a.	Earthy
29.17	3,5-Octadien-2-one	124	0.76 ± 0.15	4.34 ± 1.62	Fatty fruity hay, green herbal
34.39	Acetophenone	120	0.55 ± 0.1	n.a.	Sweet pungent
	Lactone				
47.09	2(3H)-Furanone	154	0.8 ± 0.13	0.13 ± 0.09	Strong of coconut
	Terpene				
29.99	Beta-linalool	154	0.73 ± 0.35	n.a.	Bergamot oil and French lavender
	Phthalic anhydride				
55.88	Isobutyl phthalate	278	n.a.	0.31 ± 0.12	Odorless
	Alkanes				
5.65	Methane	45	0.38 ± 0.23	n.a.	n.a.
13.50	Cyclopropane	84	0.22 ± 0.18	n.a.	n.a.
	Other				
8.88	Unknown		n.a.	0.45 ± 0.07	Odorless
31.84	Unknown		0.54 ± 0.20	n.a.	n.a.
35.91	Unknown		5.95 ± 3.36	n.a.	n.a.
44.13	Unknown		0.77 ± 0.20	n.a.	n.a.

RT: retention time, MW: molecular weight. *Odor classification was obtained from PubChem (2017).

acid, 1-nonenal, 1-butanol, 4-ethylcyclohexanol, 2,6-bis(1,1-dimethylethyl)-4-methyl phenol, 2-pentyl ester, 4-methyl-cyclopentene, benzene, heptadecane, 1-octene, 2-butanone, 3-octen-2-one, acetophenone, beta-linalool, methane, and cyclopropane. However, there were new compounds formed in bulgur such as benzoic acid, 2-heptenal, furfural, decanal, 2-methoxy-4-vinylphenol, decane, heptacosane, and isobutyl phthalate. The change in volatile flavor compounds and the generation of new compounds can especially occur due to the cooking and drying operations, which are basic thermal processes found in the bulgur production (bulguration effect). Additionally, debranning and polishing can affect the composition due to the removal of some parts of wheat. Because of the availability of water and high temperatures, which lead to the change in the chemical structure of the components easily as a result of breaking the weak bonds between the elements of single compound during cooking and drying or because of the removal the bran of Durum wheat during the debranning and polishing processes, some chemical compounds that most of the flavor components present in bran disappear.

The high concentrations of dodecane, nonanal, and styrene compounds in bulgur cause the distinct flavor formation. The major flavor for Antep bulgur can be considered as a mix of woody, sweaty, floral, and rose-orange flavors. These chemical compounds were not available during the analysis of fermented wheat extracted germ as pointed out by Yusuf and Bewaji [30]. However, dodecane was previously identified as a volatile component of peanut oil, Beaufort cheese, fried bacon, roasted filberts, chickpea seed, mutton, chicken, beef volatiles, fried chicken, and kiwi fruit flowers [31].

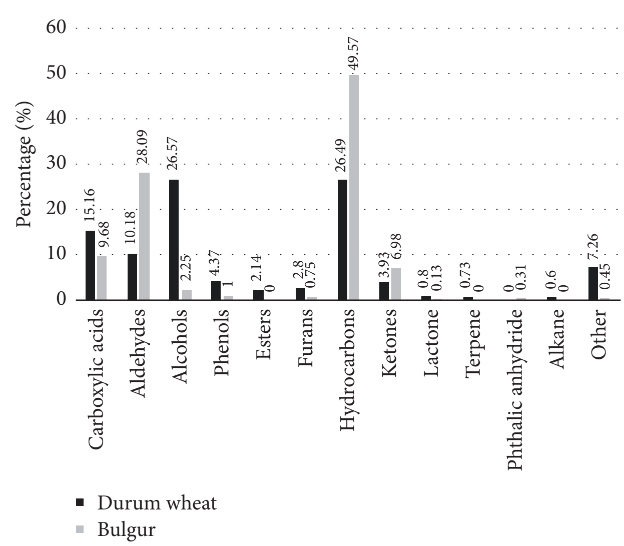

Figure 4: Change in total volatile flavor compound groups during the bulgur production.

Figure 4 allows us to better understand the magnitude of the change in volatile flavor compound groups (combined volatile flavor compounds) during the production of bulgur. There are important decreases in the concentrations of alcohol, carboxylic acids, and phenols. Moreover, aldehydes and hydrocarbons increase during the production of bulgur.

4. Conclusions

This is the first study to identify volatile compounds of Durum wheat and Antep bulgur. A total of 47 and 37 volatile compounds were observed in the Durum wheat and Antep bulgur, respectively. Among these compounds, carboxylic acid, alcohols, and aldehydes were found to be the main types of volatile components. Dodecane predominated in Antep bulgur, while in Durum wheat the most abundant compound was 1-hexanol. As mentioned, overall the world, there are different production methods, for example, Antep type, Karaman (Mut) type, village type, and sun-dried type. This study gives the information about the flavor of Antep type bulgur and will also lead to new studies about this topic for different bulgur types.

Additional Points

Highlights. (i) A modified SPME/GC-MS technique was developed to analyze volatile flavor compounds in the cereal products. (ii) Unit operations change the flavor of bulgur. (iii) This study shows that about 47 important volatile flavor components are available in Durum wheat. (iv) This study shows that about 37 important volatile flavor components are available in Antep type bulgur.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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