Quality Assurance and Safety of Crops & Foods, 2019; 11 (5): 421-429

Wageningen Academic Publishers

Effect of different raw materials on aroma fingerprints of 'boza' using an e-nose and sensory analysis

K. Kemahlıoğlu[1*], P. Kendirci[2], P. Kadiroğlu[3], U. Yücel[1] and F. Korel[4]

[1]Ege University, Ege Vocational School, Food Technology Department, Bornova, İzmir, Turkey; [2]İzmir Katip Çelebi University, Gastronomy and Culinary Arts Department, Çiğli, İzmir, Turkey; [3]Adana Science and Technology University, Food Engineering Department, Sarıçam, Adana, Turkey; [4]İzmir Institute of Technology, Food Engineering Department, Urla, İzmir, Turkey; omer.kemal.kemahlioglu@ege.edu.tr

Received: 3 March 2019 / Accepted: 22 April 2019

RESEARCH ARTICLE

Abstract

Boza is a Turkish traditional beverage produced by fermentation of maize, rice, wheat, millet, cracked wheat, and durum clear flour. The aim of this study was to determine the effect of different raw material combinations on the aroma fingerprints of boza samples using an electronic nose equipped with surface acoustic wave detector in combination with sensory analysis. According to flavour profile analysis of boza samples, significant differences were obtained among the samples. Hierarchical clustering analysis of e-nose and sensory analyses indicated that boza samples were clustered based on their aroma profiles, odour and taste properties revealing the effect of different cereals as raw materials. Rheological analysis showed that all boza samples exhibited pseudoplastic flow behaviour as the apparent viscosity decreased with increasing shear rate. This revealed that differences in raw materials did not change flow behaviour of boza samples. The results indicated that e-nose could be used as a fast and non-destructive method to assess the influence of raw material formulation on aroma profiles of boza samples in correlation with sensory analysis.

Keywords: e-nose, boza, cereals, flavour profile analysis, rheology

1. Introduction

Boza is one of the most known traditional fermented non-alcoholic beverages. It is produced from maize, millet, rice, semolina, wheat flour by yeast and/or lactic acid bacteria fermentation. Sweet-sour taste and pale yellow colour is the main characteristic of boza. The chemical composition and sensory properties are affected by the amount and types of raw materials (Akpinar-Bayizit *et al.*, 2010; Altay *et al.*, 2013; Gotcheva *et al.*, 2001). Yeast and lactic acid fermentation also have influence on digestibility and nutritional value beside sensory quality of boza (Steinkraus, 1994).

The type and amount of the raw materials, microflora, fermentation, and storage conditions affect the sensory properties of boza (Zorba *et al.*, 2003). Millet is the mostly preferred boza related to its organoleptic properties (Coskun and Cakır, 2014). Akpinar-Bayizit *et al.* (2010) investigated the effect of using rice, maize, millet, and wheat flours on total titratable acidity, pH, alcohol and organic acid profiles, and sensory properties of boza. Sensory evaluation of boza samples showed that maize boza got the highest score from the trained panellists related to the similar flavour and colour properties of boza purchased from a market. The effect of different starter culture combinations on sensory properties of boza produced from maize, rice, and wheat was investigated in another study (Zorba *et al.*, 2003). *Saccharomyces cerevisiae* in combination with *Leuconostoc mesenteroides* subsp. *mesenteroides* and *Lactobacillus confusus* were mostly preferred by the panellists according to odour, taste, and general appearance properties of boza.

Electronic nose (e-nose) is an instrument equipped with electronic chemical sensors and the computer system recognising the fingerprints of signals. Several sensors are used commercially in e-noses such as metal oxide semiconductors, metal oxide semiconductor field effect transistors, conducting organic polymers, piezoelectric crystals. E-noses have found application area in various fields of food science focusing on the evaluation of microbiological and chemical quality of food products and detection of adulteration combined with multivariate statistical methods (Korel and Balaban, 2008). In previous studies, it is seen that e-noses were used to determine the quality of many foods such as oils (Kadiroglu and Korel, 2015; Oates *et al.*, 2018; Pacioni *et al.*, 2014), milk (Yang *et al.*, 2015), wine (López de Lerma *et al.*, 2013; Rodriguez-Mendez *et al.*, 2014), tea (Qin *et al.*, 2013), coffee, spice, fish, and meat (Peris and Escuder-Gilabert, 2016). E-noses with other analytical techniques were also performed for prediction of sensorial characteristics of wines by building regression models (Buratti *et al.*, 2007). In recent years, researches on the use of e-nose have been increasing for determination of the effects of storage times on quality characteristics of several fruits (citrus fruits, mango, bayberry, jujube, quince, litchi, etc.) (Chen *et al.*, 2018; Guohua *et al.*, 2015; Jian *et al.*, 2015; Lihuan *et al.*, 2017; Qiu and Wang, 2015; Ying *et al.*, 2015; Zheng *et al.*, 2016) and seafoods (Jiang *et al.*, 2016; Li *et al.*, 2016).

Rheological properties of food products are important for boza quality and affect the preference of consumers (Fischer and Windham, 2011). Genc *et al.* (2002) investigated the relationship between the physicochemical and sensory properties of boza produced with maize, rice, and wheat. The results of this study indicated that boza exhibited pseudoplastic flow behaviour and the consistency coefficient of boza could be used to predict mouth feel and appearance sensory properties. In another study, Arici *et al.* (2014) characterised the boza samples depending on the microbiological and rheological properties. The rheological results showed that the samples had a solid like structure and showed pseudoplastic flow behaviour. It was concluded that the formulation and production steps affected the rheological properties of boza samples.

To the best of our knowledge, no research has been performed to investigate the effect of different combinations of raw materials (cereals) on the sensory properties and aroma profiles of boza using an e-nose. Therefore, the objective of this study is to investigate the effect of different raw material (maize, rice, wheat, millet, cracked wheat and durum clear flour) combinations on aroma profiles of boza samples using a surface acoustic wave (SAW) based e-nose and sensory characteristics using flavour profile analysis (FPA). Determination of rheological properties of boza samples was also proposed in this study.

2. Materials and methods

Materials

The ingredients, maize, rice, wheat, millet, bulgur, and durum clear flours allowed in Boza Standard (Anonymous, 1992) and sugar, used in boza production, were purchased from a local market in İzmir.

Boza production

Boza production was performed by using different combinations of six raw materials according to the modified method of Zorba *et al.* (1999) under laboratory conditions. Different combinations of raw materials (cereals) used in production of eight boza samples are given in Table 1.

Cereals that were used in boza production were diluted at a ratio of 1:6 with water and boiled in steel steam jacketed vessel (FT-40 multifunctional boiler vessel, Armfield Ltd, Ringwood, UK) for approximately two hours according to the type of the raw material mixtures. During boiling as the product condensed, hot water was added to set the ratio of 1:10 (substrate:mixture). Cooling process was also conducted in the same vessel. After cooling, cereal mixture was filtrated and kept at room temperature (20±2 °C) for 12 hours with the addition of 20% sugar. After this period, the mixture was inoculated with 3% of boza purchased from a market and left to fermentation at 28±1 °C to maintain pH of the mixture to 4.00±0.10. Boza samples were cooled immediately and stored at 8±2 °C at refrigerator. Flow chart of boza production under laboratory conditions is given in Figure 1.

Table 1. Raw material combinations used in boza production.

Boza sample codes	Maize flour (g)	Rice flour (g)	Wheat flour (g)	Cracked wheat (g)	Millet (g)	Durum clear flour (g)
A	600	300	300	–	–	–
B	600	300	–	300	–	–
C	400	400	400	–	–	–
D	400	400	–	–	–	400
E	400	300	300	–	200	–
F	200	400	400	–	200	–
G	600	300	–	–	300	–
H	400	400	200	–	200	–

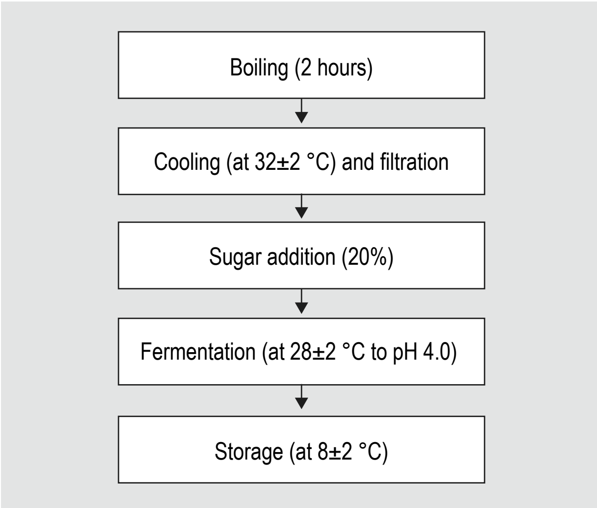

Figure 1. Flow chart of boza production under laboratory conditions.

Electronic nose analysis

Aroma profiles of boza samples produced with different raw materials were analysed with an e-nose (zNose™ 7100 vapour analysis system, Electronic Sensor Technology, Newbury Park, CA, USA) consisted of 1 m DB-5 column and SAW detector. Boza samples (10 g) were put into 20 ml septa-sealed glass vials. Four vials of each boza sample were prepared for e-nose analyses. Samples were allowed to equilibrate with the headspace in the vial at 40 °C for 40 min. Sample's vapour was pumped with a side-ported sampling needle (5 cm) into the e-nose. Aroma compounds were transferred to the column with helium carrier gas at flow rate of 4.0 cm^3/min. The column temperature was programmed from 40 to 180 °C at a rate of 6 °C/sec. The compounds were separated and detected by a SAW detector. The data were collected at every 0.02 seconds according to the deviation from the compound's set frequency change with Microsense software. N-alkane solution (C6-C14) was used to calibrate the system before starting to the analysis and after each sample analysis (Kadiroglu *et al.*, 2011). The average of 4 replicates for each vial was calculated and total of 16 measurements for each boza sample were used for data analysis.

Flavour profile analysis

Sensory evaluation of boza samples was performed four times by using FPA (Altug and Elmaci, 2011) by attendance of eight panellists (4 male and 4 female) from Ege Vocational School of Ege University. The panellists, whose ages were between 30 and 50, were selected according to their sensitivity to major tastes and odours. Training sessions were performed with the reference materials (5 g) added to the boza samples (50 ml) and continued for 2 months (Table 2). Intensity of each characteristics were evaluated by using 0-5 cm unstructured scale. Odour and flavour characteristics were evaluated separately. Panellists evaluated three different samples per session, with two sessions per day and two days per week; between 10:30-11:00 am and 14:30-15:00 pm. Boza samples of 20-25 ml at 15 °C were presented to the panellists in glass beakers.

Colour analysis

Colour analyses were conducted by using Minolta chromometer (CR-400, Minolta Sensing, Osaka, Japan). Calibration of the instrument was checked with white calibration (for illuminant D65, Y=93.8, x=0.3159, y=0.3322). Boza sample of 20 ml was put into the optical glass sample

Table 2. Descriptive terms and reference materials for sensory evaluation of boza samples.

Descriptive terms	References
Wheat	5 g of durum wheat were boiled in 50 ml water for 10 min and 5 g of boiled wheat were added to 50 ml boza sample
Corn	5 g of canned corn were boiled in 50 ml water for 5 min and 5 g of boiled wheat were added to 50 ml boza sample
Flour	5 g of flour were added to 50 ml boza sample
Vinegar	5 ml of grape vinegar were added to 50 ml boza sample
Lemon	5 ml of fresh lemon juice were added to 50 ml boza sample
Yoghurt	5 g of yoghurt were added to 50 ml boza sample
Barm	5 g of barm were boiled in 50 ml water for 10 min and 5 g of barm were added to 50 ml boza sample
Starch	5 g of starch were added to 50 ml boza sample
Bran	5 g of bran were added to 50 ml boza sample
Sweet	sucrose solution (5.76 g/l)
Sour	citric acid solution (0.43 g/l)
Bitter	caffeine solution (0,195 g/l)
Astringent	Ceylon tea (Lipton, Unilever)
Metallic	no reference
Burnt	no reference

cell and CIE L*, a*, and b* values were measured at three different positions. Three readings were taken to measure colour of each sample.

Rheological analysis

Viscosity measurements were performed at 10 °C by using Brookfield concentric cylinder viscometer (Model DV II+Pro, Brookfield Engineering Lab. Inc., MA, Middleborough, USA) equipped with a cylindrical spindle (LV-1). Sample volume enough for 600 ml beaker was used. The data were taken in duplicate and viscosity (Pa.s.) was plotted versus shear rate (1/s)

Data analysis

Hierarchical clustering analysis (HCA) was performed to discriminate boza samples based on their sensory analyses and aroma fingerprints obtained by e-nose using XLSTAT (Version 2012.6.02) package programme. HCA is an algorithmic approach to reveal separate groups with varying degrees of dissimilarity in a data set. The differences between two means of boza samples were investigated by applying analysis of variance (ANOVA) with Duncan's multiple range test at P<0.05 using XLSTAT (Version 2012.6.02).

3. Results and discussion

Electronic nose analysis

E-nose analyses were performed to obtain the aroma fingerprints of boza samples produced with combinations of different raw materials. Figure 2 shows the typical e-nose chromatogram of a boza sample. A total number of 17 aroma compounds were detected by the e-nose. The amount of aroma compounds differed and some of the compounds were not detected depending on each boza sample. The type and amounts of the raw materials caused differentiation of the aroma compounds.

The aroma fingerprints of eight different boza samples were analysed using HCA and principle component analysis (PCA) to see the discrimination of the samples based on the combinations of different raw materials. HCA dendrogram and PCA diagram are presented in Figure 3 and 4, respectively. The figures revealed that there were three clusters of boza samples close to each other; (A, E), (G, H) and (D, C, B, F). Sample C was discriminated from samples (B, F) and D completely separated itself from boza samples (C, B, F). The differences between the aroma fingerprints could be related to the amount and type of the raw materials used in boza production. In a previous study, it was clearly demonstrated that e-nose could be applied for discrimination of damaged fuji apples in combination with PCA, linear discriminant analysis and different pattern recognition techniques (Ren *et al.*, 2018). In another study, e-nose/mass spectrometry with PCA and discriminant function analysis was used successfully to classify cabbage samples cultivated in geographical regions of Korea and China (Lee *et al.*, 2017).

Sensory analysis

Flavour profile analysis was performed for sensory evaluation of boza samples. The results of sensory evaluation of boza samples according to odour attributes are given in Table 3. There were significant differences among the boza samples according to odour attributes. Sample A had the highest vinegar, yoghurt, and yeast odour properties. Sample B had the highest corn, flour, and lemon odour while it had the lowest wheat odour. Corn odour of A and B samples were correlated with the amount of corn flour used for boza production. Vinegar flavour was detected in all boza samples except sample B. This could be related to spontaneous fermentation of boza samples (Akpinar-Bayazit

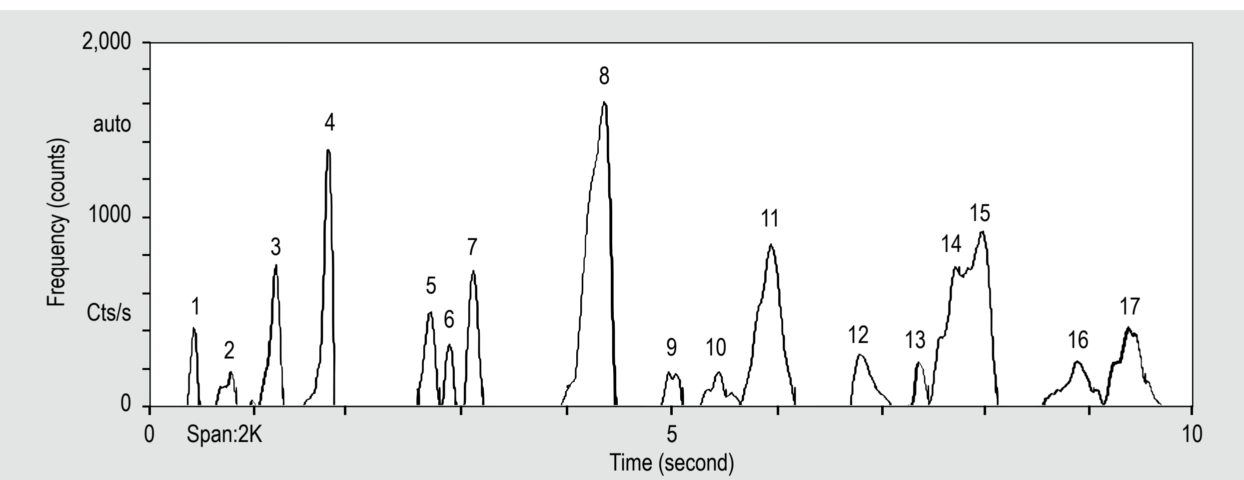

Figure 2. Typical e-nose chromatogram of boza.

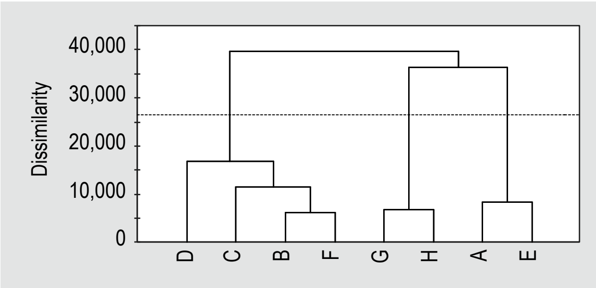

Figure 3. Hierarchical clustering analysis of boza samples based on e-nose data.

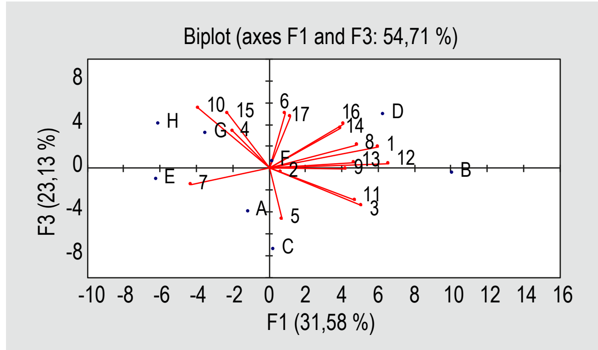

Figure 4. Principle component analysis of boza samples based on e-nose data.

Table 3. Flavour profile analysis (FPA) results of boza samples according to their odour attributes.

Sample	Odour descriptors[1]						
	Wheat	Corn	Flour	Vinegar	Lemon	Yoghurt	Yeast
A	–	1.44±0.32[ab]	–	1.44±0.50[a]	0.63±0.44[b]	1.44±0.56[a]	0.75±0.89[ab]
B	0.47±0.09[d]	1.56±0.32[a]	1.56±0.32[a]	–	2.25±0.27[a]	–	0.44±0.18[a]
C	0.94±0.12[b]	1.44±0.12[ab]	–	0.69±0.22[bc]	–	0.78±0.31[b]	0.41±0.19[a]
D	0.75±0.19[c]	0.59±0.13[b]	0.34±0.38[b]	0.81±0.37[b]	0.34±0.30[c]	0.66±0.19[b]	0.25±0.00[b]
E	0.94±0.26[b]	1.41±0.42[ab]	–	0.75±0.27[bc]	–	0.59±0.38[b]	0.06±0.12[c]
F	0.84±0.13[bc]	0.84±0.30[b]	–	0.84±0.30[b]	–	0.69±0.22[b]	0.06±0.12[c]
G	0.81±0.12[bc]	1.38±0.19[ab]	–	0.81±0.55[b]	–	–	–
H	1.22±0.16[a]	0.69±0.12[b]	–	0.53±0.16[bc]	–	0.47±0.28[b]	–

[1] Means followed by different letters within a column are significantly different ($P<0.05$).

et al., 2010). The yoghurt flavour of samples was perceived except samples B and G due to lactic acid fermentation. The reason of absence vinegar and yoghurt odours in these samples could be related to the dominant flavour of lemon and corn in these samples, respectively.

HCA and PCA were carried out to discriminate the boza samples based on odour properties as shown in Figure 5 and 6, respectively. As seen on the figures, B formed one group and other samples formed another group. The discrimination of B from other boza samples was related to its cracked wheat content. In the second group D, F, H and G, C, E formed two clusters and discriminated from sample A. Odours of F and H samples were found closer associated with the same type of raw materials.

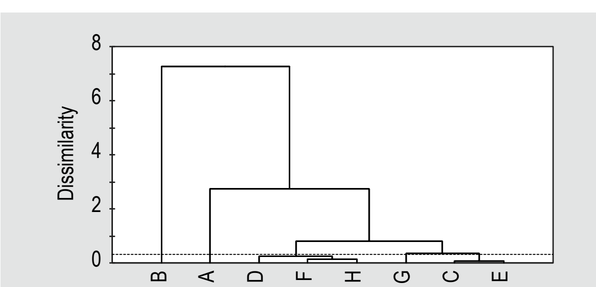

Figure 5. Hierarchical clustering analysis of boza samples according to odour properties.

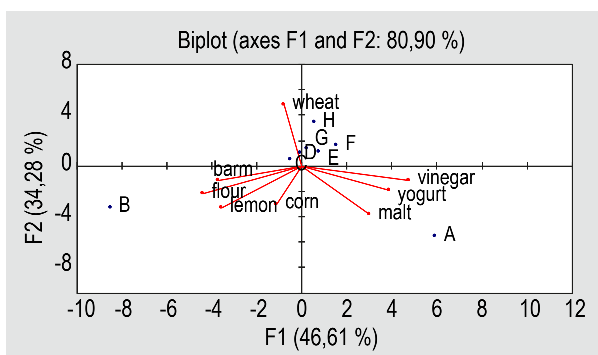

Figure 6. Principle component analysis of boza samples according to odour properties.

Table 4. Flavour profile analysis (FPA) results of boza samples according to their taste attributes.

Sample	Taste descriptors[1]									
	Wheat	Corn	Flour	Bran	Yoghurt	Lemon	Sweet	Sour	Astringent	Metallic
A	2.13±0.23^{b}	–	–	–	–	–	2.06±0.32^{a}	2.06±0.32^{a}	1.06±0.32^{a}	0.44±0.18^{bc}
B	2.63±0.35^{a}	–	–	–	–	–	1.63±0.23^{b}	1.22±0.31^{bc}	0.56±0.18^{bc}	–
C	1.44±0.18^{c}	1.16±0.38^{a}	–	–	0.72±0.39^{b}	–	1.47±0.45^{b}	0.88±0.40^{d}	0.50±0.19^{cd}	0.50±0.33^{bc}
D	0.75±0.57^{de}	0.41±0.13^{c}	–	–	1.16±0.60^{a}	–	0.94±0.22^{cd}	1.31±0.22^{bc}	1.25±0.33^{a}	1.56±0.50^{a}
E	0.50±0.13^{e}	0.97±0.09^{b}	0.84±0.13	–	–	0.31±0.35^{b}	1.00±0.00^{cd}	0.38±0.23^{e}	0.66±0.19^{bc}	0.34±0.19^{c}
F	0.72±0.25^{de}	0.81±0.22^{b}	–	–	0.25±0.19^{c}	–	1.16±0.13^{c}	0.84±0.19^{d}	0.78±0.41^{b}	0.72±0.47^{b}
G	0.56±0.12^{e}	0.88±0.13^{b}	–	0.44±0.18	–	0.53±0.31^{a}	1.06±0.35^{c}	1.13±0.27^{cd}	0.25±0.00^{d}	–
H	0.94±0.29^{d}	0.53±0.21^{c}	–	–	–	0.41±0.19^{ab}	0.75±0.00^{d}	1.50±0.33^{b}	0.28±0.16^{d}	–

[1] Means followed by different letters within a column are significantly different (P<0.05).

Flavour profile analysis results of boza samples according to taste attributes are given in Table 4. There were statistically significant differences among the boza samples according to the taste properties. According to the results wheat, sweet, sour, and astringent sensory properties were commonly perceived in all boza samples. Wheat was perceived as the highest taste in sample B followed by A and C samples. Addition of saccharose to boza samples after boiling and filtration of raw materials caused the increment of sweet taste in all samples. However, there were significant differences (P<0.05) between the sweetness of samples depending on the ratio and structure of carbohydrates. Concerning the previous studies on sensory properties of boza, Akpinar-Bayizit *et al.* (2010) reported that there were important differences between the sensory properties of boza samples prepared with different cereals. Maize boza got the highest scores from the panellists according to appearance, taste, odour, mouth feel, and texture properties. HCA dendrogram (Figure 7) and PCA diagram (Figure 8) were used to illustrate the graphical representation of discrimination of boza samples according to their taste attributes. The figures indicated that samples A and B were differentiated from other samples. This result could be based on the perception of wheat, sour, and sweet taste of these boza samples very intensively by the panellists.

Colour analysis

Colour analysis results were given by using CIE L^*, a^*, b^* colour coordinates. The results were analysed with ANOVA. Duncan's multiple range test at 5% significance level was performed to differentiate means of different boza samples. The results showed that boza samples had statistically significant different colour values as given in Table 5. The sample coded with F had the lowest L^* value and H sample had the less negative a^* value and highest b^* value according to the colour results. The preferred colour of boza was obtained using white corn in production. Yellow corn grits were added to adjust the boza colour (Kose and Yucel, 2003). However, the different values of colour coordinates in this study could be related with the addition of different cereals as raw materials.

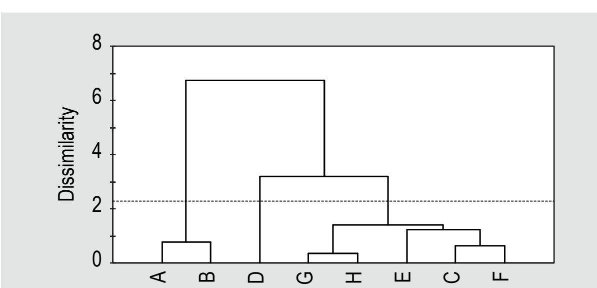

Figure 7. Hierarchical clustering analysis of boza samples according to taste attributes.

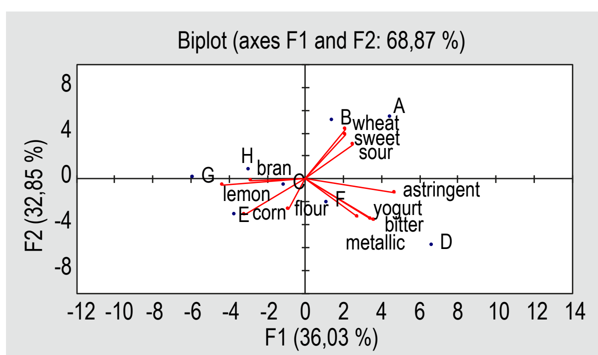

Figure 8. Principle component analysis of boza samples according to taste attributes.

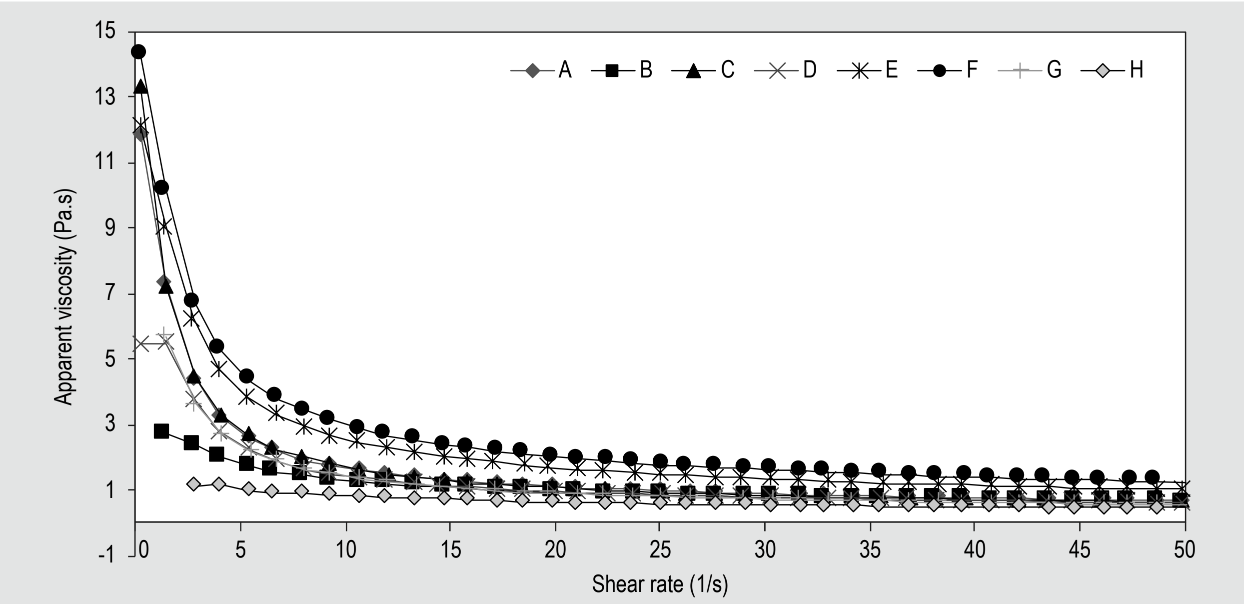

Figure 9. Apparent viscosity of boza samples versus shear rate at constant temperature (10 °C).

Table 5. Colour measurements of boza samples.[1]

Sample code	L*	a*	b*
A	56.85±0.16^{c}	-3.95±0.02^{g}	7.38±0.14^{f}
B	60.87±0.05^{a}	-3.93±0.02^{fg}	9.84±0.08^{c}
C	55.22±0.05^{g}	-3.67±0.04^{e}	6.70±0.18^{g}
D	55.40±0.01^{f}	-2.96±0.02^{c}	8.06±0.12^{d}
E	55.85±0.03^{e}	-3.91±0.02^{f}	7.86±0.07^{e}
F	55.03±0.04^{h}	-3.48±0.02^{d}	5.42±0.06^{h}
G	56.56±0.02^{d}	-2.72±0.02^{b}	11.82±0.06^{b}
H	58.92±0.02^{b}	-2.38±0.02^{a}	13.09±0.07^{a}

[1] Means followed by different letters within a column are significantly different (P<0.05).

Rheological measurements

The apparent viscosity of boza samples versus shear rate at constant temperature (10 °C) is illustrated in Figure 9. As shown in the figure, all boza samples showed pseudoplastic flow behaviour as the apparent viscosity decreased with increasing shear rate. Differences in raw materials did not change flow behaviour of boza samples. In accordance with our study, Genc *et al.* (2002) studied the rheological properties of laboratory boza samples and reported that boza exhibited pseudoplastic behaviour. They found correlation between viscometric constants and dry matter content of boza samples. Similar results were obtained for salep drink flavoured with increasing amounts of cocoa powder. Alpaslan and Hayta (2007) reported that salep samples mixed with different concentrations of soymilk exhibited pseudoplastic flow behaviour. Hayta *et al.* (2001) studied the effects of fermentation on viscosity, protein solubility, and pH of boza prepared with corn, rice, and wheat flour. The flow behaviour of fermented and unfermented boza samples at 10, 20, and 30 °C were pseudoplastic.

4. Conclusions

In this study, boza samples were produced in the laboratory using different formulations in terms of different cereals. Aroma profile analysis with e-nose and sensory flavour profile analyses indicated that boza samples prepared with different raw materials had different aroma fingerprints and sensory profiles. There were statistically important differences between the samples regarding odour and taste attributes of boza samples. HCA of samples showed the similar clusters depending on panellists' preferences. Based on e-nose analysis, it was concluded that e-nose could be utilised as a rapid and simple method for the discrimination of aroma fingerprints of boza samples. Rheological measurements revealed that differentiation of raw materials did not affect the pseudoplastic flow behaviour of boza samples.

Acknowledgements

The authors would like to thank to Dr Mehmet Reşat Atılgan and Cihan Kahraman for their help and assistance during viscosity analyses and Semra Özışıklar and Fulya Akdağ for their help in boza manufacturing. The authors also gratefully acknowledge all panellists in sensory analyses.

References

Akpinar-Bayizit, A., Yilmaz-Ersan, L. and Ozcan, T., 2010. Determination of boza's organic acid composition as it is affected by raw material and fermentation. International Journal of Food Properties 13: 648-656.

Alpaslan, M. and Hayta, M., 2007. Effect of soymilk substitution on the rheological and sensory properties of salep, a traditional Turkish milk beverage. International Journal of Food Properties 10: 413-420.

Altay, F., Karbancioglu-Guler, F., Daskaya-Dikmen, C. and 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.

Altug, T. and Elmaci, Y., 2011. Gıdalarda duyusal değerlendirme. Sidas Media, İzmir, Turkey, 134 pp.

Anonymous, 1992. TS 9778, Boza Standard. Turkish Standards Institution, Ankara, Turkey.

Arici, M., Ersöz Tatlisu, N.B., Toke, Ö.S., Yilmaz, M.T., Cankurt, H., Durak, M.Z. and Sagdic, O., 2014. Microbiological, steady, and dynamic rheological characterization of boza samples: temperature sweep tests and applicability of the Cox-Merz rule. Turkish Journal of Agriculture and Forestry 38: 377-387.

Buratti, S., Ballabio, D., Benedetti, S. and Cosio, M.S., 2007. Prediction of Italian red wine sensorial descriptors from electronic nose, electronic tongue and spectrophotometric measurements by means of Genetic Algorithm regression models. Food Chemistry 100: 211-218.

Chen, Q., Song, J., Bi, J., Meng, X. and Wu, X., 2018. Characterization of volatile profile from ten different varieties of Chinese jujubes by HS-SPME/GC-MS coupled with e-nose. Food Research International 105: 605-615.

Coskun, F. and Cakir, E., 2014. Effect of the addition of different spices on some characteristics of boza during storage. Bulgarian Journal of Agricultural Science 20: 1079-1084.

Fischer, P. and Windham, E.J., 2011. Rheology of food materials. Current Opinion in Colloid & Interface Science 16: 36-40.

Genc, M., Zorba, M. and Ova, G., 2002. Determination of rheological properties of boza by using physical and sensory analysis. Journal of Food Engineering 52: 95-98.

Gotcheva, V., Pandiella, S.S., Angelov, A., Roshkova, Z. and Webb, C., 2001. Monitoring the fermentation of the traditional Bulgarian beverage boza. International Journal of Food Science and Technology 36: 129-134.

Guohua, H., Jiaojiao, J., Deng, S., Xiao, Y., Mengtian, Z., Minmin, W. and Dandan, Y., 2015. Winter jujube (Zizyphus jujuba Mill.) quality forecasting method based on electronic nose. Food Chemistry 170: 484-491.

Hayta, M., Alpaslan, M. and Köse, E., 2001.The effect of fermentation on viscosity and protein solubility of Boza, a traditional cereal-based fermented Turkish beverage. European Food Research and Technology 213: 335-337.

Jian, L., Feixiang, Z., Jinghao, J., Han, L. and Guohua, H., 2015. Chinese bayberry (Myrica rubra Sieb. et Zucc.) quality determination based on an electronic nose and non-linear dynamic model. Analytical Methods 7: 9928-9939.

Jiang, J., Li, J., Zheng, F., Lin, H. and Hui, G., 2016. Rapid freshness analysis of mantis shrimps (*Oratosquilla oratoria*) by using electronic nose. Journal of Food Measurement and Characterization 10: 48-55.

Kadiroglu, P. and Korel, F., 2015. Chemometric studies on zNose™ and machine vision technologies for discrimination of commercial extra virgin olive oils. Journal of the American Oil Chemists' Society 92: 1235-1242.

Kadiroglu, P., Korel, F. and Tokatli, F., 2011. Classification of Turkish extra virgin olive oils by a SAW detector electronic nose. Journal of the American Oil Chemists' Society 88: 639-645.

Korel, F. and Balaban, M.Ö., 2008. Electronic nose technology in food analysis, In: Ötleş S. (eds.) Handbook of food analysis instruments. CRC Press Taylor and Francis Group, Boca Raton, FL, USA, pp. 365-378.

Kose, E. and Yucel, U., 2003. Chemical composition of boza. Journal of Food Technology 1: 191-193.

Lee, W.-H., Choi, S., Oh, I.-N., Shim, J.-Y., Lee, K.-S., An, G. and Park, J.-T., 2017. Multivariate classification of the geographic origin of Chinese cabbage using an electronic nose-mass spectrometry. Food Science and Biotechnology 26: 603-609.

Li, J., Feng, H., Liu, W., Gao, Y. and Hui, G., 2016. Design of a portable electronic nose system and application in k value prediction for large yellow croaker (*Pseudosciaena crocea*). Food Analytical Methods 9: 2943-2951.

Lihuan, S., Liu, W., Xiaohong, Z., Guohua, H. and Zhidong, Z., 2017. Fabrication of electronic nose system and exploration on its applications in mango fruit (*M. indica* cv. Datainong) quality rapid determination. Journal of Food Measurement and Characterization 11(4): 1969-1977.

López de Lerma, M.N., Bellincontro, A., García-Martínez, T., Mencarelli, F. and Moreno, J.J., 2013. Feasibility of an electronic nose to differentiate commercial Spanish wines elaborated from the same grape variety. Food Research International 51: 790-796.

Oates, M.J., Fox, P., Sanchez-Rodriguez, L., Carbonell-Barrachina, Á.A. and Ruiz-Canales, A., 2018. DFT based classification of olive oil type using a sinusoidally heated, low cost electronic nose. Computers and Electronics in Agriculture 155: 348-358.

Pacioni, G., Cerretani, L., Procida, G. and Cichelli, A., 2014. Composition of commercial truffle flavored oils with GC-MS analysis and discrimination with an electronic nose. Food Chemistry 146: 30-35.

Peris, M. and Escuder-Gilabert, L., 2016. Electronic noses and tongues to assess food authenticity and adulteration. Trends in Food Science & Technology 58: 40-54.

Qin, Z., Pang, X., Chen, D., Cheng, H., Hu, X. and Wu, J., 2013. Evaluation of Chinese tea by the electronic nose and gas chromatography-mass spectrometry: correlation with sensory properties and classification according to grade level. Food Research International 53: 864-874.

Qiu, S. and Wang, J., 2015. Application of sensory evaluation, HS-SPME GC-MS, e-nose, and e-tongue for quality detection in citrus fruits. Journal of Food Science 80(10): 296-304.

Ren, Y., Ramaswamy, H.S., Li, Y., Yuan, C. and Ren, X., 2018. Classification of impact injury of apples using electronic nose coupled with multivariate statistical analyses. Journal of Food Process Engineering 41(5): e12698. DOI: https://doi.org/10.1111/jfpe.12698

Rodriguez-Mendez, M.L., Apetrei, C., Gay, M., Medina-Plaza, C., De Saja, J.A., Vidal, S., Aagaard, O., Ugliano, M., Wirth, J. and Cheynier, V., 2014. Evaluation of oxygen exposure levels and polyphenolic content of red wines using an electronic panel formed by an electronic nose and an electronic tongue. Food Chemistry 155: 91-97.

Steinkraus, K.H., 1994. Nutritional significance of fermented foods. Food Research International 27: 259-267.

Yang, C.J., Ding, W., Ma, L.J. and Jia, R., 2015. Discrimination and characterization of different intensities of goaty flavour in goat milk by means of an electronic nose. Journal of Dairy Science 98: 55-67.

Ying, X., Liu, W. and Hui, G., 2015. Litchi freshness rapid non-destructive evaluating method using electronic nose and non-linear dynamics stochastic resonance model. Bioengineered 6(4): 218-221.

Zheng, L., Gao, Y., Zhang, J., Li, J., Yu, Y. and Hui, G., 2016. Chinese quince (*Cydonia oblonga* Miller) freshness rapid determination method using surface acoustic wave resonator combined with electronic nose. International Journal of Food Properties 19: 2623-2634.

Zorba, M., Hancioglu, O., Genc, M., Aslan, A., Ova, G. and Karapinar, M., 1999. The choice of starter culture combination for the boza production by using sensory evaluation and determination of the chemical and rheological properties, In: Toldra, F., Ramon, D. and Navarro, J.L. (eds.) Proceedings of the international congress: improved traditional foods for the next century. October 28-29, 1999. Valencia, Spain, pp. 79-83.

Zorba, M., Hancioglu, O., Genc, M., Karapinar, M. and Ova, G., 2003. The use of starter cultures in the fermentation of boza, a traditional Turkish beverage. Process Biochemistry 38: 1405-1411.