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Comprehensive Analysis of Bioactive Compounds in Malt Beverages: A Chemometric Approach for Quality Control

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ABSTRACT

Organic acids remarkably affect the microbial control, stability, and organoleptic characteristics (flavor, color and aroma) of beverages. This study focuses on the determination of organic acids, including oxalic, citric, tartaric, malic, succinic, lactic, fumaric, acetic, propionic, and gallic acid, in 100 commercial malt beverages from different brands (five Iranian and five various imported brands) and flavored variants (classic, pomegranate, peach, tropical and lemon). In addition, the contents of total phenols, total flavonoids, ascorbic acid, and free amino acids were measured to assess the overall composition. Liquid Chromatography (LC) was employed to develop a method for analyzing the organic acids, while spectrophotometric techniques were used for quantifying other bioactive compounds. The results revealed significant variations in the organic acid profiles, with succinic acid being the most abundant, while tartaric acid was absent in all samples. Chemometrics technique (PCA method) was applied to classify the results. The results show that PCA can classify the malt drinks based on the additive values with a very high precision. To improve the quality control of malt beverages, some extra assessments, like organic acids and free amino nitrogen determination, should be considered for Iranian National Standard.

Keywords: Liquid chromatography, Organic acid, Spectrophotometry.

INTRODUCTION

Malt drink is a non-alcoholic beverage derived from wort that has not been derived from the fermentation process. The malting process, encompassing soaking, germination, and drying, is employed to transform grains into malt. This malt serves as a fundamental ingredient in the production of various alcoholic and non-alcoholic beverages, including the globally renowned non-alcoholic malt drink known by its trade name "Malta" (Pradhanang, 2013).

Regarding the alcohol content of Malta beverages, a classification is carried out as follows: alcoholic (more than 1.2% v/v), low alcoholic (0.5-1.2% v/v) and non-alcoholic (less than 0.5% v/v). Worldwide popularity of non-alcoholic Malta beverages has grown due to valuable nutritional content, high fiber and bioactive compounds amount (Hosseini *et al*., 2012; Yalçınçıray *et al*., 2020). Consumers around the world have recently become interested in Malta drinks in comparison to beers due to their lower calorie content (Zabihpour *et al*., 2021).

Since the production process of beer is

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similar to the procedure for Malta beverage and barley malt is a major ingredient in both of them, the physicochemical content derived from malt are similar in these beverages (Shopska *et al*., 2021; Hajieghrary and Homayouni and Rad, 2016). The composition of malt derived from barley grain plays a crucial role in determining the quality of beer. Beer is a fermented beverage that is abundant in carbohydrates, amino acids, minerals, vitamins, organic acids and phenolic compounds (Jahn *et al*., 2020).

Organic acids have a crucial function in upholding the quality of food. The analysis of organic acid profiles in foods and beverages can be utilized to verify the authenticity of the product, making it valuable for quality control purposes (Uzhel *et al*., 2021).

Organic acids, besides polyphenols, significantly contribute to the flavor characteristics, such as sourness, tartness, and acidity of the beer. These organic acids also provide a certain level of protection against microbial spoilage and exhibit robust buffering capabilities, which can extend the shelf life of the beer (Rani *et al*., 2024).

The process of beer staling leads to lipid oxidation, resulting in the formation of saturated and unsaturated aldehydes that can significantly affect the beer's flavor. In the brewing industry, both synthetic and natural antioxidants, such as ascorbic acid, can be utilized to enhance the stability of beer flavor (Zabihpour *et al*., 2021). Since ascorbic acid is usually added to food products as an antioxidant, its evaluation in malt drink would be beneficial.

The composition of polyphenols, as the other investigated compound at the current study in beers, is regarded as a significant indicator of beer processing and marketing quality. Beer is known to contain various groups of phenolic compounds, in which phenolic acids and tannins are most dominant, as well as flavones and flavonols (Ambra *et al*., 2021). Flavonoids found in beer are also capable of enhancing oxidative stability by inhibiting the oxidation of other molecules present in the beverage (Šibalić *et al*., 2021).

Assessment of phenolic compounds in Malta beverages can be carried out from two points of view: 1) Their influence on the physical properties like flavor, stability, color, bitterness, shelf-life and organoleptic properties, and 2) Their effect on health improvement because of their antioxidant activity (Yalçınçıray *et al*., 2020).

Nitrogen compounds can be mentioned as the other considerable compounds in Malta beverages that affect flavor, foam stability, haze formation, color, yeast nutrition, and biological stability. Amino acids are made of these important compounds, which come from barley malt (Baigts-Allende *et al*., 2021).

Yeasts use amino acids during the fermentation process, so there is a low level of free amino acids in the final product; hence, establishing a suitable and selective method for their measurement is of value (Jastrzębska *et al*., 2020).

Nowadays, fraud detection in food has usually been performed using analytical methods along with multivariate analyses to detect the fraud in complex matrices of some food and beverages. Multivariate statistical analysis takes into account all the complex interactions between components in the entire matrix and allows the sample to be examined in all aspects (Power *et al*., 2020). In this study, chromatography and chemometrics methods were used to find the most suitable method for studying Malta's beverages.

Due to the importance of evaluation of organic acids, total phenolic, total flavonoid, total free amino nitrogen, and ascorbic acid contents in Malta beverage, to control the quality of Malta drink, these compounds were measured in the current study by LC and spectrophotometric techniques tandem with chemometrics methods in different brands.

MATERIALS AND METHODS

Sampling

In accordance with the market availability, 100 commercial malt beverage samples from 10 different brands (including

five Iranian and five imported brands) that had five types of flavors including classic, pomegranate, peach, tropical and lemon, were purchased between June 2022 and January 2023 from Tehran Market. All analyses procedure were carried out before expiry date of the beverages.

Chemicals

Standards of oxalic acid (99%), citric acid (99.5%), tartaric acid (99%), malic acid (100%), succinic acid (99%), lactic acid (100%), acetic acid (100%), fumaric acid (100%), propionic acid (99.5%), and gallic acid (100%) were purchased from Merck Germany (Darmstadt, Germany). Sulfuric acid (HPLC grade), Folin-Ciocalteau reagent, aluminum chloride, 2, 4-dinitrophenylhydrazine thiourea copper (II) sulfate solution and ninhydrin were purchased from Sigma (St Louis, MO, USA).

Spectrophotometric Analysis

Determination of Total Phenolic Content

Folin-Ciocalteau method with slight modifications was applied to determine total phenolic content. To do so, 1.5 mL Folin-Ciocalteau reagent was diluted 10-fold by distilled water and mixed with 300 µL of the sample. Then, the prepared solution was kept at room temperature for 5 min. After that, 3 mL sodium bicarbonate solution (60 g L^{-1}) was added to the mentioned solution. The solution was incubated at room temperature for 90 minutes. In order to prepare the blank solution, 1.5 mL Folin-Ciocalteau reagent was added to 300 µL distilled water and was incubated at room temperature for 5 min. Following that, 3 mL of sodium bicarbonate solution (60 g L^{-1}) was added to the mixture. The mixture was again incubated at room temperature for 90 min. The absorbance of the prepared samples was measured at 725 nm using a UV-Visible spectrophotometer. Quantification of the total phenolic content was carried out by plotting the calibration curve, which was plotted by measuring the absorbance of 6 various concentrations (10, 20, 50, 100, 200, 300 mg L^{-1}) of gallic acid standard. The results were expressed as gallic acid equivalent g^{-1} per 100 mL of the initial samples.

Determination of Total Flavonoid Content

Aluminum chloride colorimetric method, with some modifications, was used to determine the total flavonoid content. For this purpose, 15 mL of the sample was transferred to 25 mL volumetric flask. Then, 1 mL of aluminum chloride solution (2 g aluminum chloride per 100 mL of 5% v/v acetic acid in methanol) was added to the flask. The flask filled up to the 25 mL volume by the solution of 5% v/v acetic acid in methanol. The prepared sample solution was incubated at room temperature for 30 minutes. Ultimately, the absorbance of the samples was measured at 415 nm using UV-Visible spectrophotometer. To prepare the standard solutions in order to plot the calibration curve, 15 mL of 6 different concentrations of quercetin (1, 2.5, 5, 10, 20, 30 mg L^{-1}) was added to 1 mL of aluminum chloride solution. After transferring the mentioned solution to 25 mL volumetric flask, it was filled up to the mark with 5% v/v acetic acid in methanol. The prepared standard solutions were incubated at room temperature for 30 min. The used blank was the solution of 5% v/v acetic acid in methanol. The results were expressed as mg quercetin equivalents per 100 mL of the initial samples.

Determination of Ascorbic Acid Content

Dinitrophenyl hydrazine method with some modifications was applied for measuring the ascorbic acid content. In order to prepare DTC (2, 4-dinitrophenylhydrazine thiourea copper (II) sulfate solution), 3 g of powdered 2,4-dinitro-phenyl hydrazine, 0.4 g of tiourea and 0.05 g of copper sulfate were diluted by sulfuric acid solution (4.5 mol L^{-1}) in a100 mL volumetric flask. The least stability of this solution was one week. The amount of 80 µL of DTC was added to 75 µL of sample. After that, the samples were put into 37°C water bath for 3 hours. After adding 600 µL of 65% v/v sulfuric acid, the gas was excited by shaking the sample solution. The prepared sample solution was incubated at room temperature for 30 min. The absorbance level was determined at 520 nm using UV-Visible spectrophotometer. The absorbance of 400 µL of five ascorbic acid various concentrations (5, 10, 20, 40, 50 mg L^{-1}) was used to plot the standard calibration curve. The results were expressed as mg of ascorbic acid g^{-1} of initial samples.

Determination of Total Free Amino Nitrogen (FAN)

To prepare ninhydrin color reagent, 10 g Na2HPO4, 6 g KH2PO4, 0.5 g ninhydrin and 0.3 g fructose were diluted with 100 mL of distilled water. Then, the pH was adjusted between 6.6 -6.8. This solution remains stable under refrigeration condition for 2 weeks. Additionally, in order to prepare the dilute solution, 2 g potassium iodide was dissolved in 600 mL distilled water. Then, 400 mL of 96% v/v ethanol was added. Glycine stock solution was prepared by dissolving 107.2 mg glycine in 100 mL of distilled water (storage temperature: 0°C). After that, glycine standard solutions were prepared in four different concentrations (1, 2.5, 5, 7.5 mg L^{-1}) of glycine, by diluting the glycine stock solution. For analysis, 1 mL of malt drink was transferred to a 50 mL volumetric flask and diluted by distilled water. Then, 1 mL of ninhydrin color reagent was separately added to 2 mL of the diluted sample, the standard solutions, and distilled water as blank solution. The solutions were heated at 100°C for 16 minutes, then, cooled at 20°C for 20 min. After adding 5 mL of the diluted solution, the absorbance of the prepared solutions was measured at 570 nm using UV-Visible spectrophotometer.

LC ANALYSIS

Sample Preparation

Firstly, samples were sonicated and filtered by a PVDF 0.45 µL syringe filter. Then, 1 mL of the sample was transferred to a 10 mL volumetric flask and diluted with deionized water. After shaking, the prepared sample solution was injected into the LC.

Standard Preparation

Standard stock solutions of organic acids (including oxalic, citric, tartaric, malic, succinic, lactic, acetic, fumaric, propionic and gallic acid) were prepared at the concentration of 1000 mg L^{-1}. Following that, working standard solutions for fumaric acid, gallic acid and oxalic acid, were made in the range of 0.5-5 mg L^{-1}, for succinic acid, acetic acid and propionic acid in the range of 5-20 mg L^{-1}, and for citric, tartaric, malic, and lactic acid in the range of 10-100 mg L^{-1}. After injecting the working standard solutions, the calibration curves were plotted for all the 10 mentioned organic acids.

Chromatographic Conditions

An Agilent 1200 series liquid chromatograph equipped with a gradient pump capable of mixing four solvents, a vacuum membrane degasser, a 20-µL loop injector, and a UV Detector was used for chromatographic analysis. This was carried out isocratically using a Eurokat H Vertex

Plus column (300×8 mm, 10 µm) as the stationary phase and sulfuric acid (0.1 N)/deionized water (10:90 v/v) as the mobile phase with the flow rate of 0.5 mL min^{-1}. The temperature of column was kept at 50°C and the UV detector was set at 210 nm. Running time was 33 min.

Analytical Metrics

The calibration curves were plotted for all the mentioned parameters. Each concentration of standards mentioned above was analyzed three times in order to plot the calibration curves. The linearity between the concentration and the absorbance or the peak areas was observed.

For determining the Limit Of Detection (LOD) and the Limit Of Quantitation (LOQ), the following equations were used:

$LOD=3.3\times Sy/S$

$LOQ=10\times Sy/S$

Where, Sy and S are the intercept Standard deviation and Slope of the calibration curve, respectively. The calculation of Sy was based on the data of calibration curve. Sample recovery was calculated by analysis of sample before and after the addition of specific amounts of the parameter for confirming the accuracy. In order to evaluate the precision, samples were analyzed in three consecutive days and three times each day (ICH Guideline, 2005).

Chemometric Analysis

Principal Component Analysis (PCA) was performed using MATLAB software (version 7). Also, the Kennard-Stone algorithm was used to divide the train and test data (Algorithm written by M. Daszykowski - University of Selesia, Poland). A total of 100 samples of different brands and flavors commercially available in the market were evaluated. Data from LC was organized in 100 X 10 matrices, where the samples were placed in rows. Datasets were processed by auto scale method and analyzed by unsupervised PCA.

Statistical Analysis

Data analysis was carried out using MATLAB software (version 7) and the SPSS statistical package, version 21 (SPSS Inc. Chicago, IL, USA). Evaluation of the differences between various brands and types of malt beverages was performed by Analysis Of Variance (ANOVA) and TUKEY test. Statistical significance was set at ($P< 0.05$).

RESULTS AND DISCUSSION

Spectrophotometric Methods

In the present study, total phenol, total flavonoid, total free amino nitrogen and ascorbic acid amounts were determined in non-alcoholic malt drinks.

Validation parameters measured by spectrophotometric methods are shown in Table 1.

Table 1. Analytical characteristics of total phenol, total flavonoid, total free amino nitrogen and ascorbic acid contents.

Analyzed content	Reference standard	Linear range (mg L^{-1})	Linear regression	Determination coefficient (r^2)	LOD[a] (mg L^{-1})	LOQ[a] (mg L^{-1})
Total phenolic	gallic acid	10-300	Y=0.0033x-0.0127	0.992	8.812	9.763
Total flavonoid	quercetin	1-30	Y=0.0462x-0.0255	0.996	0.743	0.952
Ascorbic acid	ascorbic acid	5-50	Y=0.0074x+0.0842	0.992	2.484	4.527
Free amino acid	free amino acid	1-7.5	Y=0.1734x+0.1662	0.998	0.214	0.649

[a] LOD: Limit Of Detection, LOQ: Limit Of Quantitation

Based on the one-way Anova test, significant differences were observed in the amounts of total phenol, total flavonoid, ascorbic acid and free amino acid in different malt beverage flavors and brands. Regarding the flavor of the drink, this difference was mainly due to differences between classical taste and other flavors.

According to MEBAK (Central European Brewing Technical Analysis Commission), the range of free amino acids in beer should be 100-120 mg L^{-1} (MEBAK, 2002). Only 1% of our samples had amounts higher than this range. The other measured amounts were within or lower than the determined range by MEBAK. Free amino acids appear to be good indicators for the efficiency of the fermentation process at the production stage of barley malt extract (Nie *et al*., 2010). Since the fermentation process has been eliminated in the non-alcoholic malt drinks production in Iran (Sohrabvandi *et al*., 2010), the rational for low levels of free amino acids at the current study can be explained.

In the brewing industry, it is essential to have a comprehensive understanding of the properties of phenolic compounds found in beer beverages. This knowledge is significant because polyphenols play a role in the development of beer attributes such as the flavor, bitterness, color, oxidation process and the shelf life of beers. Furthermore, the consumption of foods containing phenolic compounds has a beneficial effect on human health (Oliveira Neto *et al*., 2017; Šibalić *et al*., 2021). Since the quantity of phenolic content and their antioxidant activity in malt drinks is influenced by the quality, quantity, and variety of the raw materials used, as well as the production process employed (Yalçınçıray *et al*., 2020), it is recommended that Malta drinks should be further investigated for total phenol content in market samples and also raw materials.

MEBAK expresses that the standard total phenol range for beer is 150-200 mg L^{-1} (MEBAK, 2002). The results of our study showed that only 33% of the samples were in this range.

Moura -Nunes *et al*. (2016) investigated the phenolic compounds in different types of Brazilian beers and the results were analyzed by chemometric methods. The study showed that the amount of phenolic compounds in alcoholic beers with high bitterness was higher than the non-alcoholic beers and beers with low bitterness (Moura-Nunes *et al*., 2016). In comparison with the current study, it can be explained why only 33% of our samples in terms of total phenol content were within the determined range by MEBAK.

Zabihpour *et al*. (2021) investigated the total phenolic, flavonoid, B vitamins amounts and antioxidant activity in four bottles of Iranian non- alcoholic beers during a three-month storage time. the findings of this study indicated that Iranian non-alcoholic malt drinks contained a noteworthy concentration of phenolic and flavonoid compounds. In the present study, the total phenol levels of 100 samples were investigated, with note taken of the considerable number of samples examined.

According to the results regarding the ascorbic acid content, some samples contained remarkable amounts (the maximum level: 0.25% w/w); this may be due to the usage of ascorbic acid as an additive in malt beverage production.

LC Method

Due to the importance of organic acids assessment in malt drinks in the present study, simultaneous determination of 10 organic acids including oxalic, maleic, citric, succinic, fumaric, acetic, lactic, tartaric, gallic and propionic acid in these malt beverages was developed using an ion-exchange column Liquid Chromatography (LC) method.

Validation parameters of organic acids are presented in Table 2. Additionally, Chromatogram of organic acids is illustrated in supplementary file number1.

Table 2. Analytical characteristics of organic acids.

Analyzed organic acid	Linear range (mg L^{-1})	Linear regression	Determination coefficient (r^2)	LOD (mg L^{-1})	LOQ (mg L^{-1})	Concentration of spiked solution (mg L^{-1})	Recovery (%)
Citric	10-100	y=2.4625x+0.1293	0.999	1.92	5.83	50	94.16
Oxalic	0.5-5	y=21.846x-1.0595	0.999	0.12	0.36	1	95.81
Tartaric	10-100	y=1.6023x+0.6829	0.999	1.76	5.34	50	99.21
Fumaric	0.5-5	y=311.56x-14.54	1	0.03	0.09	1	93.32
Gallic	0.5-5	y=347.13x-23.1	0.999	0.05	0.15	1	98.45
Lactic	10-100	y=1.1591x-1.5122	0.999	2.3	7.09	50	96.41
Succinic	5-20	y=1.5397x-1.106	0.999	0.50	1.54	10	90.62
Malic	10-100	y=1.9892x-0.6171	0.999	1.72	5.23	50	96.27
Acetic	5-20	y=1.53x-1.175	0.997	1.25	3.81	10	95.66
Propionic	5-20	y=1.4521x-0.1388	0.999	0.75	2.29	10	90.34

According to Iranian National Standard, addition of citric, lactic, tartaric and malic acid to malt beverage is permitted (ISIRI, 2011).

Based on the analysis by using One-Way ANOVA test, malic and lactic acid showed significant difference among various brands. This difference was not observed for citric and tartaric acid. One-way ANOVA test showed significant differences between citric, malic and lactic acid among different flavors.

The analysis of the other six organic acids was performed using One-Way ANOVA test and showed that the amount of these organic acids was significantly different in various malt beverage brands. Also, significant difference was observed among oxalic, fumaric, acetic and propionic acid in different flavors, but no difference was found between succinic and gallic acid.

Based on the results, they tie well with similar studies in which succinic acid has the highest level among organic acids in malt beverages. However, no tartaric acid was detected in our samples. Therefore, it was excluded from the four organic acids that could be used as an additive in malt beverages according to Iran national standard (tartaric acid, malic acid, lactic acid, and citric acid). The highest values belonged to citric and malic acid.

According to a study carried out by Dong *et al*. (2022), four organic acids including oxalic, malonic, citric, and lactic acids were determined using capillary electrophoresis technique utilizing direct Ultraviolet (UV) detection in 12 wine and beer drinks. Malonic acid and oxalic acid were not present in any of the samples, except for one beer sample. Citric acid and lactic acid were detected in the majority of beer samples, ranging from 32 to 173 mg L^{-1} and 243 to 741 mg L^{-1}, respectively. In wine, lactic acid was found in a range of 740 to 1,700 mg L^{-1}, surpassing the levels observed in beer (Dong *et al*., 2022). Citric acid was one of the organic acids with high abundance in the current study, consistent with the mentioned study. The significant presence of citric acid in malt beverages can be attributed to several factors. Firstly, citric acid is commonly used as a preservative in soft drinks and may unintentionally be introduced into drinks during the brewing process. Additionally, since citric acid naturally occurs in fruits, its presence can be attributed to the utilization of fruits in the brewing of beverages (Dong *et al*., 2022).

Within the human body, succinic acid, acetic acid, citric acid, lactic acid, and malic acid enhance the absorption of iron.

A research was performed by Uzhel *et al.* (2021) on blueberry, mango, and grape juices as well as light beer and red wine to investigate the organic acids profile using novel chemically derivatized hyperbranched anion exchanger. Lactic acid and citric acid are the dominant organic acids present in the examined beer sample, with 570 and 290 mg L^{-1} levels, respectively (Uzhel *et al*., 2021). In our study, the amounts of succinic, citric and malic acids were the highest among organic acids. Since The fermentation process determines the composition and concentration of organic acids in beverages and the fermentation is eliminated in the production process of Malta, the present difference can be explained.

Another research was done on various juices in order to measure organic acids (including oxalic, citric, malic, galacturonic, ascorbic, succinic, and fumaric acid) by Chinnici *et al*. in 2005 using ion-exclusion LC method. In the mentioned study, 18 fruit juice brands of four different types were investigated and, regardless of the type, the highest values observed in the fruit juices belonged to citric and malic acid. Additionally, pear juice had the highest amount of succinic acid compared to the other juices (Chinnici *et al*., 2005). In comparison with the present study, the total amount of organic acids in fruit juices was much higher than the amounts of organic acid in malt beverages.

In another study, ten types of barley grains and their malts were investigated by Carvalho *et al*. (2015), who found no gallic acid (Carvalho *et al*., 2015). Therefore, low levels of gallic acid in malt drinks in the current study are not unexpected.

Chemometrics Analysis

In the first step, after a pre-processing of the dataset (auto-scale), a Principal Component Analysis (PCA) model was created. PCA simplifies data complexity by maintaining trends and patterns. PCA was employed to visualize the spectra in a minor dimension to see if there was a pattern of cluster or not. To investigate the data classification in the multidimensional space, score plot was used. PCA results are shown in Figures 1 and 2. The first Principal Component (PC1) vs. the second Principal Component (PC2) were plotted on a graph as shown in Figure 1.

These two principals explained 89% of the variance (PC1= 78% and PC2= 11%). Based

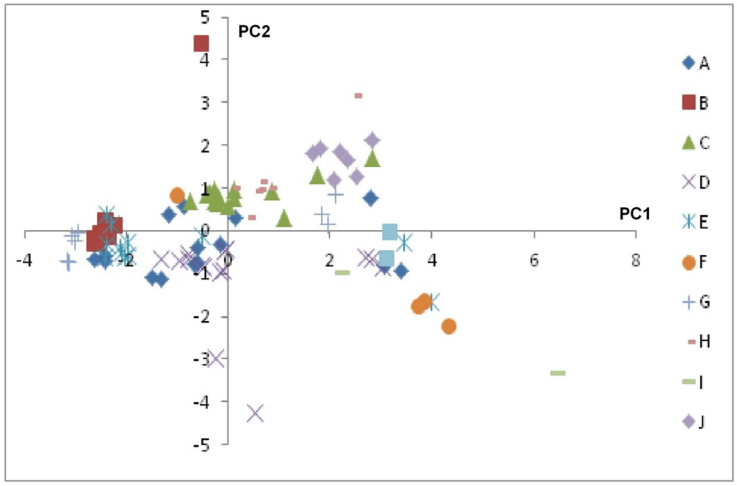

Figure 1. Principal component analysis score plot of non-acoholic malt samples with PC1 and PC2.

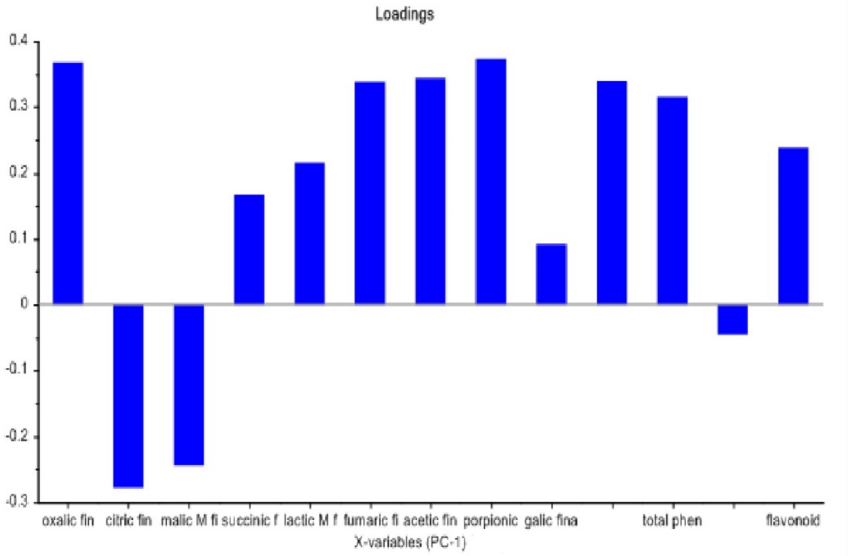

Figure 2. Principal component analysis loading plot of non-alcoholic malt samples with PC1 and PC2.

on the distribution of the samples, this model was able to differentiate beverages from different brands. In fact, in score plot, the brands are differentiated with different flavors. As we can see, the different brands of A, J and C are located in different places. But this is not the case for brands B and E. The loading plot for the first two principal components is shown in Figure 2, where the greatest variance is observed at variables V2 (citric acid), V6 (fumaric acid), V7 (acetic acid) and V8 (propionic acid), showing the greatest effect on the differentiation between the samples.

Bi-plot chart in PCA is a graphical representation that combines both the scores and loadings of the principal components in a single plot. The scores represent the projection of the original data points onto the principal components, while the loadings indicate the contribution of each variable to the principal components. This visualization

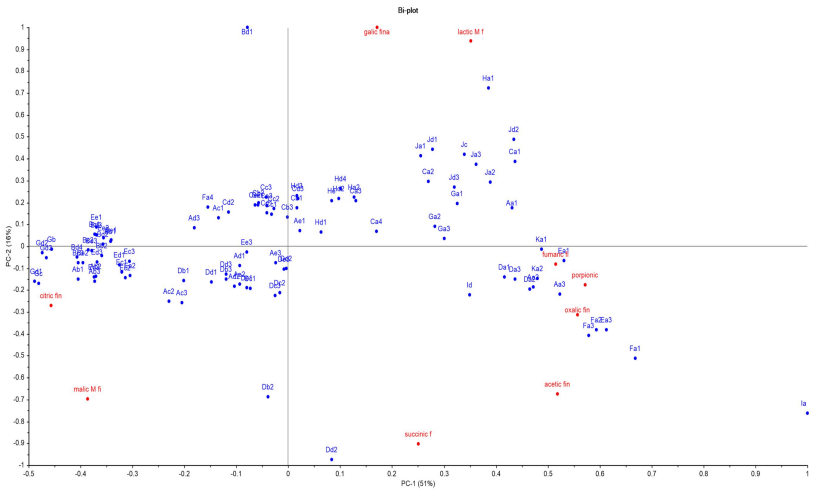

Figure 3. Biplot Principal Component Analysis (PCA) of the 100 studied beverages.

helps in understanding the relationships between variables and observations in a multivariate dataset. The Bi-plot chart shows which variables have the most value in the sample beverages and makes a distinction between different brands (Figure 3).

The observations showed that simple visual inspection of the chromatogram for classification was not enough, therefore, an unsupervised classification method was developed with completely satisfactory results.

CONCLUSIONS

In this research, the aim was to assess the levels of organic acids, total phenols, total flavonoids, ascorbic acid, and free amino acids in various types of malt beverages. This study, in conjunction with further research, could aid in developing a novel method utilizing chemometric analysis for the quality control of Malta. The findings indicate that the current standards are insufficient for detecting fraud and ensuring authenticity in Malta. Consequently, it appears that the relevant standards should be revised, and the quality assessment of malt beverages should incorporate additional parameters.

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تجزیه و تحلیل جامع ترکیبات زیست فعال در نوشیدنی های مالت: رویکرد شیمی سنجی برای کنترل کیفیت

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مقدمه

رشد روزافزون مصرف جهانی نوشیدنی‌های غیرالکلی توجه ها را به سمت شناسایی و کنترل کیفیت نوشیدنی‌های محبوبی مانند نوشیدنی‌های مالت جلب کرده است. اسیدهای آلی به طور قابل توجهی بر کنترل

میکروبی، پایداری و ویژگی های ارگانولپتیک (طعم، رنگ و عطر) نوشیدنی ها تأثیر می گذارند. این مطالعه بر تعیین اسیدهای آلی شامل اگزالیک، سیتریک، تارتاریک، مالیک، سوکسینیک، لاکتیک، فوماریک، استیک، پروپیونیک و اسید گالیک در ۱۰۰ نوشیدنی تجاری مالت از برندهای مختلف (پنج برند ایرانی و پنج برند مختلف وارداتی) و انواع طعم دار (کلاسیک، انار، هلو، گرمسیری و لیمو) تمرکز دارد. علاوه بر این، محتوای فنل کل، فلاونوئید کل، اسید اسکوربیک و اسیدهای آمینه آزاد برای ارزیابی ترکیب کلی اندازه‌گیری شد. کروماتوگرافی مایع (LC) برای توسعه روشی برای آنالیز اسیدهای آلی استفاده شد، در حالی که کروماتوگرافی مایع (LC) برای توسعه روشی برای آنالیز اسیدهای آلی استفاده شد، در حالی که تکنیک‌های اسپکتروفتومتری برای تعیین کمیت سایر ترکیبات زیست فعال استفاده شد. نتایج تغییرات قابل توجهی را در پروفایل اسید آلی نشان داد. اسید سوکسینیک فراوان ترین اسید آلی در نمونه ها بود، در حالی که اسید تارتاریک در همه نمونه ها وجود نداشت. برای تجزیه و تحلیل بهتر داده ها، از تکنیک کمومتریکس (روش PCA) برای طبقه بندی نتایج به دست آمده استفاده شد. نتایج نشان می دهد که PCA می تواند نوشیدنی های مالت را بر اساس مقادیر افزودنی با دقت بسیار بالایی طبقه بندی کند. به منظور بهبود تست‌های کنترل کیفی نوشیدنی‌های مالت، توصیه می‌شود برخی ارزیابی‌های دیگر مانند تعیین اسیدهای آلی و نیتروژن آمینه آزاد در استاندارد ملی ایران در نظر گرفته شود.