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Comparing microwave and convective heat treatment methods by applying colour parameters of wine

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ABSTRACT

This research aims to determine whether the treatment of food products in a microwave electromagnetic field is advantageous or disadvantageous compared to conventional technologies. In household practice, microwave energy transfer is used mostly for heating. One of the most important tangible benefits of microwave heat treatment is that it causes less damage to the nutritional value of the product due to its speed.

Despite the fact that microwave technology was introduced more than 70 years ago, it is still not clear whether its application results in equivalent products in terms of quality and food safety.

This study demonstrates how heat-treated wines with microwave energy transmission and with convective heating in a thermostatic water bath are affected. In the white, rose and red wine samples pasteurized at a temperature of 74 ± 0.5 °C, significant differences between the two heating methods regarding colour characteristics could be indicated.

KEYWORDS

wine, colour parameters, heat treatment, microwave

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INTRODUCTION

Heat treatment is a routine operation in food production since it effectively destroys microorganisms that cause spoilage in food, thereby increasing the shelf life of products. At the same time, high temperatures may have a negative effect on vitamins and may influence the colour and nutritional content of the product. This research aims to provide a technical solution for heat treatment where advantages dominate.

The applicability of microwave energy transfer in food industry has been investigated in several domestic and international studies (Kovács et al., 2017). The foods most frequently used in research are milk and fruit juices, which almost always undergo some degree of heat treatment during processing.

The effects of microwave heat treatment on fruit juices have been studied thoroughly, as this process often forms an integral part of their production (Jiménez-Sánchez et al., 2015). The quality of citrus products is determined by the enzyme reactions in fruits not only in different growth phases but during processing as well. For example, the inactivation of methyl-ester-pectinase is especially important to prolong shelf life. Studies have shown that the pasteurization of fruit juices can be performed faster and with a smaller decrease in ascorbic acid content. Camacho et al. (2009) is of the firm opinion that as citrus juices are concerned, heat treatment clearly helps prolong shelf life. Microwave heat treatment as a viable alternative in food processing technology significantly decreases the initial bacterial count in fruits (Peremanyer & Grébol, 2010). It has also been proven that mould reduction (*species Aspergillus*) is more substantial using microwave-based heat treatment (Valderrama & Sanches, 2008).

Kapcsándi et al. (2013, 2016), seeking to demonstrate the effects of microwave treatment on grape must fermentation, finds that sugar content of the treated samples rapidly decreases compared to the control sample and that fermentation time is 40% shorter.

The possibility of microwave pasteurization has been a determining field of research conducted by a team at the Faculty of Mechanical Engineering, Szent István University (formerly Gödöllő University of Agricultural Science) for nearly 20 years. The feasibility of microwave heat treatment as well as its energy-saving and technological advantages are proved (Sembery & Géczi, 2008; Géczi & Sembery, 2010; Garnacho et al., 2012; Géczi et al., 2013a; Géczi et al., 2013b; Korzenszky et al., 2013; Korzenszky & Molnár, 2014). Their research covers the heat treatment of fresh milk immediately after milking and the continuous fermentation of fruit juice (apple, orange juice, grape must) in order to increase the shelf life as well as to improve the quality of liquid products. During research, the effects of microwave and conventional heating methods on liquid food products are compared in parallel, and differences in the physical characteristics, chemical parameters and biological conditions of heat-treated products are investigated. Until now no significant differences between the parameters examined in the samples have been found, either when heating them using the microwave method or in the thermostatic water bath.

Most recently, heat treatment applied in winemaking technologies has been examined. Some biological stabilization effects can be achieved by pasteurization, which prolongs the shelf life of wine but has a considerable influence on the quality, colour, alcohol content and other traits of the product. In Hungary, the usual practice during heat treatment is to raise the temperature of the wine to 70–80 °C and keep it at that temperature for a few seconds, which precipitates harmful heat-sensitive substances from the wine, kills the yeast cells and extends the shelf life of heat-treated wine by 6 months (Farkas, 1988; Eperjesi et al., 2010; Margalit, 2012). Comparative examinations have been performed regarding that, as well. This research studies whether heat treatments of identical extent (temperature–time) conducted with microwave and thermostatic bath heat treatment methods produce any difference between the colour of wine products.

The CIELab system is a very common colour measurement technique in the industry, in the military, in human doctoral practise and in geography science (Cserjési et al., 2011; Huang et al., 2018; Chiang et al., 2018; Lin et al., 2019). According to Pathare et al. (2013) many researchers apply this system in the food industry.

MATERIAL AND METHODS

Wine samples

For this research, products of Hungarian small-scale producers and wineries were selected that applied no heat treatment after the fermentation of grape must and stored their product in an oxygen-free environment until consumption or sale. The characteristics of the examined samples are summarized in Table 1.

Parallel measurement configuration

The test equipment was assembled by converting a household microwave oven into a flow-through, continuous operating mode device with 900 W output power. Two holes of 7 mm in diameter, located 8 cm apart, were made in the oven to introduce and drain the liquid. The microwave equipment, supplemented with special glass spirals, was connected to a STENNER 85M5 adjustable feed-rate, peristaltic pump (Stenner Pump Company, Jacksonville, FL, USA) (Géczi & Sembery, 2010; Géczi et al., 2013a). Temperature data were measured and recorded by an ALMEMO 2590-4 temperature measuring instrument (Ahlborn, Holzkirchen, Germany).

Inside the microwave oven, the liquid flowing through the glass spirals could be heated to the desired temperature depending on the length of the spiral and the flow rate of the peristaltic pump. The temperature could be continuously monitored before entering and after exiting the microwave field, allowing the process to be controlled effectively. One of the advantages of this method is the gradual heating and constant output temperature resulting from the use of glass spirals, with which temperature fluctuations characteristic to batch processes operation can be avoided.

Table 1. Characteristics of wine samples

Code	Wine variety	Wine style	Alc. (%v/v)	Vintage chart	Region
FU-TO-15	Furmint	Semi sweet white wine	12	2015	Tokaj
ZA-KU-16	Zalagyöngye	Semi dry white wine	8.5	2016	Kunság
CA-MA-16	Cabernet Sauvignon	Dry rose wine	12	2016	Mátra
FA-MA-14	Farkasvér[a]	Dry red wine	12	2014	Mátra
ME-VI-15	Merlot	Dry red wine	12.5	2015	Villány

[a]Blend produced from Zweigelt, Turán, Cabernet Franc.

To produce a comparative study of heat treatments in which wine samples were heated in different ways but under identical circumstances (i.e. the final temperature and treatment time must be identical), a glass spiral instrument was also immersed in a T-PHYWE type water bath (Lauda DR.R. Wobser GmbH, Lauda-Königshofen, Germany). Adjusting water temperature enabled the research team to create the same treatment temperature as with the microwave method, using an identical flow rate, resulting in identical treatment time. This parallel process made it possible to compare wine samples treated under identical circumstances but with different heating methods.

For each comparative test, one glass spiral was placed into Whirlpool AT 314 microwave oven (MW-H), while another one was placed into the *T*-PHYWE thermostatic water bath (TB-H). The temperature was continuously monitored and held constant. During this test, the flow rate was set to $Q = 175\ cm^3 \cdot min^{-1}$ and the output power was set to $P = 900$ W, resulting in a wine temperature of $T_{wine} = 74 \pm 0.5$ °C. For convective heating at the same flow rate, the water bath temperature was kept at $T_{water} = 80 \pm 0.3$ °C. Control wine samples were not heated (NO-H).

Samples of a specific wine variety were heat treated in 3 different days, but to the same temperature every time ($T_{wine} = 74 \pm 0.5$ °C). Five litres of each wine sample were procured from the untreated wine control, as the wine treated with microwave energy transfer and as wine heat treated with the convective method. The large number of samples produced from each wine variety made shelf life examinations possible. After heat treatment, colour analyses were repeated once a month to draw conclusions regarding shelf life. However, this article is not aimed to present long-term results since examinations are still in progress.

Colour analysis of wine samples

The colour of wine is characteristic of the specific variety and is the basis of wine evaluation. Evidentially, the colour of a wine variety primarily depends on the colour of the grape, but several chemical compounds play an important role in colour development. Carotenoids are responsible for the green and yellow colours of grapes, while the colour of blue grapes and red wines are determined by anthocyanins (Fig. 1). Heat treatment may have a minor effect on the colour of the end product – the fact that heat treatment has been applied is visible – but we can gain precise data by instrumental measurement.

Fig. 1. Examined wine varieties (from left to right FU-TO-15, ZA-KU-16, CA-MA-16, FA-MA-14, ME-VI-15)

The colour properties of wine samples were determined using a ColorLite sph 850 spectrophotometer (ColorLite GmbH, Katlenburg-Lindau, Germany). Test results were obtained as CIE (Commission Internationale de la Éclargie) L^*, a^*, b^* colour properties with wavelengths between 400 nm and 700 nm (Kaszab et al., 2010, 2011). The instrument settings were '2° standard observer' and 'standard illuminant D65'. Results of each measurement were calculated from the average of three measurements with the ColorLite equipment. There were more than 6 million colour codes in the CIE Lab System. The colour parameters were the following: lightness – L^* which defines the grades of brightness from black to white; red-green colour coordinate – a^*; and yellow-blue colour coordinate – b^*. Colour parameters of wine samples were measured on the day following the treatment and monitored once a month throughout sample storage. This process required a large number of samples, as once the samples were measured, they could not be used again.

Statistical analysis

The measured colour property values were evaluated by R-Studio Version 1.1.414 (R-Studio, 2018). After leaving the outlier data, a normality test (Shapiro–Wilk Test) was run on colour test results of the samples from both methods of heat treatment as well as on those of the unheated control samples. ANOVA was used to identify any significant differences between the groups regarding certain parameters. As Reiczigel et al. (2019) proposed ANOVA indicated TukeyHSD test ($P < 0.05$) was used for detecting the significant differences between the groups.

RESULTS AND DISCUSSION

Fig. 2 shows the colour parameters of the untreated samples using (a^*, b^*) quadrant. The five examined wine varieties can be separated to 'white', 'rose' and 'red' wine types (Fig. 2).

Furthermore, both red wine types show very similar results, but the values of FA-MA-14 wine are more scattered. Small difference can be found between the values of two white wines as well, but the values of ZA-KU-16 sample show stronger scattering.

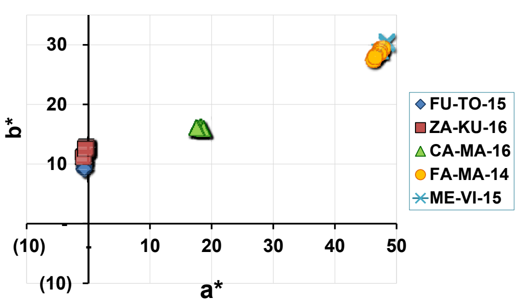

Fig. 2. Location in the (a^*, b^*) quadrant of wines examined

The effect of the heat treatment is shown on the following three wine samples: ZA-KU-16 (white), CA-MA-16 (rose), FA-MA-14 (red) wine. Fig. 3 presents the results of lightness coefficient of microwave handling (MW-H), non-heat-treated (NO-H) and thermostatic bath handling (TB-H). As white and rose wines are concerned, significant differences were found between NO-H and heat-treated samples. MW-H shows the lowest values. However, MW-H and NO-H of red wine do not illustrate noticeable difference.

Significant differences were found in the value of a^* and b^* between NO-H and heat-treated samples in case of white and rose wine (Figs. 4 and 5). The average values of red wine samples (NO-H and MW-H) were only insignificantly different.

The presence of a significant difference was tested between the groups by TukeyHSD test. Based on the results it can be concluded that the groups significantly differ in terms of the measured colour parameters (Table 2). Only in a few cases there is no significant difference (marked with blue cells in Table 2).

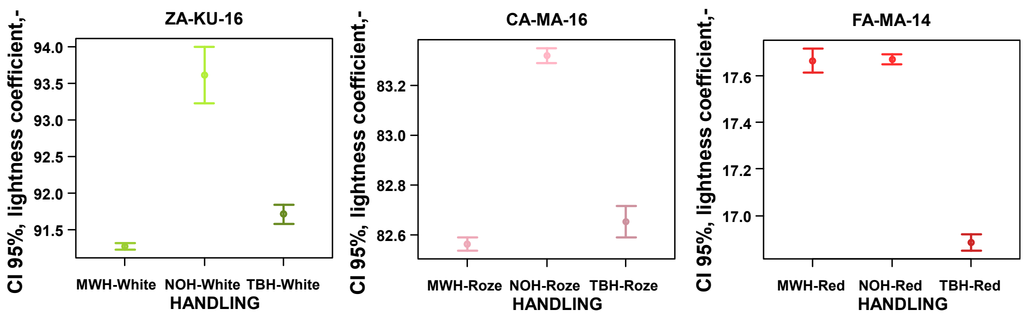

Fig. 3. Lightness coefficient (L^*) (average and the 95% CI) by treatment category (from left to right: ZA-KU-16, CA-MA-16, FA-MA-14)

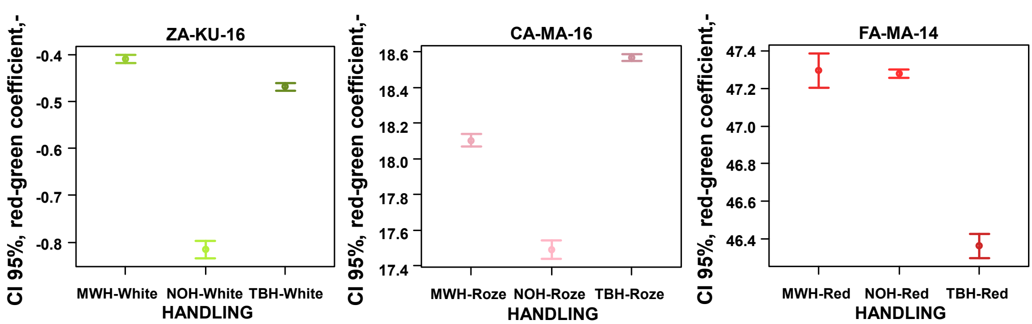

Fig. 4. Red-green coefficient (a^*) (average and the 95% CI) in different treatment categories (from left to right: ZA-KU-16, CA-MA-16, FA-MA-14)

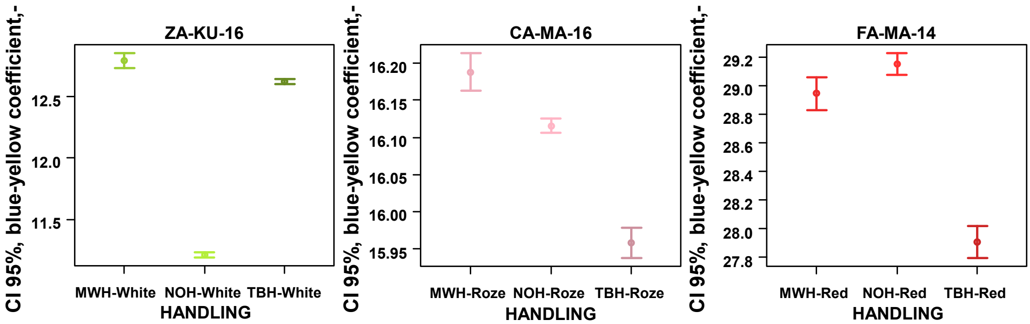

Fig. 5. Blue-yellow coefficient (b^*) (average and the 95% CI) in different treatment categories (from left to right: ZA-KU-16, CA-MA-16, FA-MA-14)

Table 2. Tukey-test results of lightness coefficient (L^*), red-green coefficient (a^*) and blue-yellow coefficient (b^*) ($P < 0.05$)

L* - lightness coefficient

	ZA-KU-16			CA-MA-16			FA-MA-14		
	MWH-White	NOH-White	TBH-White	MWH-Rozé	NOH-Rozé	TBH-Rozé	MWH-Red	NOH-Red	TBH-Red
MWH-White									
NOH-White	+								
TBH-White	+	+							
MWH-Rozé	+	+	+						
NOH-Rozé	+	+	+	+					
TBH-Rozé	+	+	+	-	+				
MWH-Red	+	+	+	+	+	+			
NOH-Red	+	+	+	+	+	+	-		
TBH-Red	+	+	+	+	+	+	+	+	

a* - red-green coefficient

	ZA-KU-16			CA-MA-16			FA-MA-14		
	MWH-White	NOH-White	TBH-White	MWH-Rozé	NOH-Rozé	TBH-Rozé	MWH-Red	NOH-Red	TBH-Red
MWH-White									
NOH-White	+								
TBH-White	-	+							
MWH-Rozé	+	+	+						
NOH-Rozé	+	+	+	+					
TBH-Rozé	+	+	+	+	+				
MWH-Red	+	+	+	+	+	+			
NOH-Red	+	+	+	+	+	+	-		
TBH-Red	+	+	+	+	+	+	+	+	

b* - blue-yellow coefficient

	ZA-KU-16			CA-MA-16			FA-MA-14		
	MWH-White	NOH-White	TBH-White	MWH-Rozé	NOH-Rozé	TBH-Rozé	MWH-Red	NOH-Red	TBH-Red
MWH-White									
NOH-White	+								
TBH-White	+	+							
MWH-Rozé	+	+	+						
NOH-Rozé	+	+	+	-					
TBH-Rozé	+	+	+	+	+				
MWH-Red	+	+	+	+	+	+			
NOH-Red	+	+	+	+	+	+	+		
TBH-Red	+	+	+	+	+	+	+	+	

CONCLUSION

In this research the colour parameters of wine were examined using samples with different methods of heat treatment and pasteurization. In household practice, microwave heating produces uneven heat distribution in the product as a result of the inhomogeneity of the electromagnetic field. According to the research team, this uneven heat distribution is the reason why there is still no breakthrough in the application of microwaves on an industrial scale. Research itself was made difficult by the fact that microwave heating operated in intermittent mode could not be compared with convective heating because of the resulting inhomogeneity. Even heating could be achieved by flowing liquid food products continuously through a glass spiral in a microwave electromagnetic field. The extent of heating was determined by the length of the glass spiral and the flow velocity of the feeding pump. By passing the same food products through a convective water bath with an appropriately selected temperature, identical heating parameters using two different heating methods could be achieved. With the parallel methods, heat treatment based on convection heat transfer and microwave energy transfer could be compared by examining the characteristics of the treated food product.

Heat treatment and, within that, pasteurization, applied in winemaking technology, proved to be suitable for the examination of microwave energy utilization. Based on the characteristics examined in this research, it could be concluded that the effects of heat treatment could be observed in changes to colour coordinates and lightness coefficient. In the white, rose and red wine samples pasteurized at a temperature of 74 ± 0.5 °C, significant difference between the two heating methods regarding colour characteristics could be indicated.

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