Effect of Sound Waves with Different dB Values at 1000 Hz Frequency on Some Aroma Substances in Strawberry Fruits

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Abstract

Plants are exposed to various environmental stresses during cultivation in plant production. Several defense mechanisms come into action together with many physiological changes in the plant after itfaces stress conditions. Sound waves are among the abiotic stress factors in vegetable production. In this study, which examined the effects of sound waves at 3 different dBs (95 dB, 100 dB, and 105 dB) at1000 Hz frequency value on aroma substances in strawberry fruits, it was assumed that sound stress could increase taste and aroma substances; therefore, it would have positive effects on the quality of the fruit. Strawberry, which is in the berry fruit group, is one of the most common fruit types in the world. Strawberry can be consumed after processing as well as after-ripening during periods when fresh fruit is low in the marketand is rich in vitamins. Nineteen volatile taste and aroma substance analyses were performed in the fruit after a 30-day trial in strawberry plants in pots that were placed in chambers where sound stress was applied at different dBs. As a result of the analyses, it was determined that as the dB increased, so did the taste and aroma of materials, increasing the quality and marketing rate of the fruit.

Keywords: Db, Freqency, Sound Waves, Abiotic Stress, Aroma, Sound Pressure, Plants

Introduction

Plants are exposed to several environmental stresses during cultivation carried out both in open area and undercover in vegetable production. Stress in plants was defined by Hale and Orcutt (1987) as the abnormal alterations in the physiological processes based on environmental (abiotic) and biological (biotic) factors or a combination of these. Sound waves are among abiotic stress factors in plant production (Telewski 2006; Wang et al., 2001).

However, there are limited studies conducted on the physiological effects of sound on plants.

Sound is a vibration wave of objects and moves from one place to another in a suitable medium (air, water, etc.) in the form of compressions and expansions (rarefactions). For this reason, the sound is a pressure wave and is one of the physical energy types spreading as waves in the medium. It is also vibration energy. One of the most important sound sizes is sound pressure, which is generated by a sound wave in space, different from atmospheric pressure. Sound pressure is the changes in air pressure during the distribution of the sound in a certain period of time. Basic sound pressure as accepted as the sound pressure 2.10^{-5} Pa on the hearing limit at 1000 Hz (Ozkurt H, Altuntas O., 2018).

Although sound pressure changes can be measured correctly and simply with a microphone, measuring the sound velocity is very difficult in terms of its technique. Sound measurements are made at an adequate distance (approximately 1m) from the source, to preserve the ratio of sound pressure and sound speed. For the sound emitting in open space conditions; correlation can be written.

$$v = \frac{p}{\rho . c}\left[\frac{m}{s}\right]$$

In this way, the sound speed is found indirectly with the help of the sound pressure. For this reason, each pot was placed at a distance of close to 65cm, or approximately 1m to the speaker in the experiment. The sensing limits of humans include different sound intensity. The feature which allows the sound produced in the same sound source to be heard differently from different distances is called the intensity of sound. In brief, it is the intensity of the sound heard by the ear. The intensity of sounds is different. The dB unit is used for perceived volume or noise level and is a logarithmic unit used to measure the sound intensity and expresses the proportion of two physical values.

$$L_I = 10.\text{Log}\frac{I}{I_0}\ [dB]$$

Sound intensity is proportional with the square of the sound pressure *($I \sim p^2$)*. Based on this, the volume pressure level becomes:

$$L_p = 10.\log\frac{p^2}{p_0^2} \ = 20.\log\frac{p}{p_0}\ [dB]$$

Sound frequency refers to the vibration of the sound per second. Sound waves are in the form of a sinus wave. The distance between two peaks is called wavelength, and the number of wave peaks observed in one second is called frequency. In other words, the amount of pressure change per unit time is called the sound frequency, which produces its own tone. As the number of vibrations per second increases, the sound becomes treble, and as the number of vibrations decreases, in other words, as the frequency lowers, the sound becomes bass (Cetinkaya, 2010) (Figures 1a, b).

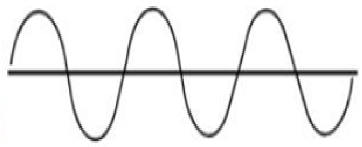

Figure 1(a). Low frequency sin wave

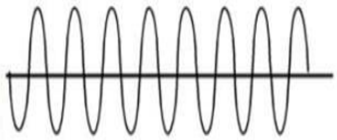

Figure 1(b). High frequency sin wave

Strawberry, which is in the berry fruits group; is one of the common types of fruits in the world due to the high ability to adapt. In our country, economic strawberry cultivation is possible from the sea level to 2000 m elevation (Aslantaş and Karakurt, 2007). Strawberry is a fruit type whose consumption increases year after year due to early maturation in spring with mineral substances like vitamins A, B, C, Fe, P, Ca, and high antioxidants and phytochemicals (Özgen, 2005 and 2006). In addition, strawberry provides a good market advantage because it maturates when fresh fruit is low in the market. It is a vitamin-rich fruit and can be consumed after processing as well as freshly.

The quality phenomenon in a fruit depends on the taste and aroma as well as on its physical appearance. Color, texture, and taste play important roles in determining the fruit quality. The flavor contains the aroma perception produced in the mouth (sweetness, acidity, and bitterness) as well as in several volatile compounds. Likein other fruits, hundreds of compounds determine the aroma of strawberries. Strawberry has one of the most complex fruit aromas consisting of approximately 350 volatile compounds (Özgen, 2005, and 2006). Several defense mechanisms act with many physiological changes in a plant when it encounters stress conditions. Plants resist this oxidative stress with some enzymatic and non-enzymatic defense systems (Sanchez *et al*., 2010). However, the effectiveness of this defense system varies depending on the factors like the plant type, its variety, stress intensity, and duration, etc. (Bian and Jiang, 2009). For example, they produce phenolic compounds as a reaction against biotic and abiotic stresses as defensive mechanisms (Nicholson and Hammerschmidt, 1992; English-Loeb *et al*., 1997).

Natural antioxidants are abundant in strawberries (Wang, Cao, & Prior, 1996; Heinonen, Meyer, & Frankel, 1998; Wang & Lin, 2000). Strawberries also contain abundant anthocyanins, flavonoids, and phenolic acids as well as usual nutrients like vitamins and minerals (Heinonen *et al*., 1998; Rice-Evans & Miller, 1996). They also have obvious high scavenging activity on radicals generated chemically, which makes them effective to inhibit oxidation of human low-density lipoproteins (RiceEvans & Miller, 1996).

Based on previous studies, the present study was conducted on the hypothesis that aroma substances, which are a component of fruit quality, can increase with sound stress and improve the quality of flavor and marketing in strawberry. In the present study, the effects of sound waves at 3 different dBs on aroma substances in strawberry fruits were investigated.

Material And Method

The study was conducted in special sound-resistant chambers in the greenhouses on the application area of Çukurova University, Karaisalı Vocational School, Adana, Turkey at 36'59^{o}N, 35'18^{o}E, 20 m above the sea level.

#An amplifier with dB indicator, regionally adjustable at various dB values, was used in the experiment. A signal generator (Adjustable frequency element) was used to create a frequency at various values (600Hz, 1000Hz, 1240Hz, 1600Hz) in closed chambers whose 4 sides could be opened and closed prepared for the experiment in three 2m×2m sizes. In addition, an Sound Measurement Device (noise measuring instrument) and speakers with 360^{o} audio-capable speakers were used (Figure 2). The thickness of the glass that was used in the chambers was 4 mm double-glass with a space of 10.5 mm.

Strawberry plants belonging tothe Festival variety were used in the experiment. A total of 54 pots were placed in each chamber. All the strawberries that were harvested from these pots were used in the analysis to detect the volatile components.

#The speakers used in each chamber were hung at an elevation of 43cm of the ground and were placed in the center of the chambers. Different sound waves were sent to the 2-liter pots that contained plants placed in chambers where different sound areas were created. The pots were placed in each chamber in the form of a circle. Each pot was placed 65 cm away from the speaker so that all the pots used in the experiment had the same distance from the speaker. The reason for choosing 65 cm distance was that the sound measurements could be made sufficiently away from the source to ensure that the sound pressure and sound speed rates could be maintained, and this was about 1 m (Figure 2).

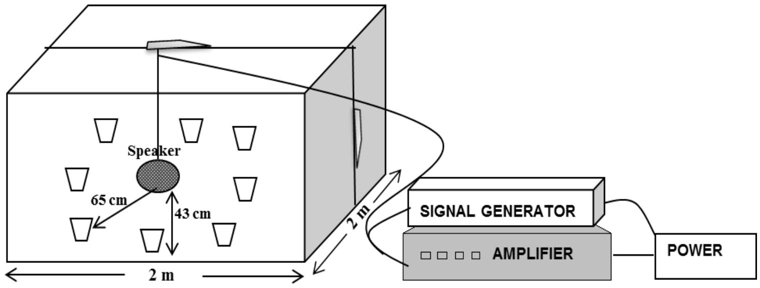

Figure 2. The experimental design

The dB value for each chamber was fixed from the amplifier at levels 95 dB, 100 dB, and 105 dB in the three chambers where the experiments were done. It is reported by experts that exposure to sound over 85 dB can be dangerous. For this reason, the dB values were fixed over 85 dB in the experiment. In addition, the control plants were compared with the control in a separate chamber with the same characteristics as other chambers where the sound application was not made.

The implementation of the experiment took 1 month (30 days). Different sound fields were created in each chamber by sending a sound wave with different dB levels (95 dB, 100 dB, 105 dB), and the fixed frequency value was selected as a reference at 1000 Hz. The frequency value was kept constant during the experiment. The plants were exposed to 1000 Hz fixed frequency and different dB areas in three separate chambers for 30 days. The data were obtained after the analysis of strawberry fruits that were harvested at the end of the trial. Sound waves were sent to the chambers once a day between 10:00 and 11:00 a.m. for one hour. The plants that were used in the trial were kept only in chambers when they received sound waves. The plants were not fed during the 1-month trialand were watered in equal quantities only every 2 days.

During this time, the strawberries that were at harvest maturity were harvested from the pots, and some aroma components were analyzed. For aroma analyses, aroma substances were isolated using Peak Cavity (HS) and Dip-in SPME techniques with the help of magnetic mixers for 30 minutes in fresh fruit samples. Polydimethylsiloxane (PDMS) absorbent that had a phase thickness of 100µm on fiber cover was used. The aroma compounds that were absorbed on the fiber were analyzed in the GC/MS system using polar and apolar columns with HS and Im-SPME techniques. In addition to the “TBAM Essential Oil Components Library”, the Wiley and Adams LIBR (TP) Library Scanning software were used in the evaluation processes.

Results And Discussion

The aroma substances found in the strawberry fruits were determined with the HS and SPME and GC/MS analyses by using polar and apolar columns, and are shown in Table 1 (Kafkas, and Paydaş, 2007). The volatile component contents of the strawberry samples were calculated with their relative percentages of the corresponding components in the chromatogram. A total of 19 volatile components were identified as a result of the analysis.

Table 1. The aroma components analyzed in fresh strawberry fruits (%)

Component Name	**HS-SPME (%)**			
	95 dB	**100 dB**	**105 dB**	**Kontrol**
ethyl acetat	36,694	45,616	49,63	32,713
Butanoic acid,pentyl ester	14,714	15,89	25,953	7,61
Pentanoic acid,methyl ester	0,344	1,146	1,888	0,16
Hexanoic acid,ethyl ester	2,194	3,85	6,894	1,99
(n)-2-Phenylbutyric acid	0,408	0,30	0,233	0,665
Acetic acid	0,37	0,236	0,581	1,047
Botanoic acid,2-octyl ester	0,78	0,049	0,09	0,19
2-methyl-pentanoic acid	0,00	n.d.	n.d.	2,963
2-methyl-propanoic acid	0,00	n.d.	n.d.	0,644
Octanoic acid,methyl ester	0,00	n.d.	0,041	n.d.
Hexanoic acid	0,12	0,136	0,173	n.d.
a-caryophyllene	0,49	n.d.	n.d.	n.d.
4-methoxy-2,5-dimethyl-3(2H)-Furanone	0,26	0,676	0,56	0,05
2-Ethoxyethyl butrate	0,03	0,023	0,02	0,302
3-methyl-6-propyl-Phenol	0,00	n.d.	n.d.	n.d.
2(3H)-Furanone	21,48	15,63	6,566	5,726
2-Furanol	0,00	n.d.	0,025	n.d.
1-hexanol	0,526	0,59	1,581	0,49
n-propyl acetate	0,00	0,426	n.d.	0,889

In addition to the "TBAM Volatile Oil Components Library", Wiley and Adams'sLIBR (TP) Library Scanning Software were used in the evaluations.n.d.: The component could not be found.

When the results were examined, it was determined thatas the sound intensity increased, some ester compounds and furanone compounds and derivatives also increased in general (Figure3, Figure4). (n)-2-Phenylbutyric acid component was found to be high in the control design; and the 2-methyl-propanoic acid component was measured in the control application and Octanoic acid and the methyl ester component was measured at 105 dB.In other applications, these components were almost as low as none-existent (Figure 5). However, furanone compounds and derivatives increased at significant levels compared to the controls with the increase in sound intensity.

To make a generalization, the rate of the aroma substances in the chambers where sound applications were made was found to be high compared to the control application. Especially the furanone compounds increased at significant levels, and acid derivatives decreased with the sound application.

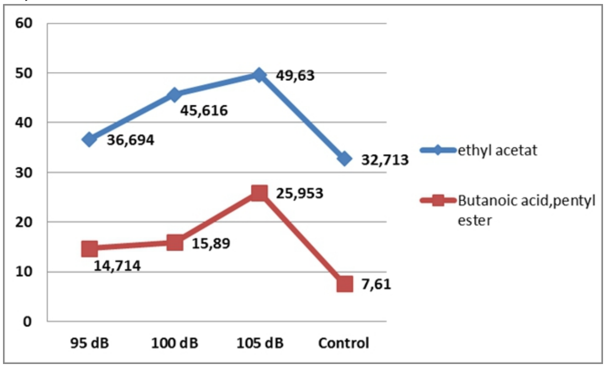

Figure 3. Ethyl acetat, Butanoic acid,pentyl ester contents at different dB values at 1000 Hz

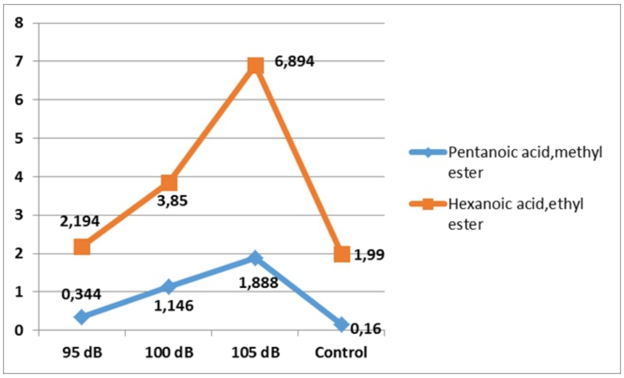

Figure 4. Pentanoic acid,methyl ester , Hexanoic acid,ethyl ester contents at different dB values at 1000 Hz

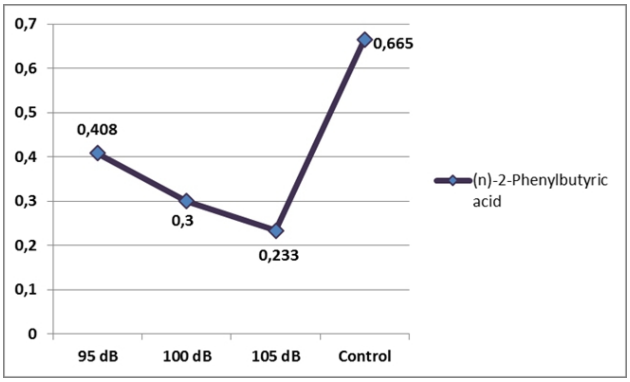

Figure 5. (n)-2-Phenylbutyric acid contents at different dB values at 1000 Hz

The aroma is one of the main components of fruit quality. These volatile components include acids, aldehydes, ketones, alcohols, esters, terpenes, and phenols. High ester content produced a pleasant flavor in most fruits (Sumitani et al., 1994). In the present study, the ester components increased as dB increased. In other words, the flavor of strawberries that were exposed to sound applications was found to be higher compared to the controls. Ozkurt and Altuntas applied sound waves applications at different dBs (95, 100 and 105 dB) on strawberries in 2018, and found that this increased the quality of fruit, total sugar, total acid, total phenol, and vitamin C in strawberries compared to the control. Again, Altuntas and Ozkurt (2019) conducted a study on tomatoes with sound applications at 90 dB fixed and at different hertz values (600, 1240 and 1600 Hz).They determined that as the volume frequency density level increased, the amount of lycopene, vitamin C, total sugar, total acid, and total phenol also increased. The total phenol contents, lycopene contents, and ascorbic acid rates of tomato plants that were exposed to sound waves at different frequencies increased at a rate of 70%, 20%, and 14%, respectively.

The aroma perception during the consumption of foods depends on the structure, concentration and food matrix of the volatile organic compounds that make up the aroma (Benjamin et al., 2012). Each food aroma is characterized by different compositions of key substances, which give a certain number of odors. The aroma that is released in the mouth during chewing food stimulates the characteristic aroma perception that is associated with a particular food (Guichard, 2014).In the present study of ours, both the characteristic aroma of the strawberry and the components that are associated with the smell and flavor in these aroma substances increased with the sound intensity.

Conclusion

As a result, it was determined in many studies that plant activates defense mechanisms in stress conditions. It was also determined that the plant increases its antioxidants, total sugar, as well as aroma substances, which are important in fruit quality in these defense mechanisms. The increase of flavoring substances are important in terms of quality in fruits such as strawberries. It is a desired feature in marketing. In fruits such as strawberries, quality and fragrant fruits can be sold at a high price. Other abiotic stress factors (such as drought, salinity) increase antioxidants and flavoring substances in the plants (including strawberry), but also cause low yield. Whereas, sound waves cause stress in plants and trigger the defense mechanism in plants, increase the nutritional value (such as total sugar, antioxidants and vitamin C) and marketing value, besides, we believe that it will not cause low yield.

In subsequent studies, this research, which increases both the quality of eating and the level of marketing, can be carried out at large production levels, especially in closed greenhouse environments. Because our study was carried out in a small indoor (chambers) as a pot experiment. By conducting researches on sound waves in fruits such as vegetables and strawberries grown in the greenhouse, it can also be investigated how it affects the yield while obtaining products with high nutritional value.

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