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Effect of the damages caused by the green shield bug (*Palomena prasina* L.) on the qualitative traits of hazelnuts

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SUMMARY: This study was conducted in 2018 to determine the effects of green shield bug damage (GD) on the chemical properties of the hazelnut cultivar "Tombul". The proximate composition, protein, total lipid (TL), carbohydrate, total ash ratio (TA), vitamin E (VE), total phenolics, energy values (EV), color value, fatty acid composition, total fatty acids, lipid oxidation, and nutritional quality index properties of the kernel were detected in relation to the "bug damage". The level of TL, TA, VE, EV, monounsaturated fatty acids (MUFA), and unsaturated/saturated fatty acids (UFA/SFA) were found to be lower in GD kernels than in good kernels (GK). Although the GD kernels had higher iodine, free fatty acidity, and peroxide levels, they showed lower oleic/linoleic acid levels, and rancimat values. In addition, the GD kernels contained lower PUFA/SFA and hypocholesterolemic/hypercholesterolemic ratios but higher atherogenicity and thrombogenicity index values.

KEYWORDS: *Bug damage;* Corylus avellana *L.; Fatty acid profile; Oil oxidation; Proximate composition*

RESUMEN: ***Efecto de los daños causados por el insecto escudo verde (*Palomena prasina *L.) en las características cualitativas de la avellana.*** Este estudio se realizó en 2018 para determinar el efecto del daño del insecto escudo verde (DV) en las propiedades químicas del cultivar de avellana "Tombul". La composición proximal, proteína, lípidos totales (LT), carbohidratos, relación total de cenizas (CT), vitamina E (VE), fenólicos totales, valores de energía (E), color, composición de ácidos grasos, ácidos grasos totales, oxidación de lípidos e índice de calidad nutricional se determinaron en relación con los daños causados por el insecto. Se encontró que el nivel de LT, CT, VE, E, ácidos grasos monoinsaturados (MUFA) y ácidos grasos insaturados/saturados (UFA/SFA) fue menor en los granos de DV que en los granos buenos (GB). Aunque los granos de DV tienen niveles más altos de yodo, acidez, grasa libre y peróxidos, tienen niveles más bajos de la relación ácido oleico/linoleico y de los valores de rancimat. Además, los granos de DV tienen una relación más baja PUFA/SFA y de hipocolesterolémica/hipercolesterolémica, pero tienen valores de índice de aterogenicidad y trombogenicidad más altos.

PALABRAS CLAVE: *Composición proximal;* Corylus avellana *L.; Daño por insecto; Oxidación de aceite; Perfil de ácidos grasos*

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1. INTRODUCTION

Among nuts, the hazelnut is the richest in terms of vitamin E and oleic acid (C18:1) contents. In addition, it is a good source of bioactive compounds (Alaşalvar *et al*., 2010). 100-g portion of hazelnut kernels containing on average 10%-24% protein meets 22% of the daily protein intake, and contains 50-65% fat, with the oleic acid as the primary fatty acid, followed by linoleic, palmitic, stearic, and linolenic acid (Köksal *et al*., 2006; Seyhan *et al*., 2007). Parcerisa *et al*., (1995) reported that the Spanish hazelnut (*Corylus avellana* L.) contained 60.23% fat, 5.79% palmitic, 0.28% palmitoleic, 1.97% stearic, 79.1% oleic, and 12.58% linoleic acids. In addition, Cristofori *et al*., (2015) reported that the Italian hazelnut contained 47.06%-49.65% fat, 5.29-7.06% palmitic, 79.78-83.66% oleic acid, and 7.48-10.52% linoleic acids.

Hazelnuts are a good source of monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), tocopherol, phytosterol, polyphenol, and phytochemicals (Alaşalvar *et al*., 2006; Shahidi *et al*., 2007; Seyhan *et al*., 2007). The high level of unsaturated fatty acids (UFA) not only increases the nutritional quality of the hazelnut but also makes it more sensitive to oil oxidation. A high level of MUFA tends to increase HDL cholesterol; whereas LDL has a tendency to lower cholesterol (Olivera *et al*., 2008). Therefore, hazelnuts are highly beneficial as they prevent the vascular occlusion associated with cholesterol.

Fatty acids do not remain constant but vary based on genetic, ecological, morphological, and physiological properties and cultural practices. As a result of the lack of accurate and timely agricultural measures associated with cultural practices, damage to hazelnuts by bugs causes large economic losses in the form of kernel abortion, malformation, and the occurrence of necrotic tissues (Memoli *et al*., 2017). Numerous bug species that cause such damage and affect cultivar quality are found in Turkish hazelnut orchards (Bosco *et al*., 2018). There are more than 15 detrimental bug species, and the green shield bug (*Palomenaprasina* L.) is known to be the most harmful (Erper *et al*., 2016; Ak *et al*., 2018). The damage to hazelnuts which is caused by green shield bugs, called kernel spot, is not detectable by appearance. Therefore, manufacturers can sell the products without any problem. However, there is no management strategy to prevent this damage. Spotted kernel damage is a serious concern, particularly for hazelnut exporters. The kernel spot damage negatively affects hazelnuts in terms of appearance and taste and causes problems for their use in chocolate production and as dried nuts (Saruhan and Tuncer, 2010).

It has been reported that cimiciate damage reduces the total fat, saturated fatty acids (SFA), and single SFA levels in the Italian hazelnut cultivar Tonda di Giffoni (Memoli *et al*., 2017). Neverthless, information regarding the effects of pests on the chemical properties of Turkish hazelnut cultivars is extremely limited. Therefore, this study was conducted to determine the effect of GD on the qualitative traits and kernel composition on "Tombul", the most widely used hazelnut cultivar in Turkey.

2. MATERIALS AND METHODS

2.1. Kernel samples

The study was conducted on “Tombul” hazelnuts in 2018 from a single orchard, and nut samples were provided by Yavuz Gıda Sanayi ve Ticaret AŞ (Giresun, Turkey) (40°54′37.33″N, 38°26′17.23″E, and altitude 12 m). The average kernel moisture content was ~27.5% at the time of harvest (August 4 - August 5, 2018). The clusters were spread on the grass ground and dehydrated for 3 days (August 9 to August 12, 2018) to allow moisture loss (~21.52%). Then, the nuts were separated from their husks by hand. The samples were dried in the sun and the drying process continued until the moisture content was 6.45%.The samples (unshelled) were kept in a 2 kg vacuum polyethylene package (150 ± 8 µm thickness, 0.029 gm^{-2}/day oxygen permeability, 5 gm^{-2}/day water vapor permeability), and stored in a refrigerator (Bosch KDN53NW22N A, No-Frost, Germany) at 60-65% relative humidity and −5 °C temperature until oil extraction and further analysis.

2.2. Oil extraction

Hazelnut oil was extracted using a Ceselsan cold press oil extraction system (AISI3004, Ceselsan, Giresun, Turkey) (compression force: 10,000 kgf, pressure: 34.7 MPa, temperature: -5 °C to +45 °C, and capacity: 250 g kernel) (Turan, 2018a). The extracted hazelnut oil was stored in the freezer at −18 °C until analysis (Bosch KDN53NW22N A, No-Frost, Germany).

2.3. Proximate analysis

2.3.1. Moisture, protein, total lipid, ash, carbohydrate, and energy value

Moisture content is based on the Turkish Standards Institute (EN ISO 65-2000) -TS 3075/T1 hazelnut kernel standard (Turan, 2018b). Shredded hazelnuts (Fakir Motto 800 w, Germany) were dried at 105 °C until constant weight (Refsan RK 55, Kutahya, Turkey). The protein level was determined according to the AOAC standard method (N×6.25) with 0.5 g of sample using the macro Kjehldahl method (method 945.18B) (Velp UDK 149, Europe).,The fat level was determined according to the AOAC method (AOAC, 2000) with 5 g sample using Soxhlet extraction (110 °C) with petroleum ether (method 960.39) (Velp Ser 148, Milan, Italy). The total ash content was determined by gradual temperature increase (250-650 °C) and constant weight maintenance (AOAC, 923.03). The total carbohydrate content was calculated by subtracting other contents from 100% (Rezai *et al*., 2014) (1).

$$\text{Total carbohydrate} = 100\ \% - (\%\ \text{moisture} + \%\ \text{protein} + \%\ \text{fat} + \%\ \text{ash}) \quad (1)$$

The energy value was calculated using the following formula (Fernandes *et al*., 2019): (2).

$$\text{Energetic value}\left(\frac{\text{kcal}}{100\text{g}}\right) = 4\ \text{x}\ [(\%)\text{carbohydrate} + (\%)\text{protein}] + 9\ \text{x}\ [(\%)\text{lipid}] \quad (2)$$

2.4. Vitamin E

The vitamin E (tocopherol) composition of the samples was determined using the standard method described in AOCS Ce 8-89 (AOCS, 1997). One gram of extracted hazelnut oil was diluted with 10 mL hexane and the resulting mixture was injected into the HPLC instrument using a 0.45 µm PTFE syringe filter. It was analyzed by Shimadzu-Prominence LC-20A under the following HPLC conditions: column: C8 (250×4 mm) 5 µm, flow rate: 1 mL min, mobile phase: Hexane:Isopropyl alcohol (99:1), wavelength: 295 nm, column temperature: 25 °C.

2.5. Total phenolics

The total phenolic content was determined by modifying the Folin-Ciocalteu colorimetric method with a UV-visible spectrophotometer (Singleton *et al*., 1965). For analysis, 20 µL of sample extract was taken in a micro cuvette and 1.58 mL of purified water and 100 µL of Folin-Ciocalteu reagent were added. After 5 min, 300 µL of a saturated Na_2CO_3 solution were added. The solution was stored in a dark place for 2 h. After 2 h, the absorbance of the samples was determined at 760 nm simultaneously in triplicate. A calibration curve was created by using a set of solutions with 40, 80, 120, 160, 200, 250, and 300 mg gallic acid/L concentrations to calculate the results. The results were expressed as gallic acid equivalent (GAE).

2.6. Color ordinates

The color ordinates of the hazelnut kernels were determined by Hunter Lab Color Flex Ez color instrument (HunterLab, USA) as L* (lightness), a* (redness), and b* (yellowness). The colors of the samples were read following calibration to X:79.05, Y:84.02 and Z:89.03 (Mexis and Kontominas, 2009). The browning index (BI) was measured based on CIE L*a*b* coordinates, using the following formula (Marzocchi *et al*., 2017):

$$\text{BI} = 100 \times \left(\frac{\text{x} - 0.31}{0.17}\right) \quad (3)$$

$$\text{X} = \frac{(\text{a}^* + 1.75\text{L})}{(5.645\text{L} + \text{a}^* - 3.021\text{b}^*)} \quad (4)$$

2.7. Fatty acid analysis

To obtain fatty acid methyl esters (Turan, 2018a), 0.5 g oil was weighed in Erlenmeyer flasks, and 4 mL of iso-octane and 2 mL of methanolic KOH solution were added, followed by agitation for 30 s. The mixture was stored in a sealed container in a dark place for 6 min; 2 drops of 1% methyl orange indicator were added; and the mixture was then titrated with 1 M HCl solution until a pink color was developed. After it was kept for 15 min, the colorless layer formed on top of the mixture was put into glass vials and analyzed by GC. The composition of fatty acids was determined by gas chromatography with a flame ionization detector and TR-CN100 column (60 m × 0.25 mm I.D., 0.20 µm; Shimadzu GC-2010, Japan). Both injector temperature and detector temperature were set at 250 °C. The sample (1.0 µL) was injected and helium was used as the carrier gas at 200 kPa. The injection was made at a ratio of 1:100. The column

temperature was held at 90 °C for 7 min and then increased to 240 °C at 5 °C/min. Finally, it was maintained at 240 °C for 15 min. Fatty acids were characterized by comparison of the FAME mixture consisting of 37 standard components (Supelco 37 Component FAME Mixture, Cat. No. 18919-1AMP, Bellefonte PA, USA) based on their elution times (Turan, 2018b). SFA (saturated fatty acid), UFA (unsaturated fatty acid), MUFA (monounsaturated fatty acid), and PUFA (polyunsaturated fatty acid) were calculated by the following equations:

$$SFA = C14{:}0 + C16{:}0 + C17{:}0 + C18{:}0 + C20{:}0 + C22{:}0 \quad (5)$$

$$MUFA = C16{:}1 + C17{:}1 + C18{:}1 + C20{:}1 + C24{:}1 \quad (6)$$

$$PUFA = C18{:}2 + C183 \quad (7)$$

$$UFA = MUFA + PUFA \quad (8)$$

2.8. Oil oxidation parameters

Free fatty acidity (method Ca 5a-40) was determined by the AOCS Standard Method (AOCS, 2004), peroxide level (method Cd 8-53) by AOCS (AOCS, 2004) (Metrohm, Dosimat 799, Switzerland), and the Rancimat value by the Rancimat 743 device (Metrohm, Switzerland) (Velasco *et al*., 2004). The iodine value (IV) was calculated using the percentage of fatty acids (Belviso *et al*., 2017; Turan, 2019) (9).

$$IV = (C16{:}1 \times 1.901) + (C18{:}1 \times 0.899) + (C18{:}2 \times 1.814) + (C18{:}3 \times 2.737) \quad (9)$$

2.9. Oil quality indices

Data from the fatty acid profile analyses was used to evaluate the nutritional composition of the lipid fraction. Three oil quality indices were used: Index of atherogenicity (IA), index of thrombogenicity (IT) and hypocholesterolemic/ hypercholesterolenic fatty acid ratio (H/H). The IA (10) and IT (11) were calculated as described by Bezerra *et al*., (2017).

$$AI = \frac{C12{:}0 + 4 \times C14{:}0 + C16{:}0}{\sum MUFA + \sum FA\omega 6 + \sum FA\omega 3} \quad (10)$$

$$TI = \frac{C14{:}0 + C16{:}0 + C18{:}0}{(0.5 \times \sum MUFA) + (0.5 \times \sum FA\omega 6) + (3 \times FA\omega 3)} \quad (11)$$

The H/H (12) index was determined by Fernandez *et al.* (2019).

2.10. Statistical analysis

The experiment was conducted with three replicates based on the randomized block design. Descriptive statistics were determined by SPSS v. 22.0 (Armonk, New York: IBM Corp.). Statistical tests were performed using SAS-JAMP v. 10.0 (SAS Institute Inc., Cary, North Carolina, USA). Statistical differences were determined using the *t*-test. The differences among the results were determined at the levels of $p < 0.05$, $p < 0.01$, and $p < 0.001$.

3. RESULTS AND DISCUSSION

3.1. Proximate composition

Tombul hazelnut takes the first place in terms of quality among 18 hazelnut cultivars in Turkey; whereas the other cultivars are regarded secondary with respect to quality (Alaşalvar *et al*., 2010). The kernel of the Tombul cultivar content was determined to comprise 15.01% protein, 59.83% fat, 22.77% carbohydrate, and 2.39% ash by Seyhan *et al*., (2007); 4.63% moisture, 64.60% fat, 17.5% protein, 383.60 mg/100 g vitamin E, and 726.5 mg/100 g total phenolic substance by Köksal *et al*., (2006); 15.35% protein, 61.21% fat, 17.30% carbohydrate, 3.90% moisture, 2.24% ash, and 631 kcal/100g energy by Alaşalvar *et al*., (2009); and 61% fat, 16% carbohydrate, 14.9% protein, and 5.3% moisture by Memoli *et al*., (2017). In our study, the good kernel (GK) content was determined to contain 4.70% moisture, 54.21% fat, 15.00% protein, 23.91 g/100 g carbohydrate, 2.39% ash, 64.30 mg/kg vitamin E, 196.68 mg GAE/100 g total phenols, and 613.27 kcal/100 g energy (Table 1). Differences between bug-damaged and good kernel values were found to be statistically significant except for humidity ($p < 0.001$; Table 1). While total fat, ash, vitamin E, and energy values were higher, protein, carbohydrate, and total phenolic contents were lower in GK than in GD samples. Memoli *et al*., (2017) reported that damage caused by bugs affects the nutrient content of hazelnuts and cimiciate causes significant damage to hazelnuts. This damage is predictably caused by secretion during feeding in the developmental stages of the kernel and delay in growth (Figure 1A). Oil oxidation begins (Figure 1B) in the deformed kernel and changes in nutrient content occur.

$$\frac{H}{H} = \frac{C18{:}1 + C18{:}2 + C20{:}4 + C18{:}3 + C20{:}5 + C22{:}5 + C22{:}6}{C14{:}0 + C16{:}0} \quad (12)$$

TABLE 1. Effect of green shield bug damage on proximate composition, energetic value, and color ordinates of hazelnuts.

Parameters	Nut samples		Significant level
	Green shield bug damage	Good kernel	
Moisture (%)	4.77±0.29	4.70±0.17	ns
Total lipid (%)	46.23±0.01	54.21±1.41	**
Crude protein (%)	16.79±0.53	15.00±0.03	*
Total carbonhyrate (g/100 g)	30.48±0.01	23.91±0.01	***
Total ashes (%)	2.31±0.01	2.39±0.01	***
Vitamin E (mg/kg)	61.20±0.01	64.30±0.01	***
Total phenolics (mg GAE/100g)	262.42±0.01	196.68±0.01	***
Energetic value (kcal/100g)	576.31±1.62	613.27±11.27	**
Colour ordinates			
L* (Lightness)	58.46±0.01	58.85±0.01	***
a*(Redness)	2.95±0.01	3.16±0.01	***
b*(Yellowness)	11.23±0.01	10.99±0.01	***
Browning index (BI)	24.63±0.01	24.21±0.01	ns

Data represent the mean ± standard deviation of triplicate analyses (n=3). Differences were determined using the *t*-test. Significant level; *, **, *** and "ns" mean significance at p < 0.05, 0.01, 0.001 and "not significant", respectively, between green shield bug damage and good kernels.

Color is known to be an important parameter in the evaluation of hazelnuts (Marzocchi *et al*., 2017; Deng *et al*., 2018). The differences among the color ordinates were found to be statistically significant ($p < 0.001$) except for the browning index (BI), which is presented in Table 1 in detail. It was found that L* and a* levels were higher in the good kernel, whereas the b* level was higher in the bug-damaged nuts. The reason is that oil oxidation begins and progresses at places where bug damage occurs. Therefore, an increase in yellowness (Figure 1B), an indicator of oxidation in nuts, was noted.

3.2. Fatty acid profiles

Alaşalvar *et al*., (2010) reported that there is a generally high level of MUFA (78.10-87.26%), moderate level of PUFA 83.92-13.86%), and low level of SFA (7.46-9.59%) in hazelnuts, which is consistent with the reports of other studies (Alaşalvar *et al*., 2006; Turan, 2018a; Turan, 2019). It is known that hazelnut oil is preferred over olive, corn, and sunflower oil as it contains a higher level of UFA (Köksal *et al*., 2006; Alaşalvar *et al*., 2010) based on the scientific evidence that these fatty acids have a protective

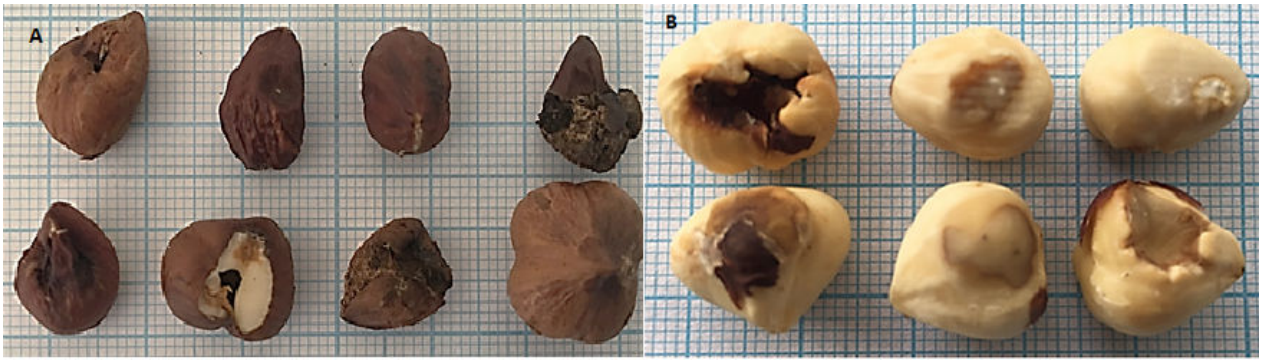

FIGURE 1. Effect of green sheld bug (*Palomena prasina* L.) damage on kernels (A, tumor, and/or spot kernel), and initial degree of oxidation (B, yellowing) of hazelnut oil

effect on the cardiovascular system (Uribe *et al*., 2018).

In our study, a total of 13 fatty acids were determined in the "Tombul" hazelnut, although 8 fatty acids were under the limit of detection (< 0.001%; Table 2). Palmitic, stearic, oleic, and linoleic fatty acids formed the major group; whereas myristic, margaric, arachidic, behenic, palmitoleic, heptadecanoic, eicosenoic, nervonic, and linolenic fatty acids formed the minor group. The fatty acids in the major group formed approximately 99.39% of the total fatty acids; whereas those in the minor group formed approximately 0.6% (Table 2). The effect of bug damage on fatty acid composition was found to be statistically significant except for margaric, behenic, and nervonic fatty acids ($p < 0.001$), which is presented in Table 2.

The effect of bug damage on SFA was found to be significant ($p < 0.001$) at 7.27% in the good kernels and 7.71% in the damaged kernels. As expected, there was a difference in the levels of palmitic and stearic major fatty acids which form the SFA. The primary fatty acid level of MUFA was 81.19% in the good kernels and 80.32% in the bug-damaged kernels. It is known that the primary fatty acid in the PUFA is linoleic acid. The effect of bug damage on linoleic acid was found to be statistically significant ($p < 0.001$; Table 2), with 11.12% in the good kernels and 11.60% in bug-damaged kernels. Telahigue *et al*., (2019) indicated that pathogens caused a decrease in fatty acids and SFA ranged between 1.82 and 0.41%, MUFA between 0.70 and 0.11% and PUFA between 2.67 and 0.38%. It was reported that this difference in PUFA is caused by the oxidation of linoleic and linolenic fatty acids (Memoli *et al*., 2017). Therefore, it should not be consumed in specific diets (Mostafavi *et al*., 2019). The effect of bug damage on UFA levels was found to be significant ($p < 0.001$). It was higher in the good kernels than in the bug-damaged kernels (92.65 and 92.29%, respectively, Table 2). It was reported that diseases and pests have an effect on the UFA/SFA ratio in hazelnuts, with 14.82% in good kernels, 16.13% in cimiciate and 15.96% in mold-effected kernels (Memoli *et al*., 2017). In our study, it was also found that bug damage has an impact on the UFA/SFA ratio ($p < 0.001$). However, it was found to be higher in the good kernels (12.74-11.98%). This difference has probably resulted from the different nutrient contents and/or various types of damage. In addition, it was stated that these differences may have been caused by the interaction of several factors such as altitude, latitude, longitude, temperature, precipitation, cultural practices, harvest time, and drying method (Koyuncu *et al*., 1997; Amaral *et al*., 2006; Cristofori *et al*., 2008; Alaşalvar *et al*., 2010; Turan *et al*., 2018b; Mostafavi *et al*., 2019).

3.3. Oxidation of hazelnut kernel oil

The oleic/linoleic acid ratio (O/L) is one of the essential characteristics used to evaluate the quality of hazelnut kernels, and linoleic acid is more sensitive to oxidation than oleic acid (Turan, 2019). Therefore, the high O/L ratio indicates resistance to oxidation (Belviso *et al*., 2017; Turan, 2018a). The effect of bug damage on the O/L ratio was found to be statistically significant ($p < 0.001$, Table 2), and O/L was higher in the good kernels (7.30%). Based on this, it can be concluded that bug damage (Figure 1A) causes oxidation in hazelnuts (Figure 1B). The iodine value (IV) is known as a measure of degree of unsaturation in fats and expressed as the amount of iodine absorbed (Belviso *et al*., 2017; Turan, 2018b). In addition, a high value of IV indicates that the content is unstable and more sensitive to oil oxidation. The effect of bug damage on IV was not found to be significant ($p > 0.05$). However, it was shown that good kernels had a lower level (93.59). In conclusion, it appears that good kernels have a longer shelf-life. Free fatty acids (FFA) are considered to be the first indicator of the lack of quality, and their level above FFA ≥1% indicates spoilage. In our study, there was a remarkable difference between FFA values in the good and bug-damaged kernels (oleic acid: 0.49, 2.62%, respectively, Table 2). Therefore, it can be concluded that bug damage results in oxidation in the nut, and these nuts cannot be purchased. The peroxide value (PV) is one of the crucial characteristics used to indicate the quality of products stored in the hazelnut industry (Turan, 2018a), and is also considered to be the most important indicator of PV oil oxidation. The effect of bug damage on PV was found to be statistically significant ($p < 0.001$), which is presented in Table 2 in detail. PV levels were noted as 21.58 $meqO_2 \cdot kg^{-1}$ in the bug-damaged kernels and 15.18 $meqO_2 \cdot kg^{-1}$ in the good kernels. It was highlighted that bug damage increased oil oxidation in nuts (Figure 1B). The rancimat value (RV) is a characteristic used to determine the shelf-life of hazelnuts (Turan, 2019).

TABLE 2. Effect of green shield bug damage on the fatty acid profiles, sum of fatty acids and oil oxidation of hazelnuts.

Fatty Acids (FA, %)	Nut samples		Significant level
	Green sheild bug damage	Good kernels	
Caproic acid (C6:0)	nd	nd	
Caprylic acid (C8:0)	nd	nd	
Capric acid (C10:0)	nd	nd	
Lauric acid (C12:0)	nd	nd	
Myristic acid (C14:0)	0.04±0.01	0.03±0.01	*
Palmitic acid (C16:0)	5.23±0.03	5.03±0.05	**
Margaric acid (C17:0)	0.06±0.01	0.05±0.00	ns
Stearic acid (C18:0)	2.24±0.01	1.99±0.02	***
Arachidic acid (C20:0)	0.09±0.00	0.12±0.00	**
Behenic acid (C22:0)	0.04±0.01	0.05±0.01	ns
Lignoceric acid (C24:0)	nd	nd	
Total saturated FA (ΣSFA)	7.71±0.03	7.27±0.05	***
Palmitoleic acid (C16:1)	0.10±0.00	0.05±0.00	***
Heptadecanoic acid (C17:1)	0.08±0.07	0.05±0.00	*
Oleic acid (C18:1)	80.32±0.12	81.19±0.09	***
Eicosenoic acid (C20:1)	0.05±0.00	0.08±0.01	*
Erucic acid (22: 1),	nd	nd	
Nervonic acid (C24:1)	0.04±0.01	0.05±0.01	ns
Total monounsaturated FA (ΣMUFA)	80.59±0.02	81.41±0.09	***
Linoleic acid (C18:2)	11.60±0.02	11.12±0.08	***
Linolenic acid (C18:3)	0.10±0.01	0.12±0.00	**
Eicosadienoic acid (20: 2)	nd	nd	
Docosadienoic acid (22: 2)	nd	nd	
Total polyunsaturated FA (ΣPUFA)	11.70±0.03	11.24±0.08	**
Unsaturated FA (UFA)	92.29±0.04	92.65±0.05	***
Unsaturated/saturated FA (UFA/SFA)	11.98±0.05	12.74±0.09	***
Oil oxidation parameters			
Oleic to linoleic acid (O/L)	6.93±0.01	7.30±0.06	***
Iodine value (IV)	93.71±0.07	93.59±0.07	ns
Free fatty acid (FFA; %, Oleic acid)	2.62±0.33	0.49±0.04	***
Peroxide value (PV, meq $O_2 \cdot kg^{-1}$)	21.58±0.22	15.18±0.20	***
Rancimat value (RV, h)	5.53±0.01	8.21±0.01	***

Data represent the mean ± standard deviation of triplicate analyses (n=3). nd: Not detected (< 0.001%). Differences were determined using the *t*-test. Significant level; *, **, *** and "ns" mean significance at $p < 0.05$, 0.01, 0.001 and "not significant", respectively, between green shield bug damage and good kernels.

Table 2 shows that the RV value is higher (8.21 h) in the good kernels. Thus, the rancimat value of the nuts is decreased due to bug damage and the shelf-life is expected to be shortened.

3.4. Quality indices

Generally, the effect of bug damage on the quality index was found to be significant, which is presented in Table 3 in detail. The effect of bug damage on the PUFA/MUFA ratio was not found to be significant ($p > 0.05$, Table 3). Consumption of low levels of SFA and high levels of PUFA/SFA is associated with a low risk of heart attack (Chan and Matanjun, 2017); therefore, this characteristic is used to determine the quality of the fat fraction in foods. The PUFA/SFA ratio is generally considered to indicate the quality of fats in a diet program (Telahigue *et al*., 2019), and values lower than 0.45 are not desirable owing to their ability to increase blood cholesterol. In our study, although the bug damage decreased the PUFA/SFA level, it was determined to be above the threshold (1.52-1.55) and higher in the good kernels (1.55, Table 3). This characteristic was reported to be 1.46 in fish (Telahigue *et al*., 2019); therefore, it can be confirmed that its amount is lower in fish than in hazelnuts. In fact, this aspect of the evaluation of hazelnuts suggested that they are a valuable nutrition source for humans. Atherogenicity (AI) and thrombogenicity index (TI) levels should approach zero (Bezerra *et al*. 2017) because this trend represents an increase in anti-atherogenic fatty acids, which has an effect on preventing heart disease. The AI (0.16) and TI (0.15) levels in the good kernels were determined to be lower than those in the bug-damaged kernels. It has been indicated that the H/H ratio is associated with the cholesterol mechanism (Fernandes *et al*., 2019) and a higher level of this ratio has a positive effect on human health. In our study, the H/H ratio (18.27) was found to be higher in the good kernels than that in the bug-damaged kernels. Based on the findings of this study, it is suggested that bug damage has a negative effect on the nut quality index values. Therefore, in case of bug-damaged hazelnuts being consumed, their expected effect on the cardiovascular system and cholesterol mechanism would not be observed.

4. CONCLUSIONS

To our knowledge, this is the first report in the literature regarding the effect of GD on nutrient content, fatty acid composition, oil oxidation, and food quality index of "Tombul" hazelnuts. In this study, the effect of bug damage was found to be statistically significant. Bug damage caused decreased UFA and UFA/SFA ratio levels. In addition, it resulted in lipid oxidation, thereby leading to decreased O/L and RV values and increased IV, FFA, and PV levels. Moreover, this oxidation also caused increased AI and TI levels and a decreased H/H ratio.

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TABLE 3. Effect of green shield bug damage on oil quality indices of hazelnuts.

Indices	Nut samples		Significant level
	Green shield bug damage	Good kernels	
Polyunsaturated (PUFA)/ Monounsaturated (MUFA)	0.15±0.00	0.14±0.00	ns
Polyunsaturated (PUFA)/ Saturated (SFA)	1.52±0.00	1.55±0.01	*
Atherogenicity index (AI)	0.23±0.02	0.16±0.02	***
Thrombogenivity index (TI)	0.16±0.00	0.15±0.00	*
Hypocholesterolemic/ Hypercholesterolemic (H/H)	17.45±0.11	18.27±0.16	**

Data represent the mean ± standard deviation of triplicate analyses (n=3). Differences were determined using the *t*-test. Significant level; *, **, *** and "ns" mean significance at $p < 0.05$, 0.01, 0.001, and "not significant", respectively, between green shield bug damage and good kernels.

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