

GREEN HUSK AND INSHELL BIOMASS PRODUCTION CAPABILITIES OF SIX WALNUT CULTIVARS

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Abstract

In this study, to determine fruit biomass production capability of walnut, three components (green husk, inshell and whole green fruit) of six different walnut cultivars (Fernette, Pedro, Kaman-1, Franquette, Fernor and Chandler) were investigated. Biomass values of fruit parts were determined by weighting. Samples were picked from trees of cultivars as green walnut at optimum harvest dates. Fresh green walnut biomass values of cultivars were determined after harvest. Then fresh and dry biomass values of green husk (hull) and inshell walnut were determined separately. To determine differences in biomass partitioning in fruits of cultivars, ratios between green husk and inshell walnut biomass values were calculated. Obtained data were statistically analyzed to compare cultivars. Green husk and inshell biomass partitioning were found significantly different between cultivars. Green husk biomass partitioning in Franquette cultivar was found the highest and inshell biomass partitioning was found the highest in Chandler cultivars. Results show that cultivars produce 16.95 % and 33.94 % dry green husk biomass for every unit dry inshell biomass.

Key words: walnut, green husk, inshell, biomass, inshell-husk ratio

1. INTRODUCTION

Walnut (*Juglans regia* L.) is an important deciduous tree grown natively and commercially in temperate areas of world. Walnut trees are grown for two main purposes in the world, quality timbers and nuts. Nuts of walnut are important in human life primarily for kernels that have high nutrition capacity due to high unsaturated fatty acid, digestible protein and dietary fiber contents. Conventionally, different parts of walnut trees and fruits are used for various purposes in the world. Green walnuts at early stage of fruit development have been used in special liquor production (Stampar et al., 2006), green husks (mesocarp) and leaves are used in both cosmetic and pharmaceutical industries (Ribeiro et al., 2015, Pereira et al., 2007), hard shells of nuts (endocarp), dividing membranes of kernels (pellicle), flowers, roots, trunk (bark and wood), branches and leaf of tree could have a chance to use (Vassilev et al., 2012, Sharma et al., 2014, Taha and Al-wadaan, 2011). Walnut trees, especially in aspect of cultivars, have differences at tree vigor, growth habit, density of branches and number of both male and female flowers, and also produce different nuts in size, shape, weights, shell thicknesses and kernel ratios (UPOV, 2017). So these differences between cultivars cause biomass production at different characteristics and quantities from different parts of tree. Walnut trees produce both wood and woody biomasses from stems, branches, roots and herbaceous and agricultural biomasses from leaves, flowers and nuts (Vassilev et al., 2012).

Green husk (hull) and hard shell of nuts are important by-products of walnut production with other biomasses obtained from tree. They are closely related with each other and come out as the result of nut production. They have different biomass characteristics from each other in terms of content, utilization, accessibility and distribution. Walnut hard shells are subject to further investigations for different utilization forms because of their higher accessibility (Demirbas, 2002, Demirbas et al., 2006). Although, green husks of walnut have many traditional use by the public (Taha and Al-wadaan, 2011) and new possibilities for utilization in different industries have been reported recently (Hong-ping, 2013), hard shell biomass obtained from nuts have advantages in utilization when compared to green husk (Srinivasan and Viraraghavan, 2008, Demirbas et al., 2006, Tay et al., 2009). Due to high calorific values, hard shells are traditionally used for direct heating in rural areas but green husks are not used as energy source (Ozturk and Bascetincelik, 2006). There are restricted number of studies on determination

of green husk calorific values for energy uses (Miles et al., 1995, ECN, 2017, Buyukada, 2017, Vassilev et al., 2010). Also, data on elemental characterization and utilization of green husk biomass is considerably less than walnut shell (ECN, 2017, Buyukada, 2017, Brosowski et al., 2016). Botanically, green husk is the outer epicarp (mesocarp) of the walnut fruit and contains high amounts of phenolics (Labuckas et al., 2008, Akbari et al., 2012, Cosmulescu et al., 2011). Thirteen different phenolics were detected in walnut husks including chlorogenic acid, caffeic acid, ferulic acid, sinapic acid, gallic acid, ellagic acid, protocatechuic acid, syringic acid, vanillic acid, catechin, myricetin and juglone with HPLC/DAD and also was identified the juglone that major phenolic in the husks with the highest content (Stampar et al., 2006). Since, phenolic compounds especially juglone in green husk show allelopathic effects on many field and horticultural crops, direct use of green husk as mulch or compost material is limited (Rietveld, 1983, Willis, 2000, Ercisli et al., 2005, Ciniglia et al., 2012, Radix et al., 1992). Due to radical scavenging (Oliveira et al., 2008, Samaranayaka et al., 2008) and antimicrobial effects (Zoral and Turgay, 2014, Fernandez-Agullo et al., 2013) of antioxidants in the green husk, it is reported that they can be used as natural antioxidants and alternative to synthetic antioxidants in foods by extraction and purifying (Pereira et al., 2007, Zhang et al., 2009). But, utilization of green husk and derivatives as food additive still requires more researches and advanced technology. According to the literature review, the best and successful utilization way of green husk as a biomass in large quantities seems sorption process to remove unwanted materials (Godini et al., 2016) and heavy metals from polluted water (Celekli et al., 2012, Wang et al., 2009, Celekli et al., 2016, Feizi and Jalali, 2015).

The amounts of biomass produced by the trees are important in calculating the total biomass quantities, waste values (Maragkaki et al., 2016) and waste/product ratios as well as in introducing evaluation alternatives for them (Yokoyama and Matsumuya, 2008). Knowledge of real nut biomass values from walnuts and their components is essential requirement for estimation of biomass quantities of husk, hard shell and kernel. There is a lack of information and uncertainties in quantity of walnut green husk biomass (Brosowski et al., 2016, Maragkaki et al., 2016). The estimations of green husk biomass quantities are being made upon undetermined and unreliable data. Walnut cultivars or genotypes show different characteristics in nut size, green husk size and thickness so they produce biomass in different quantities. As a biomass, how much hard shell could be obtained from in-shell walnut is determinable because the hard shell amounts are calculated in-directly when calculating kernel ratio in quality assessment and yield efficiency of cultivars. Walnut shell amounts differ between 30 % and 70 % of inshell walnut depending on genotype or cultivar and a ratio of 50 % is accepted for hard shell biomass calculation in walnuts (Ünal, 2005). So, it can be estimated that how much hard shell is produced depending on the inshell walnut production. However, it is not clearly known how much green husk is produced from walnut production activities. The total walnut growing areas are increasing considerably in Turkey and also in the world, (FAOSTAT, 2014, TUIK, 2016). Walnut production quantities has been increasing much faster with the use of high yielded lateral fruitful and late leafing cultivars such as Chandler and Fernor cultivars. Undoubtedly, this increase will lead to an increase in wastes and by-products from walnut production.

In this study we have mainly focused on determining the amount of walnut green husk as a biomass depending on inshell biomass. No study was found to have characterize walnut biomass quantities in whole green walnuts, the amount of green husk and its relation to inshell walnut production for biomass quantity calculations and predictions in cultivar base. The objectives of this study were the following: (1) To determine the relationships between green husk, inshell and whole walnut by obtaining fresh and dry biomass values, (2) to obtain practical ratios between fresh and dry biomass values for predicting the green husk and inshell quantities for each cultivars, (3) to determine the difference between cultivars in green husk production capability.

This knowledge can provide benefits for farmers in determining harvest strategies and applications and in managing wastes, for walnut traders that buy green walnuts in price-setting and for scientist that will make projects for utilization.

2. MATERIAL AND METHODS

2.1. Collecting of samples

Green walnuts of Fernette, Pedro, Kaman-1, Franquette, Fernor and Chandler cultivars obtained from CevizBağı orchards located in Kaman, Kırşehir, Turkey (CevizBagi, 2016) at 2016 harvest season were used to conduct this study. The samples were collected manually from 3 trees of each cultivar at optimum harvest dates in October 2016 (Table 1). Bulk green walnut samples weighted between 4-5 kg were taken from four different directions with changing heights to represent each tree. Green walnut samples included nuts with intact, early-split and partially split husk.

Table 1. Harvest dates of cultivars

<i>Cultivars</i>	<i>Harvest Date</i>
Fernette	20 October 2016
Pedro	12 October 2016
Kaman-1	5 October 2016
Franquette	17 October 2016
Fernor	16 October 2016
Chandler	14 October 2016

2.2. Determination of biomass values

Collected samples were placed into the plastic bags, labeled and weighted immediately to obtain *Total Fresh Green Walnut Biomass* (TFGWB) values. Then, green husks were removed manually from fresh green walnuts. *Fresh Inshell Biomass* (FISB) and *Fresh Green Husk Biomass* (FGHB) values were determined by weighting with a precise electronic balance. Fresh inshell walnuts and separated fresh green husks were left to natural drying in plastic cases for 3 day at room temperature. Inshell walnuts were dried in oven at 42 °C for 3 days, green husks were dried at 65 °C for 6 days until obtaining a constant dry weight. So that, *Dry Inshell Biomass* (DISB) and *Dry Green Husk Biomass* (DGHB) values determined. *Total Dry Biomass* (TDB) values were obtained by summing of *Dry Inshell Biomass* (DISB) and *Dry Green Husk Biomass* (DGHB) values.

2.3. Calculations and statistical analyses

To determine biomass partitioning in fresh and dry basis, percentages (%) of fresh biomass values of 1-Fresh Inshell Biomass / Total Fresh Green Walnut Biomass, 2-Fresh Green Husk Biomass / Total Fresh Green Walnut Biomass, and percentages of dry biomass values; 3-Dry Inshell Biomass / Total Dry Biomass, 4-Dry Green Husk Biomass / Total Dry Biomass, were calculated.

For dry biomass estimations from fresh biomasses, percentages of dry and fresh biomass values of 5-Dry Inshell Biomass / Fresh Inshell Biomass, 6-Dry Green Husk Biomass / Fresh Green Husk Biomass, 7-Total Dry Biomass / Total Fresh Green Walnut Biomass were calculated.

For practical biomass estimation calculations, ratios of fresh/ dry and dry/fresh biomass values of 8-Fresh Green Husk Biomass / Fresh Inshell Biomass, 9-Dry Green Husk Biomass / Dry Inshell Biomass, 10-Dry Inshell Biomass / Total Fresh Green Walnut Biomass, 11-Dry Green Husk Biomass / Total Fresh Green Walnut Biomass were calculated in each cultivar.

All calculated percentages for cultivars were statistically analyzed according to the Completely Randomized Design (CRD), One Way ANOVA at P<0.05 confidence level with Tukey's test for multiple pairwise comparisons by using Minitab® Release 17.1.0 software for Windows®.

3. RESULTS AND DISCUSSION

Percentages of green husk and inshell walnuts to total walnut biomass values in six cultivars were tabulated in Table 2 in fresh and dry bases. *Fresh Green Husk Biomass* (FGHB) values were found to constitute a significant proportion of *Total Fresh Green Walnut Biomass* (TFGWB). FGBH values were higher than FISB values in all cultivars at the time of harvest except of Chandler cultivar. FISB/TFGWB and FGBH/TFGWB percentages were found statistically different ($P < 0.05$) between cultivars. The highest FGBH/TFGWB percentage was obtained from Kaman 1 (65.37 %) cultivar and the lowest percentage from Chandler (43.22 %) cultivar. Since, these percentage values complement each other to 1.00, the highest FISB/TFGWB percentage value was found in Chandler (56.78 %) cultivar and the lowest in the Kaman 1 (34.63 %) cultivar as expected.

In dry base, the percentages of green husks and inshell walnut biomass to *Total Dry Biomass* (TDB) has changed remarkably when compared to fresh basis. DISB/TDB and DGHB/TDB percentages were also found statistically different ($P < 0.05$) between cultivars. The highest DISB/TDB percentage was found in Chandler cv. (85.61 %) and the lowest was found in Franquette cv. (74.89 %) and as expected the highest DGHB/TDB percentage was found in Franquette cv. (25.11 %) and the lowest was found in Chandler cv. (14.39 %). It can be seen that inshell biomass values form a significant part of the TDB, while green husk biomass constitute less than harvest time (Table 2). This change is mainly the result of the different moisture content of fruit parts. Khir et al. (2013), reported that green husks contained more moisture than hard shell, and hard shells contained more moisture than kernels in three walnut cultivars including Chandler. Also in this study, we found that green husks of cultivars contained higher amount of moisture than inshell (shell and kernel) walnut (Table 2). Moisture losses in cultivars after drying have occurred at different levels depending on the differences in biomass amounts of green husk, hard shell and kernel, and as well as moisture contents of this parts (Table 2, 3). Although, husk thicknesses of green whole walnuts were not measured in this study, it was observed that green husk layers of Kaman-1 and Franquette were thicker than other cultivars.

Table 2. Percentages of green husk and in-shell biomass to total walnut biomass of six cultivars in fresh and dry bases.

Cultivars	Fresh Inshell Biomass / Total Fresh Green Walnut Biomass (%) ***	Fresh Green Husk Biomass / Total Fresh Green Walnut Biomass (%) ***	Dry Inshell Biomass / Total Dry Biomass (%) ***	Dry Green Husk Biomass / Total Dry Biomass (%) ***
Fernette	44,68 ± 0,86 b	55,32 ± 0,86 b	78,52 ± 0,64 bc	21,48 ± 0,64 ab
Pedro	42,27 ± 0,79 bc	57,73 ± 0,79 ab	77,54 ± 0,62 bc	22,47 ± 0,62 ab
Kaman-1	34,63 ± 2,20 c	65,37 ± 2,20 a	80,51 ± 1,40 b	19,49 ± 1,40 b
Franquette	36,35 ± 2,64 bc	63,65 ± 2,64 ab	74,89 ± 2,19 c	25,11 ± 2,19 a
Fernor	37,92 ± 0,75 bc	62,08 ± 0,75 ab	78,73 ± 0,55 bc	21,28 ± 0,55 ab
Chandler	56,78 ± 2,76 a	43,22 ± 2,76 c	85,61 ± 0,82 a	14,39 ± 0,82 c
Mean	42,85 ± 1,32	57,15 ± 1,32	79,71 ± 0,63	20,29 ± 0,63

Means with the same letter are not significantly different. Comparisons significant at the 0.05 level are indicated by ***

DISB/FISB, DGHB/FGHB and TDB/TFGWB percentages were presented in Table 3. DISB/FISB, DGHB/FGHB and TDB/TFGWB percentages were found statistically different ($P < 0.05$) between cultivars. On close inspection, it can be seen that the complements of the percentages at Table 3 reflect

the moisture content of the biomasses at harvest time. Franquette cultivar was determined the highest DISB producing cultivar for per unit of FISB, while Fernette was the lowest. Investigated walnut cultivars showed statistically significant difference in DGHB/FGHB percentages. Chandler has the highest percentage of DGHB/FGHB while Kaman-1 has the lowest. In another way, it can be said that green husk of Chandler cv. has the lowest moisture content and Kaman-1 cv. has the highest, among cultivars. Khir et al. (2013) had reported the moisture contents of the husks of three walnut cultivars in % weight basis. If their results are evaluated indirectly, dry matter contents of green husks were changed between 12.1 % (Howard cv.) and 14.7 % (Chandler cv.) (Khir et al., 2013). We have determined DGHB/FGHB percentages (ratio of fresh and dry weight) between 8.62 % (Kaman-1) and 14.79 % (Chandler) with a mean of 12.2 % (Table 3). Percentage that we had determined for Chandler is almost same with that study. TDB/TFGWB percentages were found also statistically different between cultivars. These percentages reflect the total moisture contents of harvested whole green walnuts. TDB/TFGWB percentage of Chandler cv. were found higher than other cultivars.

Table 3. Percentages of dry biomasses to fresh biomasses in six cultivars

Cultivars	Dry Inshell Biomass / Fresh Inshell Biomass (%) *	Dry Green Husk Biomass / Fresh Green Husk Biomass (%) *	Total Dry Biomass / Total Fresh Green Walnut Biomass (%) *
Fernette	56,01 ± 0,25 d	12,33 ± 0,09 bc	31,86 ± 0,47 b
Pedro	61,61 ± 0,92 c	13,06 ± 0,38 ab	33,62 ± 0,93 b
Kaman-1	69,55 ± 2,01 ab	8,62 ± 0,11 d	29,69 ± 1,48 b
Franquette	74,55 ± 2,05 a	13,69 ± 0,23 ab	36,13 ± 2,46 b
Fernor	67,42 ± 0,66 b	11,09 ± 0,18 c	32,44 ± 0,50 b
Chandler	66,47 ± 0,73 b	14,79 ± 0,81 a	43,91 ± 1,86 a
Mean	66,08 ± 0,87	12,62 ± 0,37	35,12 ± 0,88

Means with the same letter are not significantly different. Comparisons significant at the 0.05 level are indicated by ***

Ratios between fresh and dry biomass values of different walnut fruit parts that can be useful for prediction of green husk and inshell quantities were presented in Table 4. FGHB value was found 1.96 times greater than FISB value in Kaman-1 and 1.24 times greater in Fernette cultivar. This rate was 0.83 in Chandler cultivar because FISB value was greater than FGHB value. The ratios of FGHB/FISB have a practical importance for harvest strategies and applications by obtaining quick and simple evaluation of green husk and inshell weights. Results emphasize that a great part of energy used in post-harvest operations is spent for dealing with green husk. So that, hulling process should be done at the nearest distance, and also the delivery of matured whole green walnuts to distant locations for sale or processing is not economical due to energy costs. DGHB/DISB ratios are important for estimating the amount of green husk biomass depending on the dry inshell walnut biomass in cultivar basis. In other words, if we accept the inshell walnuts as main (marketable) product, this ratio gives us waste/product ratio for biomass evaluations. Results of DGHB/DISB ratios show that cultivars investigated in this study produce 16.95 % (Chandler) and 33.94 % (Franquette) dry green husk biomass for per unit dry inshell biomass. This means that an average of 250 kg of green husk waste or by-product are produced for every ton of marketable walnut in walnut production. DISB/TFGWB ratios can be useful for walnut traders or orchard owners and machinery designers in determining hulling machine capacities. A trader can calculate DISB value at the time of harvest and set up a price according to these ratios. DGHB/TFGWB ratios can be used for estimation and calculations of DGHB values in relation to the harvest quantities.

Table 4. Ratios and percentages of two biomasses in fresh and dry base

<i>Cultivars</i>	<i>Fresh Green Husk Biomass / Fresh Inshell Biomass (%) *</i>	<i>Dry Green Husk Biomass / Dry Inshell Biomass (%) *</i>	<i>Dry Inshell Biomass / Total Fresh Green Walnut Biomass (%) *</i>	<i>Dry Green Husk Biomass / Total Fresh Green Walnut Biomass (%) *</i>
Fernette	124,37 ± 4,24 cd	27,41 ± 1,03 ab	25,04 ± 0,57 b	6,82 ± 0,18 bc
Pedro	137,15 ± 4,25 bc	29,03 ± 1,03 ab	26,09 ± 0,89 b	7,53 ± 0,26 b
Kaman-1	196,20 ± 16,80 a	24,45 ± 2,03 c	24,04 ± 1,70 b	5,64 ± 0,18 d
Franquette	183,80 ± 17,20 ab	33,94 ± 3,60 a	27,43 ± 2,78 b	8,71 ± 0,35 a
Fernor	164,83 ± 5,04 abc	27,09 ± 0,89 ab	25,56 ± 0,54 b	6,88 ± 0,12 bc
Chandler	82,70 ± 12,70 d	16,95 ± 1,13 c	37,73 ± 1,85 a	6,18 ± 0,25 cd
Mean	144,69 ± 6,92	25,84 ± 1,20	28,22 ± 0,92	6,90 ± 0,15

Means with the same letter are not significantly different. Comparisons significant at the 0.05 level are indicated by ***

4. CONCLUSION

With this study, it was revealed that green husk biomass are produced in different amounts by walnut cultivars. Reference values were obtained for traders, orchard owners and scientist to be able to use in biomass calculations by using fresh and dry biomass values of nut parts. Calculation of regression equations or developing new models may be useful for precise estimation of green husk and shell biomasses in cultivar basis. Green husk biomass quantities obtained from walnut cultivars are quite high as to be considered. There is a low utilization ratio of green husk and it is in the position of agricultural waste. That's why green husks are accumulated and left to natural deterioration in orchards or spread to the soil that can cause phytotoxicity. New management policies and strategies must develop for walnut green husks. Therefore, priority should be given to ways of utilization or disposing of this biomass by scientific studies. This will bring extra income to walnut producers and prevent negative effects of green husk accumulation on orchards.

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