Brief Report

Physical Trait Variation in Hass Avocados Across Different Fruit Sizes

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Abstract

Hass avocados are globally consumed, nutrient-rich fruits. While current analyses mainly benefit the industry, there is a need for research focused on consumer advantages. Understanding the statistical relationships between the physical characteristics of avocados, particularly pulp content, can help consumers make better purchasing decisions. This study examines the physical attributes of Hass avocados and their relationship with fruit weight over a wide range of weights. Our findings reveal a strong correlation between the absolute weight of the avocado and its pulp weight ($R^2 = 0.9878$). The pulp proportion remains nearly constant across different avocado weights. This constancy is explained by the compensatory relationship between the seed and peel weights, shown by the quasi-mirror-like inverse regression lines (similar coefficients with opposite signs). The regression coefficient for pulp proportion as a function of fruit weight is 10^{-5}, indicating a marginal increase in pulp mass with heavier avocados. Thus, while we can recommend purchasing larger Hass avocados based on this data, price considerations are crucial. In Chile, for instance, larger Hass avocados are more expensive, almost double the price, and the slight increase in pulp content does not justify the price difference.

Keywords: pulp content, seed weight, peel weight

Introduction

Avocado is a nutrient-rich fruit abundant in compounds with recognized health benefits (Dreher and Davenport, 2013; Duarte et al., 2016; Jimenez et al., 2021; Dreher et al., 2021; Ford et al., 2023), including anti-carcinogenic effects (Ding et al., 2007; Ericsson et al., 2023). Mexico is the leading avocado producer, followed by Colombia and Perú, while the United States of America is the primary importer ("Avocado Yearbook 2023 English Version Compressed,"). Latin Americans are the foremost avocado consumers, with the Dominican Republic being the most important, followed by Colombia, Mexico, and Chile ("Avocado Yearbook 2023 English Version Compressed,"). The case of Chile is noteworthy, as Hass avocado consumption there has risen from 4.3 kilograms per person in 2019 to 8.2 kilograms per person in 2023 ("Avocado Yearbook 2023 English Version Compressed,"). Although there are different avocado varieties, Hass avocado represents approximately 80% of all avocados consumed worldwide.

By measuring the physical characteristics of avocados, we have learned about the variation of the three components in different varieties. For example, among 24 avocado varieties surveyed, Tango et al. (2004) reported that pulp content ranges from 52,9% (Mac Donald variety) to 81.3% (Quintal variety), with an average of 68.6% ± 6.3 (Tango et al., 2004). The seed contribution varies from 10,1% (Quintal variety) to 25,1% (Waldin variety), with an average of 17.4% ± 4.1 (Tango et al., 2004). In comparison, the peel ranges from 8,6% (Quintal variety) to 22,9% (Mac Donald variety), with an average of 14% ± 4.2 (Tango et al., 2004). Regarding the Hass avocado, its pulp content is located at place 10, with an average value of 67,5%, not very different from the average of all varieties (Tango et al., 2004). The contribution of the seed and peel is 19% and 13,5%, respectively (Tango et al., 2004). In a more recent study, Mendez Hernandez et al. (2024) characterize the Hass avocado produced in different localities on the island of Tenerife (Méndez Hernández et al., 2024). Their Hass avocado weights average 239 ± 54 g (N=50), and their proportion of pulp is not very different (70.6% ± 4.7), although a little bit higher compared to the value reported by Tango et al. (2004). With similar fruit weights, between 184 and 243 g (N = 400), Henao-Rojas et al. (2019) reported similar values for the percentage of pulp (69.56% ± 2.3), seed (16.8% ± 1.7), and peel (13.45% ± 1.1) (Henao-Rojas et al., 2019). Working with bigger Hass avocados (mean 310.25 ± 17.44 grams, N=24), Rodriguez-Carpena et al. (2011) reported a higher proportion of pulp, 75.85%, and lower values for the seed (13.04%) and peel (11.11%) compared

to the other studies (Rodríguez-Carpena et al., 2011). A similar value for the percentage of pulp (77.8% g ± 0.4), a higher proportion of seed (14.6% ± 0.3), and a lower for the peel (7.6% ± 0.3) was obtained by Rozan et al. (2019) working with Hass avocados between 100 and 300 g (N = 3) (Rozan et al., 2021).

While this information is mainly helpful for the industry, consumers would benefit from understanding the variations within the Hass avocado variety. Knowing the contribution of the different components of the Hass avocado, especially from the amount of pulp across different weights and price information, would help consumers make better buying decisions. Thus, our work aims to help Hass avocado buyers by describing the physical characteristics of the Hass avocado (peel, seed, and pulp) and their statistical relationships with the fruit weight. To do this, we analyzed a sample of 327 Hass avocados, with a weight variation of almost an order of magnitude from 51 to 473 g. Our results show a strong correlation between the absolute weight of the Hass avocado and the pulp weight, where approximately 98.78% of the variability in the weight of the pulp can be explained by the weight of the Hass avocado. By analyzing the proportions of the different components of the fruit, we also found that as the Hass avocado becomes heavier, the mass of the pulp slightly increases.

Materials and Methods

The 327 Hass avocados were obtained in different markets in Valdivia City, Chile, between 2021 and 2024. Each avocado was weighed in a balance with a systematic gram error. Each avocado was cut in two halves; its seed was removed, and the pulp was carefully cleaned from the peel. Then, the seed and peel were weighed. The pulp weight was estimated as the total weight minus the weights of the seed and the peel. This matrix of 327x4 values constitutes our raw data table (Supplementary File S1). As a pretreatment of the data, additional variables derived from the raw weights were created in the table for posterior analysis. These include the weight proportions of the pulp, seed, and peel weights with respect to the absolute weight of the Hass avocado.

Descriptive statistics of the variables were followed by a correlation matrix. This matrix guided the selection and generation of the following regression models: The absolute weight of the pulp as a function of the absolute weight of the fruit, and the regression models of the proportions of the weights of the pulp, seed, and peel also as a function of the absolute weight of

the fruit. Additional histograms, analysis of variance (ANOVA) of the models, as well as validation of the assumptions of the models are included in Supplementary File S2. All statistical analyses were carried out using R software (https://www.R-project.org/). The figures for publication, which include plots and regression lines, were created using Microsoft Excel and Inkscape software (https://inkscape.org/).

Results and Discussion

Our study examined 327 Hass avocados from Valdivia, Chile, which exhibited a wide range of weights. The weight of the fruit ranged from 51 to 473 g, with an average of 187.46 ± 84.25 grams. The weight of the seed ranged from 1 to 87 g, with an average of 24.76 ± 14.21 grams (13.21%). This value is, in general, lower compared to other studies (Tango et al., 2004; Henao-Rojas et al., 2019; Méndez Hernández et al., 2024), although similar to the value reported by Rodríguez-Carpena et al. (2011), where 24 Hass avocados obtained from a supermarket in Madrid were measured (Rodríguez-Carpena et al., 2011). The peel weight ranged from 9 to 45 g, averaging 23.26 ± 7.49 grams (12.41%), a value not different from other studies (Tango et al., 2004; Henao-Rojas et al., 2019; Méndez Hernández et al., 2024), although higher than the one reported by Rozan et al. (2021), which is the lowest (Rozan et al., 2021). The weight of the pulp ranged from 40 to 374 g, with an average of 140.5 ± 64.72 grams (74.95%). The value obtained in our study is in the range described for 24 avocado varieties, although higher than the average, and the value reported for the Hass variety (Tango et al., 2004). The value is also higher compared to two more recent studies (Henao-Rojas et al., 2019; Méndez Hernández et al., 2024). Finally, our result is similar to the values of Rodriguez-Carpena et al. (2011) (Rodríguez-Carpena et al., 2011) and Rozan et al. (2021).

Taking advantage of a range variation of almost an order of magnitude in the weight of our sample of Hass avocado, our first approach was to examine the relationship between the absolute weight of the fruit and the absolute weight of the pulp (Fig. 1, upper panel). After plotting the two variables, we tried different models: linear, exponential, logarithmic, and polynomial (order 2). Our results showed that the simple linear model shows the most significant coefficient of determination (R^2), 0.9878 (Fig 1, upper panel), indicating that approximately 98.78% of the variability in the weight of the pulp can be explained by the weight of the Hass avocado. They also

suggest that, on average, 76.81% of the Hass avocado corresponds to a pulp (Fig. 1, upper panel). This value differs slightly from the average (see above) because it is calculated differently. While the average 74.95% is the unbiased estimator of the center of the distribution of pulp weight proportion with respect to the total Hass avocado weight, the coefficient of the model, 76.81%, is an estimation of the slope of a regression line of the pulp absolute weight as a function of the total weight of the fruit. Although numerically different, both estimations are similar and convey the same underlying meaning. Thus, our analysis shows that the absolute weight of the Hass avocado is a strong predictor of the absolute weight of the pulp and that around three-fourths of the absolute weight of the fruit is pulp (Fig 1, upper panel).

Our next step was to analyze the proportions of the different components of the Hass avocado in relation to the weight of the fruit to see if different-weighted fruits have different proportions of their components, particularly the pulp, which is of consumer interest (Fig. 1, lower panel). As we see, the proportion of pulp remains nearly constant across the Hass avocado of different weights (Fig. 1, lower panel). A factor explaining this phenomenon is the compensation between the weight proportion of the seed versus the weight proportion of the peel, as evidenced by the quasi-mirror-like regression lines (similar coefficients with opposite signs) in the lower panel of Figure 1. The regression coefficient of the proportion of pulp as a function of the absolute weight of the fruit is 10^{-5} (Fig. 1 lower panel), which is barely statistically significant (t-test, p-value = 0.053). This indicates that as the Hass avocado becomes heavier, the mass of the pulp slightly increases. Specifically, the total mass of the pulp in an avocado is larger by 1 and 2 g when it is in the range of 320 to 450 g. While this change may seem insignificant for the average consumer, it could lead to significant savings for larger businesses, such as restaurants, if the prices of the Hass avocados of different weights are the same. However, the Chilean markets typically sell larger Hass avocados at almost double the price per kilogram compared to smaller Hass avocados. Thus, despite the potential for larger Hass avocados to offer more pulp, the price difference, particularly in Chile, makes it more convenient to buy smaller ones. This scenario also applies to the average consumer.

Conclusions

Our work shows that the weight of the Hass avocado is a strong predictor of the weight of the pulp and that around three-fourths of the weight of the fruit is pulp. Further, we also show as the Hass avocado becomes heavier, the mass of the pulp slightly increases.

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Author contribution

All authors contributed equally in all stages of this research

Supplementary Materials

Supplementary File S1. This Excel file contains the raw data table, including the Hass avocado, pulp, seed, and skin weights. It also includes the proportions with respect to the total and normalized weights.

Supplementary File S2. This R notebook contains the commands of the distributions, plots, regressions, and ANOVA results.

References

Avocado Yearbook 2023 English Version Compressed. calameo.com. https://www.calameo.com/read/007154470f00c74f47e06 (accessed 16 May 2024).

Ding, H., Y.-W. Chin, A.D. Kinghorn, and S.M. D'Ambrosio. 2007. Chemopreventive characteristics of avocado fruit. Semin. Cancer Biol. 17(5): 386–394.

Dreher, M.L., F.W. Cheng, and N.A. Ford. 2021. A Comprehensive Review of Hass Avocado Clinical Trials, Observational Studies, and Biological Mechanisms. Nutrients 13(12). doi: 10.3390/nu13124376.

Dreher, M.L., and A.J. Davenport. 2013. Hass avocado composition and potential health effects. Crit. Rev. Food Sci. Nutr. 53(7): 738–750.

Duarte, P.F., M.A. Chaves, C.D. Borges, and C.R.B. Mendonça. 2016. Avocado: characteristics, health benefits and uses. Cienc. Rural 46(4): 747–754.

Ericsson, C.I., L.S. Pacheco, A. Romanos-Nanclares, E. Ecsedy, E.L. Giovannucci, et al. 2023. Prospective Study of Avocado Consumption and Cancer Risk in U.S. Men and Women. Cancer Prev. Res. 16(4): 211–218.

Ford, N.A., P. Spagnuolo, J. Kraft, and E. Bauer. 2023. Nutritional Composition of Hass Avocado Pulp. Foods 12(13). doi: 10.3390/foods12132516.

Henao-Rojas, J.C., J.H. Lopez, N.W. Osorio, and J.G. Ramírez-Gil. 2019. Fruit quality in Hass avocado and its relationships with different growing areas under tropical zones. Rev. Ceres 66(5): 341–350.

Jimenez, P., P. Garcia, V. Quitral, K. Vasquez, C. Parra-Ruiz, et al. 2021. Pulp, leaf, peel and seed of avocado fruit: A review of bioactive compounds and healthy benefits. Food Rev. Int. 37(6): 619–655.

Méndez Hernández, C., A. Grycz, D. Rios Mesa, B. Rodríguez Galdón, and E.M. Rodríguez-Rodríguez. 2024. The Quality Evaluation of Avocado Fruits (Mill.) of Hass Produced in Different Localities on the Island of Tenerife, Spain. Foods 13(7). doi: 10.3390/foods13071058.

Rodríguez-Carpena, J.-G., D. Morcuende, M.-J. Andrade, P. Kylli, and M. Estévez. 2011. Avocado (Persea americana Mill.) phenolics, in vitro antioxidant and antimicrobial activities, and inhibition of lipid and protein oxidation in porcine patties. J. Agric. Food Chem. 59(10): 5625–5635.

Rozan, M.A.A-G., E.G. Boriy, and H.M. Bayomy. 2021. Chemical composition, bioactive compounds and antioxidant activity of six avocado cultivars Persea americana Mill. (Lauraceae) grown in Egypt. Emir. J. Food Agric. 33(10): 815-826.

Tango, J.S., C.R.L. Carvalho, and N.B. Soares. 2004. Caracterização física e química de frutos

de abacate visando a seu potencial para extração de óleo. Rev. Bras. Frutic. 26(1): 17–23.

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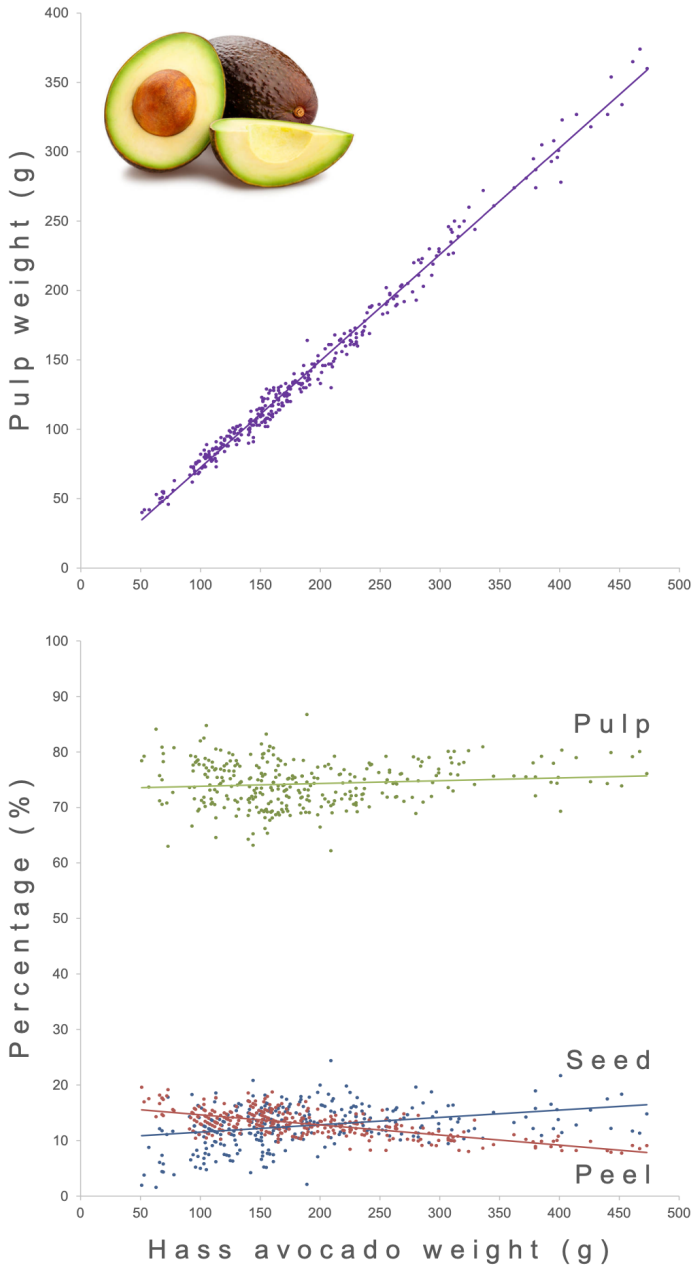

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203 **Figure 1.** Upper panel, linear relationship between the absolute weight of the Hass avocado and
204 the absolute weight of the pulp ($y=0.7681x-4.3988$, $R^2 = 0.9878$). Lower panel, linear relationships
205 between the absolute weight of the Hass avocado and the proportion of pulp (green,
206 $y=0.005x+73.335$, $R^2 = 0.0115$), seed (blue, $y=0.0132x+10.197$, $R^2 = 0.0976$), and peel (red, $y=-$
207 $0.0182x+16.468$, $R^2 = 0.4323$).