Short Communication  

Note on in vitro digestion of avocado products for pigs 

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Abstract  

In vitro (pepsin/pancreatin) digestibility coefficients of pulp, seed, and peel of avocados of the Creole and Hass varieties were studied according to a 2 x 3 factorial arrangement in which the factors were the variety and parts of the fruit. Creole avocado were heavier in natura than Hass exemplars (310.7 g and 156.8 g), whereas Hass had a greater proportion of pulp than the Creole fruits (76.9% and 64.6%). No significant interactions were observed. In vitro digestibility of dry matter (DM), organic matter (OM), and nitrogen (N) were higher for the Creole variety compared with the Hass. In vitro digestibility of N was similar in the pulp and seeds, and higher than in the peels (731, 773, and 550 g/kg⁻¹, respectively). Use of the entire avocado as pig feedstuff would have a lower nutritional value compared with feeding just avocado pulp. Supplementation of a diet based on avocado with additional protein may be needed for optimal production.

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The Hass avocado (Persea americana Mill) is a tropical fruit that is produced in Mexico (Zafar & Sidhu, 2018). In fact, Mexico leads the world in the production of avocados, with a contribution of 30%, the state of Nayarit being a primary area of production (SIAP, 2017).

In processing avocados, substantial quantities of the fruit are discarded. This by-product has high nutritional value and could be destined for animal feeding (Skenjana et al., 2006; Grageola et al., 2010; Skenjana, 2011; Carter, 2015; Carter et al., 2015; Eliyahu et al., 2015; Fránguez et al., 2017). These local by-products could partially replace imported feed ingredients and reduce production costs (Woyengo et al., 2014; Romero-Huelva et al., 2017). Increasing the level of avocado flour in rations for sheep reduced the cost of the diet without affecting their performance (Lemus et al., 2020). Avocado bagasse, the by-product of processing avocados for human consumption, has been evaluated as a feedstuff for ruminant animals (Skenjana et al., 2006; Skenjana, 2011). However, few studies have evaluated avocado materials for use in feeding pigs, which is common practice in the extensive backyard pig production of rural Mexico (Grageola et al., 2010; Wang et al., 2016).

The in vitro digestibility (pepsin/pancreatin) technique is a rapid and useful way to determine the nutritive value of nonconventional feed resources (Dierick et al., 1985; Boisen & Fernández, 1995). Thus, the aim of the current study was to assess the nutritive value of avocado materials of possible use for feeding pigs by applying the in vitro digestibility technique.

Pulp, peel and seeds from Hass and Creole avocados were used in this study. A total of 32 ripe fruits of each variety were collected from two local markets and two avocado plantations in Nayarit at the end of the harvest. Physical composition was determined by manual separation of pulp, seed and peel. The number of assays was reduced to eight per avocado cultivar by thoroughly mixing the parts from four fruits. The concentrations of DM (method 930.15) and N (method 984.13A-D) were determined in fresh aliquots from the samples (AOAC, 2006) and then the samples were dried in an oven at 60 °C. Organic matter content was calculated as 100 minus the percentage of ash. High-pressure liquid chromatography was used to
determine the amino acid content of the samples (AOAC, 2006) (method 982.30E) after acid hydrolysis of three lyophilized samples. In vitro digestibility of DM, OM, and N were determined according to Dierick et al. (1985). In brief, the samples were incubated with pepsin and 1 g/L HCl 0.075 N (pH 2.0) in a 39 °C bath with periodic agitation. Then 0.05 N NaOH was added to neutralize the solution, and incubation progressed for another four hours with a mixture of porcine pancreatin enzymes and 1 g/L phosphate buffer (pH 6.9). At the end of the incubation period, the samples were filtered and the residue was isolated, washed with ethanol (95%) and acetone (99.5%), and dried, and digestibility was estimated gravimetrically. Analytical grade casein was used as the reference material. All determinations were carried out in duplicate.

Data were analysed using Minitab 13.31 (Minitab Co. State College, Pennsylvania, USA). Tests of significance were made using analysis of variance, and mean separation was carried out using the Duncan multiple range test when the analysis of variance revealed significant ($P <0.05$) differences between treatments.

There were few similarities in the amino acid composition of avocados reported by Hall et al. (1980) and those obtained in this investigation (Table 1). More studies should be conducted to provide a more definitive characterization of the amino acid composition of avocado materials.

**Table 1** Amino acids profile of whole fresh avocado paste from Hass and Creole varieties (dry matter basis)

| Amino acid | g/kg dry matter | g/kg amino acid |
|------------|----------------|-----------------|
|            | Mean | Standard deviation | Mean | Standard deviation |
| Methionine | 0.8  | 0.1              | 21.8 | 0.3              |
| Cysteine   | 0.6  | 0.1              | 15.7 | 0.1              |
| Lysine     | 2.2  | 0.3              | 60.4 | 0.7              |
| Threonine  | 1.9  | 0.2              | 52.5 | 0.4              |
| Arginine   | 2.1  | 0.3              | 58.6 | 0.5              |
| Isoleucine | 2.0  | 0.3              | 54.8 | 3.2              |
| Leucine    | 3.3  | 0.4              | 90.6 | 0.4              |
| Valine     | 2.5  | 0.3              | 66.8 | 0.6              |
| Histidine  | 1.0  | 0.1              | 28.0 | 0.4              |
| Phenylalanine | 2.2 | 0.3     | 60.7 | 1.2              |
| Glycine    | 2.3  | 0.3              | 62.6 | 0.1              |
| Serine     | 2.2  | 0.3              | 59.4 | 0.8              |
| Proline    | 2.4  | 0.3              | 64.1 | 1.0              |
| Alanine    | 2.7  | 0.3              | 72.9 | 1.4              |
| Aspartic acid | 4.0 | 0.5     | 109.1| 1.0              |
| Glutamic acid | 4.5 | 0.6     | 123.0| 0.7              |

There were no significant interactions between cultivars and the parts of the fruits. All parts and the entire Creole avocados were heavier in natura ($P <0.001$) than the Hass exemplars. However, compared with the Creole cultivar, Hass avocados had significantly greater proportions of pulp (76 ± 2 and 65 ± 2%, respectively) and peel (10 ± 1 and 12 ± 1%, respectively). The weights of the pulp, seed, peel and entire avocado fruits are shown in Table 2.

Some aspects of avocado chemical composition and in vitro digestibility coefficients (pepsin/pancreatic) are shown in Table 3. For comparison, Fránquez et al. (2017) reported that the fresh paste of whole avocado contained 32.34% DM, 3.33% ash, 14.33% crude fibre, 49.13% crude fat, and 9.20% crude protein. Both Creole- and Hass-type avocado samples showed a typical low N content (Hall et al., 1980; Tango et al., 2004; Vekiari et al., 2004; Mooz et al., 2012). There was a tendency for the N concentration to be higher in the pulp and peel than in the seeds.
Table 2 Physical composition of Creole and Hass avocado fruits, based on 16 samples of each cultivar

| Material    | Cultivar | SE | P-value |
|-------------|----------|----|---------|
|             | Creole   |    |         |
| Pulp        | 201.2    | 119.3 | 8.4  | <0.001 |
| Seed        | 79.6     | 18.2   | 3.3  | <0.001 |
| Peel        | 29.9     | 19.2   | 2.5  | <0.001 |
| Entire fruit| 310.7    | 156.8  | 7.6  | <0.001 |

Table 3 Chemical composition and in vitro digestibility coefficients of Creole and Hass avocados from Nayarit state of Mexico (dry matter basis)

| Composition, g/kg⁻¹ | Creole | Hass | SE | P-value | P-value |
|---------------------|--------|------|----|---------|---------|
| Dry matter          | 251.8  | 336.7| 15.6 | >0.05 | 227.0\(^a\) | 429.0\(^b\) | 226.6\(^a\) | 10.2 | 0.002 |
| Ash                 | 31.8   | 25.9 | 1.9 | >0.05 | 34.5\(^a\) | 13.4\(^b\) | 33.5\(^a\) | 1.6  | 0.045 |
| Organic matter      | 968.2  | 974.1| 2.0 | >0.05 | 965.5\(^a\) | 982.6\(^b\) | 965.5\(^a\) | 1.5  | 0.033 |
| Nitrogen            | 10.3   | 11.4 | 0.5 | >0.05 | 12.3 | 8.8  | 11.6 | 0.4  | 0.055 |

| Digestibility, g/kg⁻¹ | Creole | Hass | SE | P-value | P-value | P-value |
|-----------------------|--------|------|----|---------|---------|---------|
| Dry matter            | 553    | 435  | 17.8 | 0.035 | 631\(^a\) | 460\(^b\) | 392\(^b\) | 22.1 | 0.010 |
| Organic matter        | 567    | 442  | 18.9 | 0.025 | 635\(^a\) | 466\(^b\) | 414\(^b\) | 28.6 | 0.050 |
| Nitrogen              | 591    | 449  | 28.9 | 0.020 | 731\(^a\) | 774\(^a\) | 550\(^b\) | 46.5 | 0.001 |

Means in the same row with different letters differ significantly (\(P<0.05\)).

The casein standard has in vitro DM digestibility of 0.973 and N digestibility of 0.990. In this assay, in vitro digestibility values for DM, OM, and N were higher (\(P<0.05\)) for Creole fruit than for the Hass avocado (Table 3) and the digestibility of DM and OM from the pulp was higher than for seeds and peels. However, the digestibility of N was similar in pulp and seeds, but higher than peels. The in vitro evaluations observed in this study tended to follow those found in vivo by Grageola et al. (2019), who observed that in situ digestibility of nutrients was higher in the entire fruit compared with seeds alone and mixed with peels. This result can be attributed to the higher digestibility of pulp compared with seeds and peels, as was found in the current investigation. The numerical dispersion of N digestibility was greater than that observed for either DM or OM.

The entire avocado fruit could be used as feed for pigs because of its high digestibility. However, the entire avocado as pig feedstuff would have lower nutritional value than the pulp. In application, the nutritive value of fruits varies according to the cultivar. Supplemental protein is likely to be needed if avocado is to comprise a significant portion of the diet for pigs. Additional evaluations should be undertaken to confirm the present results and to explore this nutritive value in avocado products that could be used to feed pigs.

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Authors’ Contributions
JL designed the experiment, conducted the laboratory analyses, collaborated in interpreting the results, and wrote the initial draft this manuscript. PF conducted the laboratory analysis, and collected the data for this study. GR conducted
the statistical analyses, collaborated in interpreting the results, and revised the initial draft of this manuscript. CL conducted the statistical analyses, collaborated in interpreting the results. IAD collaborated in interpreting the results, revised initial draft of this manuscript; FG developed the original hypotheses, designed the experiment, collaborated in interpreting the results, and finalized the manuscript. All authors have read and approved the finalized manuscript.

Conflict of Interest Declaration

The authors have no conflicts of interest relative to this work.

References

AOAC. 2006. Official methods of analysis of AOAC International. 18th ed. Association of Official Analytical Chemists, Arlington, Virginia, USA.

Boisen, S. & Fernández, J.A., 1995. Prediction of the apparent ileal digestibility of protein and amino acids in feedstuffs and feed mixtures for pigs by in vitro analyses. Anim. Feed Sci. Tech. 51, 29-43. https://doi.org/10.1016/0377-8401(94)00686-4

Carter, N.A., 2015. Enhancing pig productivity on East African smallholder farms. PhD thesis, University of Guelph. Guelph, Ontario, Canada. Pp. 296.

Carter, N.A., Dewey, C.E., Lukuyu, B., Grace, D. & De Lange, C.F.M., 2015. Nutrient composition and seasonal availability of local feedstuffs for pigs in western Kenya. Can. J. Anim. Sci. 95, 397-406. https://doi.org/10.4141/cjas-2015-003

Eliyahu, D., Yosef, E., Weinberg, Z.G., Hen, Y., Nikbachat, M., Solomon, R., Mabjeesh, S.J. & Miron, J., 2015. Composition, preservation and digestibility by sheep of wheat by-products from the food industry. Anim. Feed Sci. Tech. 207, 1-9. DOI: 10.1016/j.anifeedsci.2015.05.005

Dierick, N., Vervaete, I., Decuyper, J. & Henderickx, H.K., 1985. Protein digestion in pigs measured in vivo and in vitro. In: A. Just, H. Jorgensen & J.A. Fernández (eds.). Digestive physiology in the pig. 580 Beretning Statens fra Husdyrbrugsforsøg, Copenhagen, Denmark. Pp. 329-332.

Fránquez, P., Rodríguez, G., Lemus, C., Grageola, F. & Ly, J., 2017. Performance traits and indices of the intake pattern of fattened pigs with fresh paste of whole avocado. Cuban J. Agric. Sci. 51, 329-336.

Grageola, F., Sanginés, L., Díaz, C., Gómez, A., Cervantes, M., Lemus, C. & Ly, J., 2010. The effect of breed and diet level of avocado fat on the N and energy balance in young pigs. J. Anim. Feed Sci. 19, 37-49. DOI: 10.22358/jafs/66268/2010

Grageola, F., Ly, J., Fránquez, P., Rodríguez, G., Ponce, J.L. & Lemus, C., 2019. Digestibility indices in pigs fattened ad libitum with diets based on cereals and fresh paste of discarded entire avocados. Cuban J. Agric. Sci. 53, 387-396.

Hall, H., Smoot, J.M., Knight, R.J. & Nagy, S., 1980. Protein and amino acid composition of ten tropical fruits by gas-liquid chromatography. J. Agric. Food Chem. 28, 1217-1221. https://doi.org/10.1021/jf60232a066

Koller, O.C., 1992. Abocaticultura. Universidade Federal do Rio Grande do Sul. Porto Alegre. Pp 138.

Lemus-Flores, C., Bugarin, P.J.O., Grageola, N.F., Valdivia, B.R., Ruiz, D.I., Bonilla, C.J.A. & Segura, C.J.C. 2020. The effect of avocado flour, sunflower oil and different forage to concentrate ratios in the final diet on feed intake, digestibility and productive performance of male sheep. Veterinarski Arhiv. 90, 4, 353-364. 0802 http://intranet.vefr.hr/vetarhiv/index.php?p1=item&p2=2020&p3=90&p4=4&p5=6&p6=4

Mooz, E.D., Gaino, N.M., Shimano, M.Y.H., Amancio, R.D. & Spoto, M.H.F., 2015. Physical and chemical characterization of the pulp of different varieties of avocado targeting oil extraction potential. https://doi.org/10.1590/S0101-20612012005000005

Romero-Huelva, M., Ramirez-Fenosa, M.A., Planelles-González, R., Garcia-Casado, P. & Molina-Alcaide, E. 2017. Can by-products replace conventional ingredients in concentrate of dairy goat diet? J. Dairy Sci. 100, 4500-4512. https://doi.org/10.3118/jsd.2016-11766

SIAP, 2017. Servicio de Información Agroalimentaria y Pesquera. Atlas Agroalimentario. Primera edición, Ciudad de México, México. http://nube.siap.gob.mx/gobmx_publicaciones_siap/pag/2017/Atlas-Agroalimentario-2017

Skenjana, A., 2011. The potential nutritive value of waste products from the sub-tropical fruit processing industry as livestock feed. MSc. thesis, University of Pretoria, Pretoria. Pp. 80.

Skenjana, A., Van Niekerk, J.B.J. & Van Rysen, W.A., 2006. In vitro digestibility and in situ degradability of avocado meal and macadamia waste products in sheep. S. Afr. J. Anim. Sci. 36, 78-81.

Tango, J.S.T., Carvalho, C.R.L. & Soares, N.B., 2004. Physical and chemical characterization of avocado fruits aiming its potential for oil extraction. Revista Brasileira de Fruticultura 26, 17-23.

Vekiari, S.A., Papadopoulou, P.P., Lionakis, S. & Krystalis, A., 2004. Variation in the composition of Cretan avocados cultivare during ripening. J. Sci. Food Agric. 84, 485-492. https://doi.org/10.1002/jsfa.1595

Wang, M., Zheng, Y., Khougn, T. & Lovatt, J.C., 2016. Developmental differences in antioxidant compounds and systems in normal and small-phenotype fruit of ‘Hass’ avocado (Persea americana Mill.). Scientia Horticulturae 206, 15–23. https://doi.org/10.1016/j.scienta.2016.04.029

Woyengo, T.A, Beltranena, E. & Zijlstra, R.T., 2014. Controlling feed cost by including alternative ingredients into pig diets: a review. J. Anim. Sci. 92, 1293-1305. https://doi.org/10.2527/jas.2013-7169

Zafar, T. & Sidhu, J.S., 2018. Avocado production, processing, and nutrition. In: M. Siddiq & M.A. Uebersax (ed.). Handbook of vegetables and vegetable processing. John Wiley & Sons. Hoboken, New Jersey, USA. Pp. 509-534.