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Characterization of fruit and vegetable waste as an alternative ruminant feed in Pachuca, Hidalgo, Mexico

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ABSTRACT

Objective: Measure and characterize the fruit and vegetable waste generated during a working day in a commercial juice and fruit cocktail establishment in Pachuca, Hidalgo, Mexico, for four weeks.

Design/methodology/approach: The total amount of fruit waste generated during a working day in a commercial juice and smoothie establishment in Pachuca, Hidalgo, Mexico, was collected Monday through Saturday for four weeks in September and October 2019. Waste was weighted and separated daily into the different types of fruit. We then analyzed their dry matter (DM), crude protein (CP), and ash (Ash) content. The experimental design was completely randomized.

Results: The amount of fruit and vegetable waste was constant during the four collection weeks; the total amount of waste collected was 465 kg; orange peel was the most abundant waste (75%). The moisture content ranged from 75 to 94% based on the type of fruit. The CP concentration ranged from 4.33 to 6.95%, except for the papaya peel, which had a CP content of 11.55%.

Limitations/implications: An alternative to avoid landfilling this type of organic waste is to subject it to a silage-making process; this would reduce negative environmental impacts, generate value-added products, and reduce the pressure on natural resources.

Findings/conclusions: The amount of fruit and vegetable waste produced every week was constant for four weeks. Although their dry matter content is low, these wastes, mixed with cereal straw and subjected to a silage-making process, can result in value-added products, and avoid landfilling.

Keywords: fruit peel, organic waste, sustainability, landfills.

INTRODUCTION

Feeding strategies for an economical, safe, and quality-based production are among the main objectives of animal production (Makkar, 2016). The use of unconventional products, such as fruit and vegetable waste and agroindustrial subproducts, as ruminant feed, represents an important recycling strategy (Almaraz *et al*., 2012). This alternative use reduces greenhouse gas emissions into the atmosphere (Almaraz *et al*., 2012), production costs, competition for food between

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animals and humans (Dellomonaco *et al*., 2010), and the destruction of forests and biodiversity resulting from agricultural practices (Torres *et al*., 2020). In Mexico, orange is the most important fruit used for preparing juices and fruit cocktails (Bautista-Mayorga *et al*., 2020); significant amounts of organic waste correspond to orange peel and pulp, which are rich in fiber, vitamins, and minerals (Gómez and Schwentesius, 1997; Cedillo-Portugal and Anaya-Rosales, 2018). Fruit and vegetable landfill wastes represent an important source of greenhouse gas emissions (CH_4 and CO_2 mainly) and promote pest development (Environmental Protection Agency [EPA], 2020). Data on the amount of fruit and vegetable waste generated by food processing, such as in juice and cocktail making, is limited to zero. Plazzotta *et al*. (2020) estimate that fruit and vegetable waste represent 60% of the annual food waste generated worldwide; this amount is continuously increasing and requires implementing proper management strategies and alternative uses to obtain value-added products, such as biogas.

Thus, this study aimed to estimate the amount of fruit waste produced daily in a commercial juice and fruit cocktail establishment in Pachuca, Hidalgo, Mexico, and its dry matter and protein content as a potential alternative for ruminant feed.

MATERIALS AND METHODS

Materials and Methods. The total amount of fruit waste generated during a working day in a commercial juice and smoothie establishment in Pachuca de Soto, Hidalgo, Mexico, was collected Monday through Saturday for four weeks in September and October 2019. Wastes were weighted and separated daily by fruit type: carrot (*Daucus carota*) and beetroot (*Beta vulgaris*), orange peel (*Citrus × sinensis*), banana peel (*Musa × paradisiaca*), pineapple peel (*Ananas comosus*), papaya peel (*Carica papaya*), and vegetable waste containing mixtures of lettuce (*Lactuca sativa*), spinach (*Spinacia oleracea*), celery (*Apium graveolens*), and others. In the end, the amount of waste was grouped by day to identify the weekly trend.

Chemical analysis. Chemical analyses were carried out in the Animal Nutrition and Reproduction Laboratory of the Universidad Autónoma del Estado de Hidalgo. Partial dry matter was obtained by weighting representative samples (5-10% of each fruit waste) and placing them on aluminum trays for dehydration in a drying oven (Riossa, Mexico) for 48 h at 55 °C. Samples were then processed to determine total dry matter (DM, method 934.01), crude protein (CP, method 954.01), ashes (Ash, method 942.05), and organic matter (OM) according to the Association of Official Analytic Chemists (AOAC, 1990).

Statistical analysis. The statistical analysis was performed with the Microsoft® Excel® Solver Add-in data analysis tool (2013). The experimental design was completely randomized, and means were compared with the function "Two-factor analysis of variance with various samples per group" adjusted to a significance level of α=0.05.

RESULTS AND DISCUSSION

Orange peel was the most abundant waste during the collection period (Figures 1 and 2), representing 75% of the total waste (351 kg from Monday to Saturday for four

Figure 1. Fruit and vegetable waste generated in the commercial establishment "Sandwichon" in Pachuca, Hidalgo, Mexico.

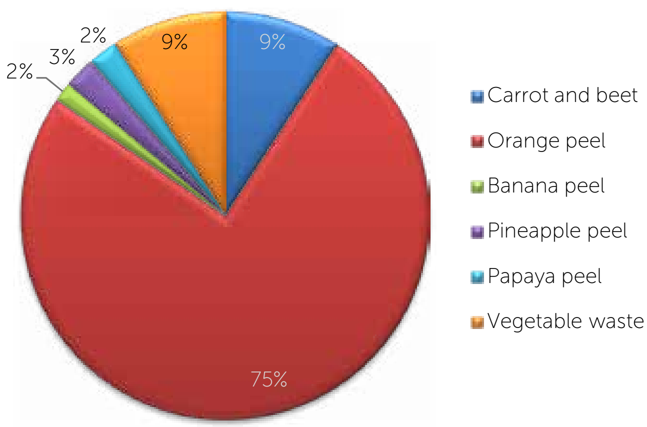

Figure 2. Proportion of fruit and vegetable residues generated in a commercial juice and fruit cocktail establishment in Pachuca, Hidalgo, Mexico.

weeks, Table 1). The second most abundant waste was carrot and beetroot (9%); the remaining waste represents 2 and 3%.

These results coincide with previous reports by Gómez and Schwentesius (1997) and Bautista-Mayorga *et al.* (2020) that indicate that orange is the most consumed fruit in Mexico. Banana peel was the least produced waste; pineapple and papaya peel were generated in similar amounts ($p>0.05$, Table 1). The amount of waste per day was similar throughout the week ($p>0.05$), which implies that the consumption of these products and the expenses necessary for their transportation and disposal are also constant throughout the week.

A total of 465 kg of waste was collected during the four-week collection period in a commercial juice and cocktail fruit establishment. These results indicate the need to generate proper sustainable management strategies in the commercial establishments of Pachuca and the main urban areas, as proposed by Inthapanya et al. (2013) and Yen et al. (2017). The DM content (Table 2) ranged between 5 and 24%, depending on the fruit type.

Yen *et al*. (2017) and Plazzotta *et al*. (2020) mention that this type of waste generates significant environmental problems due to its high moisture content and biodegradability, complicating its transportation. Despite the extensive and constant research on the management of fruit and vegetable waste, their main destination is represented by landfills, composting, anaerobic digestion, and carbonization (Yen *et al*., 2017; Dos Santos *et al*., 2020; Plazzotta *et al*., 2020). Based on the DM, OM, and CP content of the fruit and vegetable waste analyzed in this study (Table 2) and considering that this type of waste is rich in fiber, vitamins, and minerals (Gómez and Schwentesius, 1997; Cedillo-Portugal and Anaya-Rosales, 2018), subjecting it to a silage-making process represent a valuable strategy with environmental and economic advantages (income from the sale of value-added products). According to the EPA (2020), recycling food waste is one of the best organic waste management strategies. In Mexico, food waste production is constant and expected to increase due to the importance of fruit production as a source of economic resources. Mexico is a country with a great ecological, climatic, and soil diversity that promotes a great variety of fruits (Cedillo-Portugal and Anaya-Rosales, 2018).

Table 1. Fruit and vegetable waste generated from Monday to Saturday for four weeks in a commercial juice and fruit cocktail establishment in Pachuca, Hidalgo, Mexico.

	Fruit type (kg, wet basis)						
Day	Carrot and beetroot	Orange peel	Banana peel	Pineapple peel	Papaya peel	Vegetable waste	SEM
Monday	1.87^{aA}	15.00^{bB}	0.26^{cC}	0.46^{dD}	0.44^{dD}	2.15^{aA}	1.12
Tuesday	1.80^{aA}	12.50^{bB}	0.30^{cC}	0.49^{dD}	0.43^{dD}	1.77^{aA}	0.94
Wednesday	1.55^{aA}	14.00^{bB}	0.36^{cC}	0.57^{dD}	0.43^{dD}	1.80^{aA}	1.04
Thursday	1.55^{aA}	14.50^{bB}	0.28^{cC}	0.50^{dD}	0.43^{dD}	1.22^{aA}	1.09
Friday	2.02^{aA}	16.75^{bB}	0.29^{cC}	0.46^{dD}	0.46^{dD}	1.70^{aA}	1.26
Saturday	1.92^{aA}	15.00^{bB}	0.26^{cC}	0.42^{dD}	0.47^{dD}	1.92^{aA}	1.11
SEM	0.08	0.61	0.15	0.02	0.01	0.13	

^{abcd} Means in the same column with a different letter are statistically different ($p<0.05$). ^{abcd} Means in the same row with a different letter are statistically different ($p<0.05$). SEM=standard error of the mean.

For a more efficient silage-making process, forage moisture content must range between 60 and 70%, or 30 and 40% of DM. Considering the proportion of fruit and vegetable waste (Figure 1) and their DM content (Table 2), the DM concentration of the waste mixture would be 18%, which could difficult the aerobic stage of the silage-making process. However, to increase the proportion of DM up to more than 30% (Table 3), a viable option is to add cereal stubble (wheat, oats, barley, corn, or sorghum, which have a DM content of 85-90%) and maintain an 8:2 ratio of waste: stubble. Therefore, the moisture content is adjusted to what Cobos (s/a) recommends limiting the aerobic stage and obtain good silage.

Table 2. Nutrient concentration (%) in fruit and vegetable waste.

Substrate	DM	Moisture	CP	Ash	OM
Carrot	9.98	90.02	5.98	6.76	93.24
Banana	12.81	87.19	6.50	16.95	83.05
Pineapple	14.13	85.87	6.20	4.87	95.13
Papaya	12.23	87.77	11.66	9.91	90.09
Orange	24.14	75.86	4.33	8.85	91.15
Vegetable waste	5.59	94.41	6.95	8.94	91.06

DM=Dry matter; CP=Crude protein; Ash=Ashes; OM=Organic matter.

Table 3. Proposal to make silage from fruit and vegetable waste and increase the proportion of DM.

Substrate	As feed (%)	DM (%)	CP (%)
Carrot	7.20	0.72	0.43
Banana	1.60	0.20	0.10
Pineapple	2.40	0.34	0.15
Papaya	1.60	0.20	0.19
Orange	6.00	12.68	2.60
Vegetable waste	7.20	0.40	0.50
Cereal stubble	20.00	17.20	1.20
Total	100.00	31.74	5.38

CONCLUSIONS

The amount of fruit and vegetable waste generated in a commercial juice and cocktail fruit establishment is constant throughout the week, with a dry matter and protein content lower than 20% and close to 7%, respectively. This waste, added with cereal stubble, create value-added products for ruminant feeding that could decrease their disposal to landfills.

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