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Bromatological characterization of fruit waste*

Caracterización bromatológica de residuos de frutas

FLÓREZ-MONTES, CILIANA[1]; ROJAS-GONZÁLEZ, ANDRÉS-FELIPE [2]; RODRÍGUEZ- BARONA, SNEYDER[3]

ABSTRACT

In Colombia, a high amount of fruit waste is currently generated. These causes a negative environmental impact due to its high organic load. However, this type of waste has compounds in its structure that can be used in order to reduce the environmental impact and to obtain added value. The main of this study was to characterize bromatologically sixteen residues of fruit processing in Colombia, in order to propose a possible use in the food industry. The bromatological characterization of the waste was carried out by means of the quantification of dry matter (ASTM E1756-08), ash

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1 Universidad Nacional de Colombia, Facultad de Ingeniería y Arquitectura, Departamento de Ingeniería Química. M.Sc. Ingeniería Química, Manizales, Colombia. https://orcid.org/0000-0001-9190-4037

2 Universidad Nacional de Colombia, Facultad de Ingeniería y Arquitectura, Departamento de Ingeniería Química. Ph.D. Ingeniería Química, Manizales, Colombia. https://orcid.org/0000-0002-6905-0802

3 Universidad Nacional de Colombia, Facultad de Ingeniería y Arquitectura, Departamento de Ingeniería Química. Ph.D. Biología, Manizales, Colombia. https://orcid.org/0000-0002-2290-2238

Correspondencia: cflorezm@unal.edu.co

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(ASTM E1755-01), proteins (Kjeldahl method), crude fats (AOAC Official Method), total dietary fiber (AOAC 993.21) and carbohydrates. It was found that grape and soursop seeds, lulo peel and tree tomato stem presents the highest total dietary fiber with content percentages above 50 %. Also, tree tomato, soursop, tangerine and orange seeds are an important source of protein and crude fats, with values highest than 12 and 27 %, respectively. It was also found that pineapple, mango, soursop and grape peel have a carbohydrate content greater than 50%. As a conclusion, the results of this study demonstrate that fruit waste have a potential use in the food industry, due to their protein, crude fat, total dietary fiber and carbohydrates content.

KEYWORDS:

Agricultural waste; Environmental impact; Food; Green economy; Potential use.

RESUMEN

En Colombia, actualmente se genera una gran cantidad de residuos de frutas. Estos causan un impacto ambiental negativo debido a su alta carga orgánica. Sin embargo, este tipo de residuos presentan en su estructura compuestos que pueden ser aprovechados con el fin de disminuir el impacto ambiental y obtener un valor agregado. El objetivo de este estudio fue caracterizar bromatológicamente dieciséis residuos del procesamiento de frutas en Colombia, con el fin de proponer un posible uso en la industria alimentaria. La caracterización bromatológica de los residuos se realizó mediante la cuantificación de materia seca (ASTM E1756-08), cenizas (ASTM E1755-01), proteínas (método Kjeldahl), grasas brutas (Método Oficial AOAC), fibra dietética total (AOAC 993.21) y carbohidratos. Se encontró que las semillas de uva y guanábana, piel de lulo y vástago de tomate de árbol presentan el contenido de fibra dietética total más alto con porcentajes superiores al 50 %. Asimismo, las semillas de tomate de árbol, guanábana, mandarina y naranja son una fuente importante de proteínas y grasas crudas, con valores superiores al 12 y 27 %, respectivamente. También, se encontró que la piña, el mango, la guanábana y la cáscara de uva tienen un contenido de carbohidratos superior al 50%. En conclusión, los resultados de este estudio demuestran que los residuos de frutas tienen un uso potencial en la industria alimentaria, debido a su contenido de proteína, grasa cruda, fibra dietética total y carbohidratos.

PALABRAS CLAVE:

Desperdicio agrícola, impacto ambiental, alimento, economía verde, aprovechamiento.

LIST OF ABBREVIATIONS

Ash	ASH
Carbohydrates	C
Crude fat	CF
Dry matter	DM
Grape peel	GP
Grape seed	GS
Grape stalk	GSt
Lulo peel	LP
Mango peel	MP
Orange peel	OP
Orange seed	OS

Passion fruit peel	PFP
Pineapple peel	PP
Proteins	Pr
Soursop peel	SP
Soursop seed	SS
Tangerine peel	TP
Tangerine seed	TS
Total dietary fiber	TDF
Tree tomato peel	TTP
Tree tomato seed	TTS
Tree tomato stem	TTSt

INTRODUCTION

Currently, agro-industrial activities have grown due to the demand for raw materials and food products from the agricultural sector. This economic activity generates a large amount of agro-industrial waste throughout its production cycle (Gutiérrez *et al.*, 2020). In Colombia, one of the main economic activities is agriculture. Around 1.300 million tons of waste are generated in the country per year (Ministerio de ambiente y desarrollo sostenible, 2017), of which 5,5 % corresponds to agricultural residual biomass (72 million tons) (Marrugo *et al.*, 2019).

The final disposal of these wastes is usually inadequate, since they are taken to sanitary landfills or are incinerated (Chew *et al.*, 2019). This becomes an economic problem, as companies must bear the costs related to final disposal. Likewise, they generate a negative and indirect environmental impact due to the high concentration of organic matter (Chew *et al.*, 2019). Therefore, the use of this waste represents an opportunity for improvement at an economic level. This can be done by transforming agro-industrial waste to obtain other valuable products. Similarly, the use of waste materials helps mitigate negative environmental impacts, avoiding their inappropriate disposal.

Various investigations have focused on studying the use of agro-industrial waste. For many years, most of these studies were directed at the use of waste for power generation (Qian *et al.*, 2020). However, the analysis of the structural composition of biomass has shown that wastes from agribusiness, such as peels and seeds, contain compounds of great interest in their structure (Roda and Lambri, 2019). Fruit waste contains in their structure proteins, fibers, lipids and carbohydrates, which can be quantified through a bromatological analysis. By means of this analysis, it is possible to propose other types of applications for these wastes, such as obtaining compounds of interest, food for animals and even food for humans ((Roda and Lambri, 2019; Mojica-Gómez and Pérez-Mora, 2019).

In literature, studies have been found on the use of agro-industrial waste. For example, the obtaining of flour from the cocoa shell was investigated, finding a high fiber content (Ríos-Pérez *et al.*, 2020). The improvement in the quality of meat products with the incorporation of fruit peels and seeds has also been studied (Calderón-Oliver and López-Hernandez, 2020). Likewise, citrus residues are known to be rich in bioactive compounds (Russo *et al.*, 2021). On the other hand, fruit and vegetable residues can also be used for livestock nutrition (Tadesco *et al.*, 2021).

However, these investigations usually focus on the study of a specific component or a specific residue. Therefore, the bromatological characterization of a variety of fruit residues represents an important alternative in the analysis of the composition of this type of biomass. Thus, knowing the composition of fruit residues can provide a general overview for its use, knowing the benefits of proteins, fibers, fats and carbohydrates.

Proteins have a plastic function in human and animal body. These are necessary for cell and tissue renovation, and participate in enzyme, antibodies and hormone synthesis (Yu and Fukagawa, 2020). Fiber can be classified as soluble or insoluble. Soluble fiber promotes the formation of viscous gels, which slow gastric evacuation, allowing the absorption of nutrients (Soliman, 2019). The insoluble fiber increases the volume of feces, which is related to the improvement in digestive disorders such as constipation (Johnson, 2020).

Within the lipids are vegetable fatty acids, which are mostly unsaturated (Xicoy *et al.*, 2019). This type of fatty acids has great advantages in health, as they provide energy to the body, allow easy assimilation of vitamins A, D, E and K, promote heart health and reduce blood cholesterol levels, that decreases the chances of suffering a heart disease (Hernandez-Rodas *et al.*, 2016). Carbohydrates are the most abundant biomolecules in nature, its main function is to provide energy to the body, but also have plastic and regulatory function (Ahnen *et al.*, 2020). The simplest carbohydrates are absorbed quickly, these are usually found in fruits, milk, honey, among others. On the other hand, the compound carbohydrates are absorbed slowly and are present in legumes, cereals, potatoes, etc. (Ahnen *et al.*, 2020).

According to the benefits that proteins, fibers, fats and carbohydrates have on human health, the following hypothesis is contemplated: the bromatological characterization of fruit waste generated in the agro-industry is a theoretical basis for the use of these in the food industry. Therefore, the aim of the present study was to characterize bromatologically 16 types of wastes (peels, seeds, stem and stalk) generated during the processing of fruits (passion fruit, pineapple, tree tomato, mango, lulo, tangerine, orange, soursop and grape) in the Caldas province, Colombia.

METHOD

The wastes used in this research were obtained from supermarkets and agroindustries in the Caldas province–Colombia–South America. Sixteen wastes were selected from peels (9), seeds (5), stem (1) and stalk (1). The environmental working conditions were 150 m.a.s.l., 18 °C and 80 %, of average altitude, temperature and relative humidity, respectively.

Chemicals and reagents

For bromatological characterization, potassium sulfate (AR/ACS Loba Chemie), cupric sulfate (AR/ACS Loba Chemie), sulfuric acid (95 % J.T. Baker), sodium hydroxide (≥ 99,0% EMSURE®), methyl red (AR/ACS Loba Chemie), petroleum ether (RA ACS J.T. Baker), ethanol (99,5 % Scharlau), acetone (99,5 % Panreac) and distilled water were used.

Pretreatment

The wastes preparation for the analysis was carried out following NREL/TP-510-42620 norm (Pesce and Fernandes, 2020). Once obtained and separated, the wastes were stored at -20 °C until use. These were manually cut to reduce its size and dried at 45 °C in a Terrigeno brand muffle up to constant weight. Once dry, the wastes were mill in a disk mill until it reaches a particle size of 1mm or less.

Bromatological analysis

To determine the bromatological composition of the wastes, it was necessary to evaluate the percentage of dry matter (DM), ash (ASH), proteins (Pr), crude fat (CF), total dietary fiber (TDF) and carbohydrates (C). The methodology applied for all the components is detailed below. All the analysis was made by triplicate.

Dry matter. For the dry matter determination ASTM E1756-08 standard (ASTM INTERNATIONAL, 2020a) was followed. Here 1 g of sample was weighted in a porcelain crucible and dried at 105 °C for 24h in a Terrigeno muffle. For dry matter (DM) percentage determination, equation 1 was used.

$$\%DM = \frac{Dry\ waste\ weight}{Waste\ weight} * 100\% \quad \text{(Eq. 1)}$$

Ash. The ash determination was carried out following the ASTM E1755-01 standard (ASTM INTERNATIONAL, 2020b). 1 g of sample was weighted in a porcelain crucible and subjected to heating in a Terrigeno muffle, using the temperature ramp methodology for a heating rate of 10°C/min, as follows:

-Heat up to 105 °C and keep at this temperature for 12 min.

-Then warm up to 250°C and keep at this temperature for 30 min.

-Then warm up to 575°C and keep at this temperature for 3 hr.

-Cool to 105 °C and keep at this temperature until samples are removed.

For ash (ASH) percentage determination, equation 2 was used.

$$\%ASH = \frac{Ashes\ weight}{Waste\ weight} * 100\% \quad \text{(Eq. 2)}$$

Proteins: Kjeldahl method. The protein percentage determination was performed in accordance with the AOAC standard (Vargas *et al.*, 2019). For this analysis, 1 g of waste was weighed in a Kjeldahl digestion flask. Glass beads, 10 g of potassium sulfate, 0,5 g of cupric sulfate and 20 mL of concentrated sulfuric acid were added. The flask was connected to the absorption trap that contains 250 mL of sodium hydroxide 15 %. The mixture was heated at 420 °C, approximately. Once the solution is clear, heating was continued for an additional 15-20 minutes. Then, the mixture was left to cool, and 200 mL of water were added. The flask was connected to the distillation apparatus and 100 mL of NaOH 30 % were slowly added. No less than 100 mL were distilled in a flask that contained 50 mL of a sulfuric acid 0,1 N, 4 to 5 drops of methyl red and 50 mL of distilled water. Excess acid was titrated with NaOH 0,1 N until it turns yellow.

For protein (Pr) percentage determination, equation 3 was used.

$$\%Pr = \frac{14 * Equivalent\ concentration * Excess\ acid\ Volume * 6{,}25}{Waste\ weight * 1000} * 100\% \quad \text{(Eq. 3)}$$

Crude fat. Crude fat was extracted with Soxhlet according to AOAC Official Method (Lim and Abu, 2019). 2 to 5 g of waste was weighed in the filter paper cartridge and inserted into the extraction chamber. The extraction was carried out using at 95 °C petroleum ether as solvent for 6 to 8h. Once the extraction was complete, the solvent was recovered by distillation under vacuum. For crude fat (CF) percentage determination, equation 4 was used.

$$\%CF = \frac{Round\ bottomed\ flask\ plus\ crude\ fat\ weight - Round\ bottomed\ flask\ weight}{Waste\ weight} * 100\% \quad \text{(Eq. 4)}$$

Total dietary fiber. The total dietary fiber quantification was made following the AOAC 993.21 standard (Kekana *et al.*, 2020). 500 mg of waste was weighed into beaker of 250 mL, and 25 mL of water were added. The suspensions were stirred at 80 rpm for 2 min. The mixture was covered with aluminum foil and let stand 90 min without stirring in a water bath at 37 °C. After this time, 100 mL of ethanol 95 % were added and kept 1h at room temperature for 1h. The residue was collected under vacuum and washed with 2 portions of 20 mL ethanol 78 %, 2 portions of 10 mL ethanol 95 %, and 10 mL of acetone. The residue was dried for 2h at 105 °C, cooled and weighed. Then, the residue ashes and residue protein were determined. For total dietary fiber (TDF) percentage determination, equation 5 was used.

$$\%TDF = \frac{Fiber\ weight - \left(\frac{(Protein + Ashes)_{In\ fiber\ obteined}}{100}\right) * Fiber\ weight}{Waste\ weight} * 100\% \quad \text{(Eq. 5)}$$

Carbohydrates. Carbohydrates were determined by difference. For carbohydrates (C) percentage determination, equation 6 was used.

$$\%C = 100 - (\%P + \%CF + \%TDF + \%ASH) \quad \text{(Eq. 6)}$$

Statistical analysis

We performed all the analyses in triplicate; the values reported are presented as average values along with their standard deviations.

RESULTS

Bromatological analysis

The results obtained for dry matter (DM), ashes (ASH), crude fat (CF), proteins (Pr), total dietary fiber (TDF) and carbohydrates (C) are presented in Table 1. These results suggested that the DM percentage is between 11 and 73 %. Passion fruit peel (PFP) was the waste with the lowest DM content and soursop seed (SS) the waste with the highest DM content. In accordance with waste DM content, most of these could not be used for a combustion process without the use of an auxiliary fuel or without being subjected to a previous drying process, because its moisture content is over 50 % (Shojaeiaarani *et al.*, 2019).

As for the ash content, SS has the lowest percentage (1,58 ± 0,01 %) and the tree tomato stem (TTSt) the highest percentage (12,80 ± 0,21 %). Waste with an ASH content greater than 5 % is not recommended for their use in the combustion process, since these negatively affect calorific power, generate atmospheric pollution (presence of halides), form slag deposits that cause thermal resistance to passage of heat (basic ash) and cause oxidation in combustion equipment (acid ash) (Rojas-González *et al.*, 2019). According to ASH and DM content, the most suitable waste to be used in the combustion process are grape seed (GS) and SS.

On the other hand, it is important to highlight that moisture, specifically equilibrium moisture content, is an indicator of the stability of food products. Therefore, it is important to analyze the water activity of the waste in order to know what its stability would be. In this way, it is possible to define whether it is advisable for the waste to go through a dehydration process so that it can be used for food purposes (Bell, 2020). Regarding the ash content, it is important to identify the type of food in which the waste wants to be used. For example, flours may have an ash content of less than 2,5 % (ICONTEC, 2002), while in concentrates for an adult cat it is recommended that the percentage of ash be less than 10 % (Dueñas, 2018).

In the Table 1 is observed that the CF percentages are between 1 and 34 %, where the PP is the waste with the lowest CF content and OS is the waste with the highest CF content. In general, the seeds have a higher fat content. Fats are one of the main sources of energy for humans. Also, fats help in the synthesis of hormones and allow the assimilation of liposoluble vitamins including A, D, E and K (Hernandez-Rodas *et al*., 2016). Vegetable fats promote cardiovascular health because they reduce cholesterol levels. Therefore, TS, OS, SS and TTS, can be used to obtain vegetable fats, which have important applications in the food and pharmaceutical industry due to the advantages they have on health (Hernandez-Rodas *et al*., 2016). In addition, due to their high CF content, these wastes could be used in biodiesel production (Ramos *et al*., 2019). Spigno *et al*. (2013) report a value of 1,40 % for CF for GS, which is 8,8 times lower compared to that found experimentally (12,38 ± 0,18 %).

As for Pr content, the TTP has the lowest percentage (2,44 ± 0,19 %) and the TTSt the highest percentage (19,47 ± 0,23 %). Similarly, it was obtained that the seeds also have a high content. According to these results, TTS, TS, OS and SS could be used to obtain proteins, which besides being fundamental in the diet due to their contribution of essential amino acids. They have applications in the pharmaceutical and food industry, because these act as gelling agents, emulsifiers and water absorbers (Awuchi *et al*., 2019).

On the other hand, wastes with a greater amount of Pr and C like GP and SP have a potential use in the food industry considering that the interactions between these biopolymers have a positive influence on the products development with good textures and consistency like puddings and desserts (Awuchi *et al*., 2019). Gutierrez *et al*. (2003), report values of 12,00 % (C) for PP, which differ significantly from those found in this study (54,82 ± 0,86 %), which is 4,6 grater that reported by Gutierrez *et al*. (2003).

Table 1. Bromatological analysis.

Waste	% DM	% ASH	% CF	% Pr	% TDF	% C
PFP	11,34 ± 0,34	8,03 ± 0,11	1,92 ± 0,05	9,85 ± 0,29	45,22 ± 0,92	34,97 ± 1,20
PP	14,52 ± 0,23	4,81 ± 0,07	1,31 ± 0,03	7,51 ± 0,19	31,55 ± 0,75	54,82 ± 0,86
TTP	17,04 ± 0,45	8,67 ± 0,09	2,55 ± 0,06	2,44 ± 0,19	51,50 ± 0,41	34,84 ± 0,48
TTS	21,09 ± 0,24	4,03 ± 0,05	27,87 ± 0,15	19,47 ± 0,23	42,07 ± 0,65	6,56 ± 0,30
TTSt	18,33 ± 0,18	12,80 ± 0,21	3,37 ± 0,09	9,97 ± 0,33	52,93 ± 0,83	20,94 ± 0,53
MP	21,87 ± 0,31	2,80 ± 0,02	6,02 ± 0,02	5,97 ± 0,22	29,49 ± 0,12	55,72 ± 0,22
LP	14,79 ± 0,34	6,06 ± 0,06	2,14 ± 0,08	5,39 ± 0,11	55,47 ± 0,57	30,95 ± 0,60
TP	22,81 ± 0,29	3,05 ± 0,03	3,01 ± 0,09	9,40 ± 0,18	38,49 ± 1,38	46,05 ± 1,58
TS	33,26 ± 0,29	1,92 ± 0,02	31,75 ± 0,97	13,15 ± 0,89	51,32 ± 2,02	1,85 ± 0,18
OP	25,42 ± 0,17	3,53 ± 0,04	2,48 ± 0,19	7,19 ± 0,30	42,16 ± 0,62	44,64 ± 0,33
OS	42,60 ± 0,48	3,26 ± 0,08	34,45 ± 1,69	13,17 ± 0,16	37,66 ± 2,40	11,46 ± 0,88
SP	31,98 ± 0,22	6,22 ± 0,10	2,28 ± 0,07	7,65 ± 0,22	32,40 ± 0,24	51,46 ± 0,35
SS	73,48 ± 0,47	1,58 ± 0,01	31,29 ± 1,03	12,56 ± 0,20	52,74 ± 1,30	1,83 ± 0,14
GP	32,30 ± 0,23	2,44 ± 0,03	3,02 ± 0,20	8,21 ± 0,22	22,32 ± 0,56	64,01 ± 0,86
GS	69,40 ± 0,51	1,91 ± 0,05	12,38 ± 0,18	9,79 ± 0,26	61,22 ± 0,36	14,70 ± 0,60
GSt	40,80 ± 0,33	7,12 ± 0,10	2,38 ± 0,26	8,85 ± 0,22	49,52 ± 1,58	32,13 ± 1,43

Wastes such as GS, LP, TTSt and SS, which have a high TDF content, could be used in the preparation foods with satiating qualities, as the high TDF content increases the time of chewing, producing a greater amount of saliva and gastric juices and generating the stomach expansion. In addition, soluble fiber decreases digestion, which causes glycogen and fat to be mobilized as energy sources to maintain the level of glucose needed in the blood. Therefore, wastes with high fiber content can be used to treat overweight, diabetes, colon cancer, cardiovascular disease and constipation problems (Soliman, 2019).

Moreover, wastes such as GP and MP, which have a low TDF content, do not have important applications in the food or pharmaceutical industry to obtain products that improve stomach or intestinal problems. Gutierrez *et al*. (2003), report values of 15,93 % (TDF) for PP, which differ significantly from those found in this study. The value found experimentally (31,55 ± 0,75 %) corresponds to approximately double that reported in the literature.

When comparing the results for the bromatological analysis found experimentally in the present work with data from the literature, it was found that these results differ considerably for some wastes. The difference between results may be due to the raw material harvesting conditions, because a lot of data reported in the literature are from studies conducted in other countries. Therefore, it is expected that the wastes have different characteristics in their composition due to soil conditions, environmental conditions and the fertilizers used (Ruales, 2015).

Prospective use of fruit waste

Currently, the valorization of fruit wastes such as seeds and peels has become a challenge for the industries, since these present a high organic load that generates a negative environmental impact, and their adequate disposal represents great costs for those who produce this type of wastes (Vargas and Pérez, 2018). Fruit wastes are generally used for energy generation (Gutiérrez *et al.*, 2020). However, agro–industry waste has a potential use in the human food and animal feed industry due to the large number of compounds of interest that it contains, such as proteins, fibers, fats and carbohydrates (Torres-León *et al.*, 2018). The use of waste to obtain a specific food, for example, flour, cookies, energy bars, additives for meat products, or concentrates for animals, will depend on the composition of each waste.

The recovery of these compounds from agro-industry waste is a sustainable alternative that allows minimizing the costs related to waste disposal, maximizing resources and adding value to them. Therefore, one of the possible applications of these, is their use in the production of animal feed, for example, concentrates for poultry, livestock or dogs, due to the protein and fiber content present in fruit wastes. Nevertheless, it should be noted that, if these are managed properly at the microbiological level, pest control and stability, fruit residues have a potential use in the food industry for human beings (Roda and Lambri, 2019). The amount of fibers, proteins, carbohydrates and fats present in the fruit wastes, will open a general panorama on the possibility of obtaining specific food products. However, more rigorous studies are needed in order to verify the effectiveness of these applications.

The fruit wastes characterized in the present study, such as TTP, TTSt, LP, TS, SS and GS, have a high fiber content (>50 %). Therefore, they can be harnessed to obtain pectins, which are used in the food industry as food additive due to the ability they have to form gels, in addition to the beneficial properties for health such as lowering cholesterol, preventing or decreasing carcinogenesis, increasing satiety, among others (Petkowicz and Williams, 2020). Likewise, the pectin obtained from fruit wastes can be used to produce coating films to preserve the sensory properties and extend the shelf life of some fruits (Maftoonazad and Ramaswamy, 2019).

Similarly, the fruit wastes analyzed in this document could be considered as foods high in fiber, since they have a percentage of total dietary fiber greater than 6 % (European Commission, 2006). Therefore, fruit wastes can be utilized in the preparation of functional concentrates and probiotic formulations with anticancer properties (Petkowicz and Williams, 2020). High fiber content in wastes could be used as a food supplement, food ingredient or in obtaining flours for the preparation of cakes, cookies, cereal bars and bread. The use of these wastes in the food industry could have benefits such as improving intestinal health and lipid metabolism (Alves *et al.*, 2020). On the other hand, wastes such as TS, SS and TTS, which have high fiber (>40 %) and protein (>10 %) contents, can be used to obtain these compounds, which have molecular interactions that contribute functional properties to food, like decreased aggregation and protein precipitation, and increased protein thermal stability (Chevalier *et al.*, 2019).

TTS, TS, OS and SS are wastes that have a high protein content (>12 %). These could be used to obtain proteins that provide functional properties to the food (Gomes *et al.*, 2020), or as raw material for the production of concentrates for animal feed (Calvo, 2017). The use of proteins isolated from agro–industrial waste is an alternative that could reduce human dependence on animal protein. To achieve this, it is necessary to carry out studies on the quality of proteins from agro–industrial waste, considering their amino acid composition, digestibility and bioavailability, as well as the development of techniques that allow improving these last two properties (Chin *et al.*, 2019).

The carbohydrate (>44 %) and protein (>7 %) content of wastes such as PP, TP, OP, SP and GP could be used as substrates in fermentation since they are a source of carbon and nitrogen (Pereira-Da Silva *et al.*, 2020). Generally, these processes use inorganic nitrogen sources, which are usually expensive, this represents an opportunity to reduce the costs of the inputs used in the fermentation processes (Serna and Torres, 2015). The high content of carbohydrates (>50 %) in wastes such as PP, MP, SP and GP suggests that they can be used in the fermentable sugar industry to obtain alcoholic beverages (Chin *et al.*, 2019), or in obtaining foods with a high energy intake (Ahnen *et al.*, 2020). On the other hand, these wastes could be used to produce pullulan through submerged and solid-state fermentation by *A. pullulans* (Singh *et al.*, 2019). Pullulan is a microbial exopolysaccharide that can be used as a substitute for starch in the preparation of low-calorie foods, it can serve as a prebiotic and benefit the health of the consumer, it has application as a stabilizer and protective glaze in various food products, among others (Singh *et al.*, 2019).

The wastes with a high content of crude fat (>27 %), for example TTS, TS, OS and SS, have a potential use to obtain vegetable fats that can be incorporated into functional foods with benefits for human health such as the synthesis of hormones and the assimilation of vitamins A, D, E and K (Hernandez-Rodas *et al.*, 2016). However, it is important to analyze this fat content in order to determine its composition and classify them as saturated or unsaturated fatty acids. Polyunsaturated fatty acids have application in the prevention of cardiovascular diseases due to their high content of HDL cholesterol (Shahidi and Ambigaipalan, 2018). The polyunsaturated fatty acids could be obtained through solid-state fermentation (Klempová *et al.*, 2020) or using different extraction techniques such as soxhlet, microwave assisted, and ultrasound assisted extraction (Hakimi *et al.*, 2018). These same wastes, which have a crude fat percentage between 20,5 % and 37,7 % can be used in animal feed (Calvo, 2017).

CONCLUSIONS

The bromatological characterization is a theoretical base in the studies of use of agroindustrial residues. The variety in the percentages of compounds such as proteins, fibers, fats and carbohydrates present in the fruit wastes, shows that the specific application of each of these residues will depend on which component is the majority.

Grape and soursop seeds, lulo skin and tree tomato stem are a promising raw material for preparing foods with satiating properties and obtaining pectins. Tree tomato, soursop, mandarin and orange seeds that could be used in the food and pharmaceutical industry as gelling and emulsifying agents. Likewise, the seeds of tree tomato, mandarin, orange and soursop have applications in obtaining functional foods that promote the synthesis of hormones and the assimilation of vitamins, while waste rich in carbohydrates, such as pineapple, mango, soursop and skin grape, can be used in the preparation of foods with high energy content.

The results of this research are a theoretical basis that opens the doors for future research on the specific use of waste in the food industry based on the bromatological composition.

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