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Special Edition

Extraction of aromatic compounds from silver banana peel (*Musa sapientum*): qualitative and sensory approach

Extração de compostos aromáticos da casca de banana prata (*Musa sapientum*): abordagem qualitativa e sensorial

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ABSTRACT

Silver banana (*Musa sapientum*) is one of the most consumed fruits in Brazil, and the country is its fourth largest producer in the world. The use of banana peel as a raw material in the industry can help in the production of natural aromas containing substances that resemble the fruit itself, and is therefore a valuable destination to be given to an organic waste that is generated in abundance. To make this application feasible, the extraction of aromatic substances from the peel of silver banana by isopropanol was tested in this work. Analyzes were performed by gas chromatography with mass spectrometry, aiming to characterize both the peel extract obtained experimentally and a commercial banana aroma available on the market. The analysis of the extracts showed that several substances associated with the banana aroma were extracted, at variable proportions, indicating that the extraction technique with isopropanol was effective in obtaining aromatic compounds relevant to the banana aroma from its peel. In turn, the comparison between the composition of the extract obtained from the banana peel and the commercial aroma of this fruit indicated the presence of an important aromatic compound in common: isoamyl acetate, which has a sweet and fruity sensory descriptor, with banana and pear characteristics. The recovery of this compound, which is already widely used in the flavor industry, confirmed the potential of the application of simple solvent extraction technology in this industrial sector, enabling the reuse of banana waste.

Keywords: Aroma; Banana; *Musa sapientum*; Solvent extraction

RESUMO

A banana prata (*Musa sapientum*) é um dos frutos mais consumidos pela população brasileira e o Brasil é o quarto maior produtor no mundo. A utilização da casca de banana como matéria prima na indústria pode auxiliar na produção de aromas naturais contendo substâncias que lembrem a própria fruta, sendo um interessante destino a ser dado a este resíduo orgânico gerado em abundância. Para viabilizar este uso, foi testada, neste trabalho, a extração sólido-líquido das substâncias aromáticas da casca da banana-prata por isopropanol. As análises foram feitas por cromatografia gasosa com espectrometria de massas. Foram analisados tanto o extrato da casca obtido experimentalmente como um aroma comercial de banana disponível no mercado. A análise dos extratos evidenciou que diversas substâncias associadas ao aroma de banana foram extraídas, em maior ou menor proporção, indicando que a técnica de extração com isopropanol foi eficaz na obtenção de compostos aromáticos relevantes sensorialmente ao aroma de banana a partir de sua casca. Por sua vez, a comparação realizada entre a composição do extrato obtido a partir da casca de banana com o aroma comercial desta fruta indicou a presença de um importante composto aromático em comum: o acetato de isoamila, o qual apresenta um descritor sensorial doce e frutal, com características de banana e pera. A obtenção deste composto já amplamente empregado na indústria de aromas corroborou o potencial da aplicação da tecnologia simples de extração com solventes neste setor industrial, podendo viabilizar o reaproveitamento de resíduos.

Palavras-chave: Aromas; Banana; *Musa sapientum*; Extração com solventes

1 INTRODUCTION

Organic waste currently represents more than 50.0 % of the solid waste generated in Brazil, totaling a daily amount of 41 thousand tons of food (ALFAIA; COSTA; CAMPOS, 2017). The inadequate disposal of this waste generates leachate, the emission of methane into the atmosphere and favors the proliferation of disease vectors. Therefore, it is of great importance that methods for reuse of this large volume of solids are adopted (MINISTÉRIO DO MEIO AMBIENTE, 2017). In August 2010, the National Solid Waste Policy ("*PNRS*") was instituted in Brazil by Federal Law No. 12,305, which can be considered a milestone for waste management in the country (BRASIL, 2010). The objectives of this law were the reduction, reuse, recycling, treatment and proper disposal of urban solid waste, including energy recovery systems, in order to prevent damage to the environment and public health (ALFAIA; COSTA; CAMPOS, 2017). However, there is an ongoing application of a linear model of production, consumption and disposal in society that needs to be revised in light of the concept of sustainability. Above all, it is necessary to evolve to a circular model of reuse and, to aid in the implementation of this change, fruit peels have been used as raw materials for the production of viable foodstuffs for inclusion in human and animal diets, an application that makes for a highly beneficial use of waste (OLIVEIRA *et al*., 2002).

Brazilians consume, on average, 25.0 kg of bananas per year, and Brazil is the fourth largest banana producer in the world. About 70.0 % of this production corresponds to the silver banana (NOMURA *et al*., 2019). The silver banana (*Musa sapientum*) is originally from Southeast Asia, a product of the cross between *Musa acuminata* and *Musa balbasiana*, and belongs to the *Musaceae* family. The silver banana is one of the most consumed fruits by the Brazilian population, due to its nutritional qualities and for its easiness to produce (SOUZA *et al*., 2012). Due to the high acceptance of this fruit by consumers, bananas have been incorporated into several industrialized foods directly or through the inclusion of its natural or synthetic aroma in the formulation of products.

The industry of aromas and fragrances encapsulates several applications, such as the development of fine perfumes, base fragrances used in sanitary and cosmetic products, in addition to being widely used in the food industry. It represents not only a multi-billion-dollar global market, but also a source of scientific development and industrial innovation (SPEZIALI, 2012). The flavor industry has been greatly impacted by the increased consumer preference for natural products. There is a growing concern regarding the safety of raw materials that come into direct contact with the consumer's body, as in the case of aromas used in the food industry (SHARMEEN *et al*., 2021). Market research has shown that consumers expect to have access to products that contribute to a healthier diet; this is an important part of a new consumption era, in which the term "artificial" in synthetic foods or additives can generate a negative perception, and consumer preference targets products that contain natural aromas listed on the label (BRICKEL; MATULKA; BURDOCK, 2018). In this context, it is important to evaluate new production strategies that meet the global trends that demand the use of natural raw materials and products in the aroma market.

The extraction methods employed in the aroma industry should result in an extract with sensory characteristics that are as close as possible to the target product, while also retaining the functionality of the aroma ingredients despite the application of different technologies during processing (HERMAN, 2004). Currently, there are many technologies available for the production of aromas on an industrial scale, enabling the use of both natural and synthetic substances during production stages. Among the main operations used in the production of aromas, it is possible to mention the use of organic solvents as an important extraction technique, as well as rising technologies such as supercritical fluid extraction, one of the most innovative processes applied in the aroma industry (HERMAN, 2004). Among others, distillation, headspace techniques and sorption techniques, including direct thermal desorption (DTD), can also be cited as operations used in the production of aromas (BIZZO; HOVELL; REZENDE, 2009).

Solvent extraction is indicated to recover compounds from specific plant materials that lose thermolabile components when processing occurs at high temperatures, as those employed in steam distillation or hydrodistillation (HERRERO; CIFUENTES; IBAÑEZ, 2006). It basically involves the transfer of substances from a solid material to another medium using an organic solvent. The use of solvents in food production is only permitted when it is carried out within rigorous safety standards. Currently in Brazil, the legislation presents two resolutions with provisions in this regard: the resolution of the collegiate board (RDC) No. 248/2005 (BRASIL, 2005), which regulates the use of technology supporters for the production of oils and fats, and RDC No. 239/2018 (BRASIL, 2018), which indicates food additives and adjuvants authorized for use in food supplements. Isopropanol is within the regularity provided for in public consultation (CP) No. 822/2020 (ANVISA, 2020), which presents a list of solvents for use in the production of food and ingredients, in addition to the conditions of use and maximum residual concentrations.

Thus, this work aimed to evaluate the applicability of using silver banana peel, a solid waste produced in large quantities, as a raw material in the food industry. Its potential as a substrate for the production of natural aromas through the recovery of substances that present a sensory profile rich in aromatic compounds was evaluated by performing extraction with isopropanol and analysis by gas chromatography with mass spectrometry. The proposed application of the banana peel could present as an alternative to the use of synthetic banana aromas, in addition to representing a destination for a large part of this organic waste generated in society.

2 MATERIALS AND METHODS

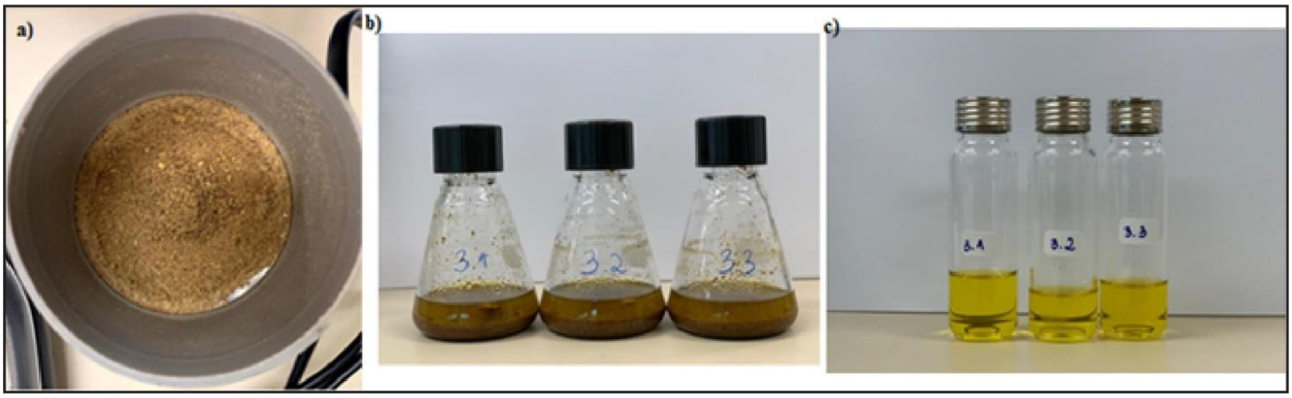
2.1 Sample preparation

The silver banana used in this work was obtained from the horticultural supply center (CEASA) in Porto Alegre/RS (Brazil). All the peels used in the experiments were cut into pieces and kept at a temperature of approximately - 3 °C in a domestic freezer until processing. In order to remove all the moisture contained in the peels and facilitate the extraction process, the samples underwent lyophilization for 24 h (Terroni Equipamentos Científicos LD1500). The equipment tray temperature was maintained at 25 °C and the condenser temperature at - 0.53 °C. The dried banana peels underwent size reduction in a knife mill (IKA A11 Basic Analytical Mill) and milling was carried out for 2 minutes for each 30 grams of sample. For sample conservation, all the powder obtained was stored in a ColdLab Ultrafreezer CL800-86V and kept at a temperature of - 80 °C. Figure 1a shows the powder obtained in the process. In addition, for comparison purposes, a commercial banana flavor sample provided by one of the flavor houses mentioned in this work was also evaluated by chromatography. The objective of this analysis was to find a correlation between the components used commercially to provide products with the banana aroma and the components found naturally in the banana peel in this work.

2.2 Extraction method

Solvent extraction with pure isopropanol (LiChrosolv, Merck, USA) was carried out for the extraction of aromas employing a solvent to dry peel ratio of 4.5 mL g^{-1} (PHYNES, 1986). It is important to emphasize that the solvent was not diluted with water (as in the aforementioned reference), as it was considered that the presence of water would negatively interfere in the analysis by gas chromatography. The contact between solvent and biomass was carried out in shake flasks, and all conditions were tested in triplicates. Three different extraction times were tested; namely, 30 min, 60 min and 120 min. During the process, the flasks were kept under constant agitation in an orbital shaker (Agimaxx AG-200), at 250 rpm and at a controlled temperature of 21 °C. All vials were sealed with lids to avoid the volatilization of the aromatic compounds present in the sample. After extraction, the solutions were filtered with Millipore Millex-FG Phobic PTFE 0.2 μm filters, and then transferred to vials for injection in the gas chromatograph. Figure 1b shows the extract obtained after 60 min of contact, before the filtration procedure, and Figure 1c shows the same extract after filtration.

Figure 1 – (a) Dry powder from silver banana peel; (b) samples at the end of extraction, pre-filtration; (c) samples of extracts post-filtration



Source: Authors, 2021

2.3 Gas chromatography

Chromatographic analyzes were performed with an Agilent 7890B gas chromatograph coupled to a 5977A MSD mass spectrometer. Samples of different extraction times were injected in triplicates, with an injection volume of 1 µL, into a non-polar capillary column composed of 5.0 % phenyl and 95.0 % methylpolysiloxane (30 m × 0.25 mm id × 1 µm df) (DB-5ms, Agilent Technologies, USA). In turn, the commercial banana aroma used as reference in this work was analyzed at a concentration of 100 ppm. Samples were injected in triplicate in splitless mode at 250 °C using a carrier gas stream of 1 mL min^{-1} of helium. The chromatographic conditions employed were: initial temperature of 50 °C (0.5 min) raised to 100 °C (17.17 min) at a heating rate of 3 °C min^{-1}; the temperature was then raised to 250 °C (42.17 min) at a heating rate of 10°C min^{-1}; finally, temperature was raised to 280 °C at a heating rate of 5 °C min^{-1}, remaining at this temperature for 5 min. The transfer line was set at 290 °C. The mass spectrum range was 33 – 500 m z^{-1} and the ionization energy was 70 *e*V. The ion source and quadrupole were maintained at 300 °C and 150 °C, respectively.

2.4 Database for qualitative approach

For the qualitative assessment of the results, substances found in the extracts were identified through a crossing between the peaks found in the mass spectra obtained experimentally and the spectra contained within the database of the National Institute of Standards and Technology of the United States (NIST), using information provided by the “NIST Mass Spectral Library” (Version 2.4, accessed March 2020) (National Institute of Standards and Technology, 2020). Through comparison, a "combination factor" could be reached, which demonstrated how well the peak of the analyzed sample resembled the pattern found in the database, while an evaluation of the Kovats retention index of each substance was also performed.

2.5 Database for sensory approach

The aromatic compounds obtained experimentally through solvent extraction were further assessed by a sensory approach in this work. For this purpose, the “Flavor Base” database was used, in a revised version of 2016 (LEFFINGWELL & ASSOCIATES, 2016). This database is considered to be the largest review ever carried out in its field, including much of the worldwide information currently available on flavors and food additives, therefore containing data relevant to sensory approaches as well as regulatory guidance important to the flavor, food, beverage and tobacco industry. In addition to the aforementioned database, “The Good Scents Company”, which is a database available online was used, as it was developed with the intention of helping perfumers in the creation of new fragrances and trends (THE GOOD SCENTS COMPANY, 2018). The sensory profile of each extracted substance was found in the aforementioned databases, and then a selection was made containing all compounds that presented the "banana" characteristic in their descriptor, i.e., all compounds that directly presented the banana aroma and were therefore of interest to the flavor industry.

3 RESULTS AND DISCUSSIONS

In order to evaluate the potential of the application of isopropanol extraction in the recovery of aromatic compounds from bananas, the characterization of a commercial aroma of this fruit currently found in circulation in the international market was carried out. This procedure was performed in order characterize its composition, indicating the main compounds used in the formulation of a synthetic aroma for contributing with sensory characteristics associated with the banana. The crossing of these data with those found in databases of sensory profiles allowed to aim at the compounds of interest among a high number of substances recovered by solvent extraction.

3.1 Characterization of the commercial banana aroma

The commercial banana aroma used as a reference in this work was analyzed and the list of components found by gas chromatography is described in Table 1. The American Chemical Society number of each substance (CAS), its molecular formula and the percentage of the total area of the chromatogram referring to each component found in the sample are presented. A chromatogram of the commercial banana aroma can be found in Figure 2.

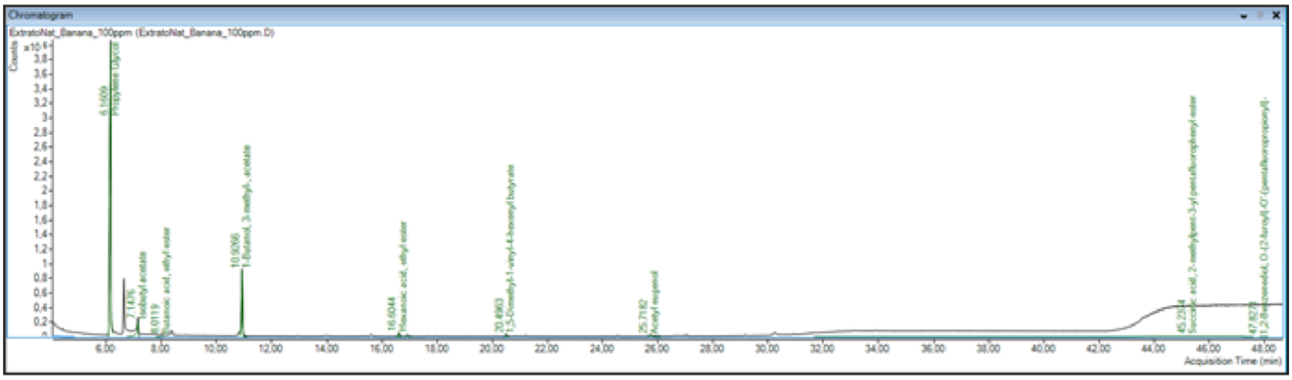
Table 1 – Components found in commercial banana aroma

Component	**CAS #**	**Molecular formula**	**Area (%)**
4-Aminotetrahydro-2H-pyran-4-carboxylic acid	39124-20-4	$C_6H_{11}NO_3$	16.18
Isoamyl acetate	123-92-2	$C_7H_{14}O_2$	15.23
Propylene glycol	57-55-6	$C_3H_8O_2$	14.89
Propylene	115-07-1	C_3H_6	10.94
Pentyl formate	638-49-3	$C_6H_{12}O_2$	10.20
Acetyleugenol	1000284-91-1	$C_{12}H_{14}O_3$	9.10
Isobutyl acetate	110-19-0	$C_6H_{12}O_2$	6.64
Ethyl hexanoate	123-66-0	$C_8H_{16}O_2$	6.17
1,2-Benzenediol, O-(2-furoyl)-O'-(pentafluoropropionyl)-	1000329-74-7	$C_{14}H_7F_5O_5$	5.62
Ethyl butyrate	105-54-4	$C_6H_{12}O_2$	2.46
1,5-Dimethyl-1-vinyl-4-hexenyl butyrate	78-36-4	$C_{14}H_{24}O_2$	2.17
Hexenyl acetate	3681-71-8	$C_8H_{14}O_2$	0.41
Succinic acid, 2-methylpent-3-yl 2-metilpent-3-il pentafluorophenyl ester	1000390-34-8	$C_{16}H_{17}F_5O_4$	0.01

Source: Authors, 2021

All these components coexist in a proportion defined by the manufacturer's formulation, bringing the final banana aroma used in the market. However, there are some specific substances among those detected that, by themselves, already present the aroma of banana in their individual sensory analyses, according to Leffingwell & Associates (2010). These substances are listed in Table 2.

Figure 2 – Chromatogram of a commercial banana aroma sample



Source: Authors, 2021

Table 2 – Compounds presenting banana flavor found in the commercial product

Compound	**CAS#**	**Sensory descriptor**
Isoamyl acetate	123-92-2	Sweet, fruity, banana and pear (odor and flavor)
Isobutyl acetate	110-19-0	Fruity, banana-apple-pineapple-pear notes
Ethyl hexanoate	123-66-0	Strong, fruity, pineapple, banana with strawberry, pear and tropical notes
Hexenyl acetate	3681-71-8	Strong, fruity-grassy odor; green banana notes

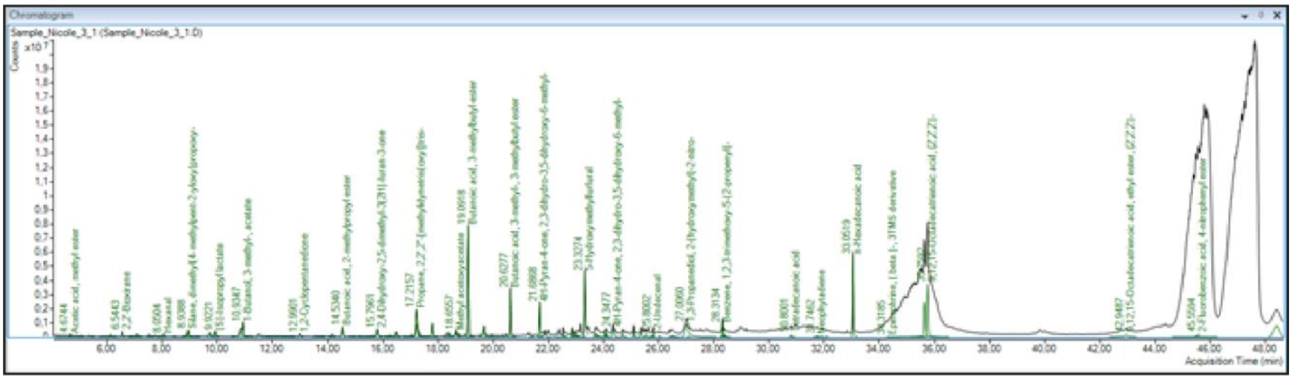
Source: Authors, 2021

The remaining substances present in the formulation of the commercial aroma (not listed in Table 2) do not present the sensory profile of banana directly, but are found within its composition as an addendum to the total aroma, bringing other necessary characteristics for the product, such as the sweet and more "rounded" notes perceived in comparison to when one smells the fruit itself. Furthermore, it is possible to find the presence of propylene glycol, which is often used as a solvent in the flavor industry.

3.2 Characterization of silver banana peel extracts

Three different extraction times (30 min, 60 min and 120 min) were tested in experimental triplicate to evaluate the composition of extracts obtained with isopropanol, since it is known that the composition of aromatic compounds in the extract can vary significantly throughout the process of extraction with organic solvents. Each sample was analyzed by gas chromatography in triplicates. To illustrate results, Figure 3 demonstrates the chromatogram of a sample after 60 minutes of extraction.

Figure 3 – Chromatogram of an extract after 60 minutes of contact with isopropanol



Source: Authors, 2021

The extract chosen for full evaluation in this work was obtained at an extraction time of 60 min. This is due to the fact that the distribution of compounds and the compositions found in the chromatograms varied little with the extraction time. However, among the three options tested, the extracts produced after 60 min of contact with isopropanol presented a slightly higher number of compounds, accounting for an average of 165 identified substances.

Due to the high number of substances detected, data obtained by gas chromatography were treated with the following procedure:

• All substances that were present in all three samples of the triplicate were kept in the listing;

• All compounds that were present in only one of the samples from the triplicate were disregarded, considering that they may have been indicated as an analytical error in the identification procedure performed by the equipment or they could be contaminants from sample handling;

• For substances that were present in only two samples of the triplicate, their relevance to aroma was evaluated, taking into account whether the substance presented a sensory descriptor that resembled that of the banana. Also, the value of relative peak area was considered, as highly discrepant or low values could also be associated with equipment error or sample contamination.

From this procedure, it was possible to obtain a reduced list, containing more than 100 substances found in the extract from silver banana peels. Table 3 shows, among these, those with the highest percentage of peak area in the analysis.

Table 3 – List of substances found in the extract of silver banana peel (highest relative peak areas)

Compound	**CAS#**	**Area (%)**
4-Cyclopentene-1,3-dione	1000411-44-6	1.66 ± 0.08
Isopentyl hexanoate	2198-61-0	1.63 ± 0.00
Isobutyl butyrate	539-90-2	1.60 ± 0.14
1,1-Ethanediol, diacetate	542-10-9	1.44 ± 0.15
5-Oxotetrahydrofuran-2-carboxylic acid, ethyl ester	1126-51-8	1.41 ± 0.37
γ-Hydroxybutyric acid lactone	497-23-4	1.40 ± 0.09
Butyl isovalerate	109-19-3	1.32 ± 0.11
Dodecanoic acid	143-07-7	1.31 ± 0.42
Maleic anhydride	108-31-6	1.27 ± 0.18
2-Undecenal	2463-77-6	1.26 ± 0.07
Decenal	3913-81-3	1.25 ± 0.28
5-Methylfurfural	620-02-0	1.23 ± 0.17
2,4-Dihydroxy-2,5-dimethyl-3(2H)-furanone	10230-62-3	1.21 ± 0.21
2,2'-Bioxirane	1464-53-5	1.20 ± 0.14
3-methyl-2,3-dihydrofuran	1708-27-6	1.15 ± 0.06
Pyroxyfur	70166-48-2	1.08 ± 0.07
2-Butyltetrahydrofuran	1004-29-1	1.08 ± 0.08

Continued...

Table 3 – Conclusion

Compound	CAS#	Area (%)
Valeric anhydride	2082-59-9	1.07 ± 0.10
Formic acid, tetrahydrofurfuryl ester	1000368-75-5	1.06 ± 0.07
2-Sec-Butylcyclohexanone	1000342-30-8	1.05 ± 0.06
Isoamyl butyrate	106-27-4	1.03 ± 0.08

Source: Authors, 2021

3.3 Extracted aromatic compounds with the “banana” descriptor

A crossing between the list of relevant substances found in the extract obtained in this work with information contained in the database (Leffingwell & Associates, 2010) was carried out. Through this procedure, 10 substances were identified that presented a sensory profile compatible with that of bananas. This list of substances, with the respective sensory descriptors, is presented in Table 4. Also, the data were analyzed in order to evaluate the overlap of substances found simultaneously in the commercial banana aroma and in the banana peel extract obtained in this work, evaluating the substances that directly present the sensory descriptor of “banana”. Making all the considerations previously described about the exclusion of components not found in all triplicates, there was a common substance found: isoamyl acetate.

Isoamyl acetate (CAS 123-92-2) has a scent and flavor sensory profile with the characteristics of sweet, fruity, banana and pear. Isoamyl acetate is produced during the fruit's ripening stage, when volatile substances are produced, and it is considered to be the main responsible for the banana aroma (OLIVEIRA *et al*., 2014). This compound can be synthesized by Fischer esterification reaction, by acid catalysis, between isoamyl alcohol and glacial acetic acid (JOÃO RODRIGUES, 2015). It can be applied as a formulation component for the leather industry, in fragrances and aromas, as a solvent for plastic and as a stain remover in the dry-cleaning process (RAUTER PRODUTOS QUÍMICOS, 2019). Furthermore, due to its pleasant and intense aroma and its low toxicity, isoamyl acetate is used to test the efficiency of gas masks (JOÃO RODRIGUES, 2015).

Table 4 – List of sensory-relevant substances with the characteristic of "banana" in silver banana extract

Compound	CAS#	Molecular formula	Sensory descriptor
Isoamyl acetate	123-92-2	$C_7H_{14}O_2$	Sweet, fruity, banana (odor and flavor)
Methylbutyl acetate	626-38-0	$C_7H_{14}O_2$	Fruity, ripe, banana, creamy, green flavor at 10 ppm
Butyl ethanoate	123-86-4	$C_6H_{12}O_2$	Strong, sweet, fruity; Notes of banana, pear, pineapple
Pentyl butyrate	60415-61-4	$C_9H_{18}O_2$	Sweet, fruity, banana, green, purple fruits
Isobutyl butyrate	539-90-2	$C_8H_{16}O_2$	Fruity sweet, pear, pineapple, banana (odor and flavor)
Butyl isovalerate	109-19-3	$C_9H_{18}O_2$	Ethereal, fruity, apple-banana odor, fruity pineapple flavor
Isoamyl butyrate	106-27-4	$C_9H_{18}O_2$	Mix of fruit odor; candy; apricot-apple-banana-pear
Butyl butyrate	109-21-7	$C_8H_{16}O_2$	Strong, sweet, fruity, banana-pear-pineapple-apple
Isobutyl isovalerate	589-59-3	$C_9H_{18}O_2$	Fruity, apple-berry odor; apple green banana flavor
Isopentyl hexanoate	2198-61-0	$C_{11}H_{22}O_2$	Fruity, apple-banana-pineapple, waxy (odor and taste)

Source: Authors, 2021

3.4 Extracted aromatic compounds used in the flavor industry

Within the list of substances found in the extract, in addition to those that present sensory descriptors directly linked to the banana aroma, several compounds that are known to be used in the aroma industry were also found. These substances and their sensory descriptors can be found in Table 5. All of these can somehow also be used in the flavor and food industry, thus enabling several other destinations for the banana peel.

Table 5 – Substances relevant to the aroma industry found in the silver banana extract

Compound	CAS#	Molecular formula	Sensory descriptor
Isoamyl alcohol	123-51-3	$C_5H_{12}O$	Alcoholic odor, breathtaking; when diluted presents wine brandy flavor
γ-Hydroxybutyric acid lactone	497-23-4	$C_4H_4O_2$	Sweet, burnt
Decadienal	25152-84-5	$C_{10}H_{16}O$	Strong, deeply greasy; Greasy and citrus notes
Decenal	3913-81-3	$C_{10}H_{18}O$	Waxy, greasy, earthy, coriander, mushroom, green, notes of pork and chicken
Methylfurfural	620-02-0	$C_6H_6O_2$	Spicy sweet, bread, walnut, caramel (odor and flavor)
Undecenal	2463-77-6	$C_{11}H_{20}O$	Fresh, sweet citrus, orange peel and lemon when diluted
Hydroxymethylfurfural	67-47-0	$C_6H_6O_3$	Hay-like herbaceous, sweet herbaceous, tobacco-like taste
Linolenic acid	463-40-1	$C_{18}H_{30}O_2$	Greasy
Linoleic acid	60-33-3	$C_{18}H_{32}O_2$	Oily fat; waxy mouthfeel
Methyl acetate	79-20-9	$C_3H_6O_2$	Sweet, ethereal volatile fruity odor; similar to Ethyl acetate
Elemicin	487-11-6	$C_{12}H_{16}O_3$	Sweet, somehow spicy woody-floral odor
Heptyl butyrate	39026-94-3	$C_{11}H_{22}O_2$	Wax, fruity, green, somehow tropical with a floral note
Isoamyl isovalerate	659-70-1	$C_{10}H_{20}O_2$	Fruity scent of green apple, pineapple, tropical, mandarin, apricot, cognac
Pentylfuran	3777-69-3	$C_9H_{14}O$	Earthy, green, vegetable and fruity
Hexanal	66-25-1	$C_6H_{12}O$	Strong, greasy-green, green grass

Continued...

Table 5 – Continuation

Compound	**CAS#**	**Molecular formula**	**Sensory descriptor**
Palmitic acid	57-10-3	$C_{16}H_{32}O_2$	Almost odorless, but has a waxy taste
Pentadecanoic acid	1002-84-2	$C_{15}H_{30}O_2$	Weak, waxy, slightly greasy (odor and taste)
Pentanoic acid	109-52-4	$C_5H_{10}O_2$	Powerful, "sweet" cheese odor; fruity, cheese, dairy taste when diluted
Propionic acid	79-09-4	$C_3H_6O_2$	Pungent, sour milk odor, cheese
Isobutyric acid	79-31-2	$C_4H_8O_2$	Sour cheese odor, in dilution reminiscent of fruit (odor and flavor)
Methyl pyruvate	600-22-6	$C_4H_6O_3$	Sweet, fruity-caramel-spicy, sour (odor); Rum-spicy-caramel (flavor)
Tetradecanoic acid	544-63-8	$C_{14}H_{28}O_2$	Very weak, waxy oil, waxy mouthfeel
Isoamyl formate	110-45-2	$C_6H_{12}O_2$	Sweet, green-fruity wine, resembles black currant, plum and apple
Oxoglutaric acid	328-50-7	$C_5H_6O_5$	Sour, used in the preparation of red meat, chicken and cheese flavors
Pentanol	6032-29-7	$C_5H_{12}O$	Wine, ethereal, fusel; weak fruity wine
Methylpentenal	623-36-9	$C_6H_{10}O$	Pungent green, fruity (odor); Sweet, fruity, brown (flavor)
Hydroxyacetone	116-09-6	$C_3H_6O_2$	Slightly green; Light sweet and caramel note
Methylthiazole	693-95-8	C_4H_5NS	Walnut, green vegetable, meat, with an aliceous note
Methyl linolenate	301-00-8	$C_{19}H_{32}O_2$	Greasy oil
Butanoic acid	107-92-6	$C_4H_8O_2$	Strong, cheese, butter, light (odor and taste)
γ-Butyrolactone	96-48-0	$C_4H_6O_2$	Weak, slightly caramelic, nutty, butter odor

Continued...

Table 5 – Conclusion

Compound	CAS#	Molecular formula	Sensory descriptor
Dodecanoic acid	143-07-7	$C_{12}H_{24}O_2$	Faint, refreshing, waxy (odor); Greasy-waxy-soapy (flavor)
Methyltetrahydrofuran	1004-29-1	$C_8H_{16}O$	Sweet, solvent, fat, slightly green
Methyl thioacetate	1534-08-3	C_3H_6OS	1 ppm: vegetable cabbage; 0.1 ppm: popcorn-cereal (flavor); cheese
Dimethoxymethane	109-87-5	$C_3H_8O_2$	Ethereal, earthy, alcoholic, slightly fruity, rum

Source: Authors, 2021

4 CONCLUSIONS

The analysis of the extracts obtained in this work indicated that the isopropanol extraction technique was effective in obtaining aromatic compounds relevant to the banana aroma using its peel as substrate. This represents an opportunity to add value to a waste that is produced in abundance both domestically and in the food industry. Furthermore, the growing demand for aromas produced using natural sources makes this approach necessary. The composition of the extracts showed that several substances associated with the aroma of bananas were extracted, to a greater or lesser extent. It is expected that the development of a selective and efficient extraction and purification process can enable the use of these substances in the formulation of aromas that require additives presenting these sensory profiles. This would signify an alternative to the use of aromas obtained by synthetic routes. In turn, the comparison between the composition of the extract obtained from the banana peel and the commercial aroma of this fruit indicated the presence of an important aromatic compound in common: isoamyl acetate. The recovery of this compound, already widely used in the flavor industry, confirmed the potential of applying simple solvent extraction technology in this industrial sector.

The approach used in the work rendered promising results, and the development of this technology will depend on the continuity of research efforts. For future work, the use of olfactory chromatography is suggested, in order to obtain a precise sensory profile of each substance in the sample, in addition to the application of quantitative analytical techniques to determine the concentration of each substance obtained in the extracts. Modifications in the fruit itself, such as the degree of maturation and even the use of other banana species should be further approached and could improve the use of the fruit peel at its best stage for extracting aromatic compounds. The optimization of the extraction process, including the use of other solvents or mixtures, in addition to the evaluation of extraction techniques such as the use of supercritical fluid extraction are suggested so that the actual potential of extraction of aromas from banana peels is achieved.

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