Chemical composition of pequi essential oil (*Caryocar brasiliense*) and nematicidal activity in the control of *Meloidogyne javanica*[1]

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ABSTRACT

The phytonematodes seriously harm plants worldwide, reducing agricultural productivity, especially root-knot nematodes, genus Meloidogyne. An alternative form of control for this pathogen is the use of essential oils, which have a complex mixture of compounds with potential nematicidal activity. The objective of this work was to identify the chemical compounds present in the essential oil of pequi and to verify the efficiency of the oil in the control of *Meloidogyne javanica*. The identification of chemical compounds was performed by comparing the mass spectra obtained with the spectra present in the equipment library, Nist08. Eighty-second stage juveniles (J2) were incubated in the following treatments: control 0 (2 mL of distilled water) 2, 4, 8 and 16 mg L^{-1} of pequi essential oil (PEO). The results obtained in the experiment were significant, with a high percentage of mortality of J2 in the treatment T5 (16 mg L^{-1}) of 82% and T3 (4 mg L^{-1}) 66%, respectively. Among the compounds identified, 58.3% are esters, highlight for ethyl hexanoate, and 25.0% are monoterpenes, and all are nematicidal compounds. Pequi essential oil has the potential to be used in the control of *M. javanica*.

Keywords: root-knot nematode; nematicide; alternative control; ester compounds; ethyl hexanoate.

INTRODUCTION

The pequi (*Caryocar brasiliense* Cambess) is a species of the *Caryocaraceae* family, native to the Brazilian Cerrado. Its agricultural exploitation occurs mainly in the states of Goiás and in the north of Minas Gerais with a great social, cultural and economic importance. In the 2020 harvest, the national production of pequi was 63,520 tons of fruit (IBGE, 2020). Commonly, its exploitation is extractivist, constituting a sustainable practice of great economic importance for the Brazilian Cerrado (Almeida *et al.*, 2018). Only the pequi kernel is used for food, industry and cosmetics, so it generates a large amount of residue from its pericarp that is usually discarded.

In relation to the pathogens capable of making agricultural crops unfeasible, nematodes represent one of the most important due to the great damage caused. The root-knot nematodes, genus *Meloidogyne*, stand out as being of great importance for world agriculture, since they have wide geographic spread, wide host range and high reproductive capacity (Silva *et al.*, 2016), in addition to making plants infected. more susceptible to attack by other pathogens (Somavilla *et al.*, 2012). Among the root-knot nematodes, *Meloidogyne javanica* has widespread occurrence causing severe and increasing damage in plants, as it is a species that has an extensive range of hosts in Brazil, manages to

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maintain its survival and reproduction with greater ease in countries of tropical climate (Correia *et al.*, 2017). The most evident symptoms caused by infection by root-knot nematodes are chlorosis (yellowing) on the leaves, formation of galls and root lesions, in addition to poor development and subsequent reduction in productivity (Pinheiro, 2017).

The management of root-knot nematodes has mainly been carried out through cultural, chemical, physical and biological practices (Rani et al., 2022). The successful control of infested areas requires a set of associated measures, as its eradication is practically impossible (Oliveira et al., 2009). The genetic management is an effective method of limiting yield losses caused by Meloidogyne spp. (Santos et al., 2018), however, the availability of commercial cultivars of plants resistant to phytonematodes is still relatively scarce. Cultural control aims to reduce the population of phytonematodes (Favoreto et al., 2019), this through manipulation of pre-planting conditions and during host development in relation to pathogen, with the aim of preventing or intercepting the epidemic that reduce contact between the susceptible host and the pathogen (Bellé & Fontana, 2018). The cultural control with incorporation of pequi exocarp into the soil at a dose of 0.020 kg of fruit resulted in a 56% reduction in the reproduction of M. javanica compared to a control treatment without pequi fruit residues (Peixoto, 2019).

Therefore, more alternatives are sought that can add to chemical and biological nematicides and cultural practices, in order to seek a more sustainable and effective management. A strategy that has potential to be used in the cultural control of phytonematodes is the use of essential oils from vegetables, whose biochemical composition may present compounds with nematicidal activity (Medeiros *et al.*, 2016).

Commonly, residues such as peels and mesocarp fruit, such as pequi, are discarded by the food industry. This fact occurs mainly because they do not have flavors, or even pleasant appearance for this type of trade, but these residues have components with different purposes, including antimicrobial, which can help in the fight against phytonematodes. Representing another sustainable nematode control option.

Active principles in the control of phytopathogens have been investigated in various structures of pequi trees (De Carvalho *et al.*, 2015). Methanolic and ethanolic extracts present in leaves, flower buds and fruits have fungitoxic effects on the germination of spores of *Botrytis cinerea* and *Fusarium oxysporum* (Ribeiro *et al.*, 2012). Researches with essential oils of rosemary pepper (*Lippia sidoides*) and citronella grass (*Cymbopogon winterianus*) reduced the reproductive rate of *M. incognita* by 83 and 29% in tomato and celosia, respectively. Concentration of 2.5 ml L^{-1} (Moreira *et al.*, 2015). Studies showing the chemical composition with nematicidal activity of essential oils from cerrado plants is still incipient.

The objective of this work was to identify the chemical compounds present in the essential oil of pequi and to verify the efficiency of the oil in the control of the nematode of *Meloidogyne javanica*.

MATERIAL AND METHODS

The test was carried out between in the Organic Chemistry and Agricultural Nematology laboratories. The nematode population used was previously identified and characterized as *M. javanica* by the esterase J3 phenotype, using the biochemical technique of isoenzyme electrophoresis, according to Carneiro & Almeida (2001).

Extraction and multiplication of Meloidogyne javanica inoculum

The eggs of *M. javanica* were obtained from the roots of a light green scarlet eggplant (*Solanum aethiopicum* L.) cultivated in a greenhouse for 60 days. For the extraction of eggs, it was carried out using the method of Hussey & Barker (1973) modified by Boneti & Ferraz (1981), which consists of cutting the roots into fragments of approximately one centimeter, about 10 grams and grinding them later in a blender at the lowest speed with 200 mL of a 0.5% NaOCl solution for a period of 20 seconds. Then, the suspension passed through 200 and 500 mesh sieves. The suspension obtained by the last sieve was placed in a Peter counting chamber and taken under a photonic microscope at 100X magnification.

Obtaining second stage juveniles (J2) of Meloidogyne javanica

The eggs obtained were deposited in a modified Baermann funnel (Baermann, 1917) and kept at room temperature (25 °C ± 1 °C), and the funnel used was made of glass (180 mm in diameter) coupled to a support, a styrofoam box with At the end of the funnel, placed a medical rubber hose (6 mm) and sealed the upper part of it with plastic tape and the lower part with a metal clip to prevent water from escaping and the loss of J2. After

12 h, the hatched nematodes were discarded, in order to discard the dead and inactive juveniles. After 24 h, the nematodes were collected for the installation test. The final suspension was calibrated to 80 J2 mL^{-1} under a photonic microscope at 100X magnification.

Collection and Preparation of the Pequi Fruit

The pequi fruit was collected in October and November 2019. The material was collected in the rural area of the municipality of Buriti Alegre (18°11’44.0”S and 49°03’33.1”W), located in the southern region of Goiás State, Brazil. It was randomly harvested with peel, and subsequently subjected to essential oil extraction.

Pequi essential oil extraction

The fruit was taken to the Organic Chemistry laboratory, where it was peeled in order to obtain only the fresh pequi mesocarp, which was crushed into small pieces of 1 cm, according to the methodology proposed by Peixoto (2019), and stored in a sealed package. in the refrigerator at 8 ºC until the essential oil extraction (Leite et al., 2020).

The pequi essential oil (PEO) was extracted through the hydrodistillation process using the Clevenger apparatus Cordeiro *et al.*, (2013); Elyemni *et al.*, (2019) in the Organic Chemistry Laboratory. Six 4-hour extractions were performed. In each extraction, 0.5 kg of fresh pequi mesocarp and 2 L of distilled water were used (yield 10 mL PEO).

The PEO was removed with a Pasteur-type pipette and stored in a 10 mL glass bottle, and placed in the freezer at -20 ºC until the time of chemical and biological analysis. From the six extractions carried out, approximately 1.0 mL of oil was obtained, which was used for the biological test and for the chemical analysis.

Chemical analysis in GC-MS

After the extraction step, the PEO samples were injected into a Gas Chromatograph coupled to a Mass Spectrometer (GC-MS - Perkin Elmer, model GCClarus680/EMClarusSQ8S), equipped with a capillary column (5% diphenyl and 95% dimethylpolysiloxane) 30 m long, 0.25 mm internal diameter and 0.25 µm film thickness. The carrier gas was helium at a constant flow rate of 1 mL min^{-1}, the temperatures of the injector (slipt mode 1:20) and detector were, respectively, 220 and 246 °C; the injection volume was 1 µL of oil diluted in hexane and dehumidified with sodium sulfate. The heating ramp was from 60 to 246 °C (3 °C min^{-1}). The mass detector was operated with an impact energy of 70 V (Adams, 2007).

Identification of essential oil componentes

The identification of the compounds present in the PEO was performed by comparing the mass spectrum obtained for each compound with the spectra of the library present in the equipment’s software, Nist08 and in the reference book by Adams (2007). In the comparison of the mass spectra, the profile of the spectra (fragmentation) and the retention time were observed.

Installation and evaluation of the experiment

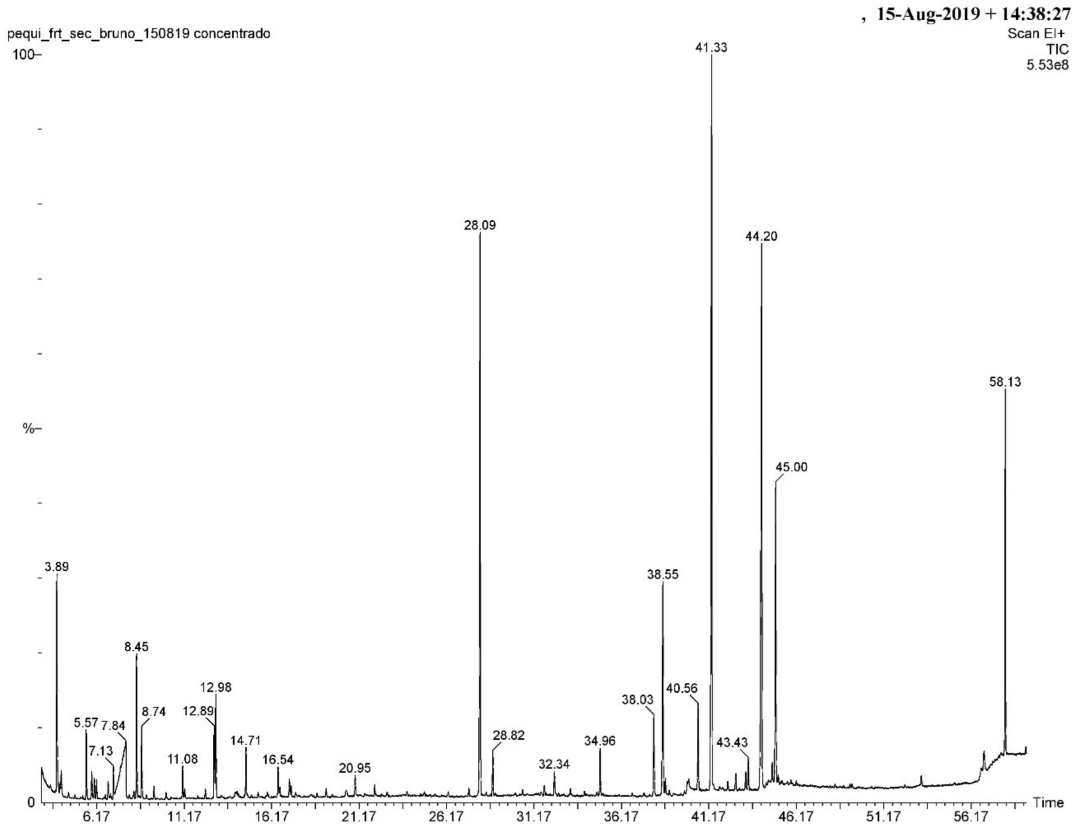
The effect of pequi fruit inner mesocarp essential oil (PEO) on juvenile mortality (J2) was evaluated under laboratory conditions at 25 ºC in test tubes with a capacity of 10 mL (25 x 150 mm). The trial was installed in a completely randomized design (DIC) with five treatments and five replications, using distilled water as a control treatment and PEO at concentrations of 2, 4, 8 and 16 mg L^{-1} (5 treatments and 5 replications), each treatment containing 80 J2 in 2 mL for each concentration. To obtain the PEO concentrations, 100 mL of distilled water, 10 mL of ethanol (v/v), 0.3 mL of Tween 20 (v/v) and pequi oil 2 mg L^{-1} (2%) were used. 4 mg L^{-1} (4%), 8 mg L^{-1} (8%) and 16 mg L^{-1} (16%). The tubes were kept on a plate in the dark for this, a cardboard box was used inside a refrigerator at a temperature of 25 °C. The evaluation was carried out after 5 days, and the suspension was taken to a 500 mesh sieve to eliminate the oil in running water and 1 mL was collected, placed the nematodes in a Peter counting chamber and taken to the photonic microscope at a magnification of 100 X to evaluate the nematicidal effect of the concentrations. The percentage of J2 mortality was determined by the equation: J2 dead (%) = (J2 dead x100)/(J2 dead + J2 alive) as reallocated by Marino *et al.* (2012).

Statistical analysis

The numerical data in relation to the mortality rate of J2 were statistically evaluated through qualitative analysis using Tukey’s test at 5% probability. The Sisvar ® software was used (Ferreira, 2011).

RESULTS AND DISCUSSION

From the analysis of the GC-MS, the PEO chromatogram was obtained (Figure 1), where the peaks presented indicate the compounds identified in the sample (Table 1).



Note: The numbers indicate compounds identified in the PEO, described in Table 1.
Figure 1: Chromatogram of pequi essential oil (*Caryocar brasiliense*).

Table 1: Chemical compounds identified in Pequi Essential Oil (PEO) in a Gas Chromatograph coupled to a Mass Spectrometer (GC-MS - Perkin Elmer, model GCClarus680/EMClarusSQ8S)

Number	Time to Retention	Molecular Formula	Molecular Mass	Compound
1	3.66	$C_7H_{14}O_2$	130	2-methylbutanoate of ethyl
2	3.73	C7H14O2	130	3-methylbutanoate of ethyl
3	5.25	NI	NI	NI
4	5.59	$C_8H_{16}O_2$	144	Sec-butanoate butyl
5	7.46	$C_8H_{16}O_2$	144	Ethyl hexanoate
6	8.45	$C_{10}H_{16}$	136	D-limonene
7	8.98	$C_{10}H_{16}$	136	α-Ocymene
7	8.98	$C_{10}H_{16}$	136	β-Ocymene
8	9.36	$C_9H_{18}O_2$	158	2-methyl propanoate of isopentyl
9	12.07	NI	NI	NI
10	14.59	$C_{10}H_{20}O_2$	172	Ethyl octanoate
11	16.29	$C_{10}H_{12}O_2$	164	2-ethyl phenylacetate

Note: NI = Not identified.

The compounds were identified by comparing the mass spectrum obtained with the mass spectra present in the equipment's software library, Nist08®. This software has a compatibility factor between the analyzed spectra that ranges from zero to 100%. All identified compounds obtained a degree of reliability greater than 90%, in addition, some compounds were also confirmed by comparing the mass spectrum obtained with those brought by Adams (2007), which presents several spectra already identified for some compounds. The structures of substances identified in Table 1 are shown in Figure 2.

It was found that 58.3% of the compounds identified in Table 1 are substances that present the ester functional group. The remainder of the identified compounds are monoterpene compounds, which represent 25.0% of the identified compounds and 16.7% were not identified. According to Lorena & Bicas (2017), this class of compounds is of great importance for the aroma of natural products, especially for citrus fruits and fruits, such as pequi.

The major compound identified in this analysis was the ester ethyl hexanoate (5), as well as in the analyzes performed by Cordeiro *et al.*, (2013) and Cordeiro (2012), who also performed the chemical analysis with the PEO. According to the work of Zhang *et al.* (2020), 20 μL of this compound was able to kill all nematodes (*Caenorhabditis elegans*) in 6 h and 12 h.

The substances marked as NI in Table 1, mean "not identified", that is, it was not possible to identify the compounds using the technique by comparing mass spectra, due to the low compatibility of the analyzed spectra of the library with the mass spectrum obtained. The outdated library may have been a factor in this impossibility of identification, given that several compounds with different structures are identified daily (Chaul *et al.*, 2013).

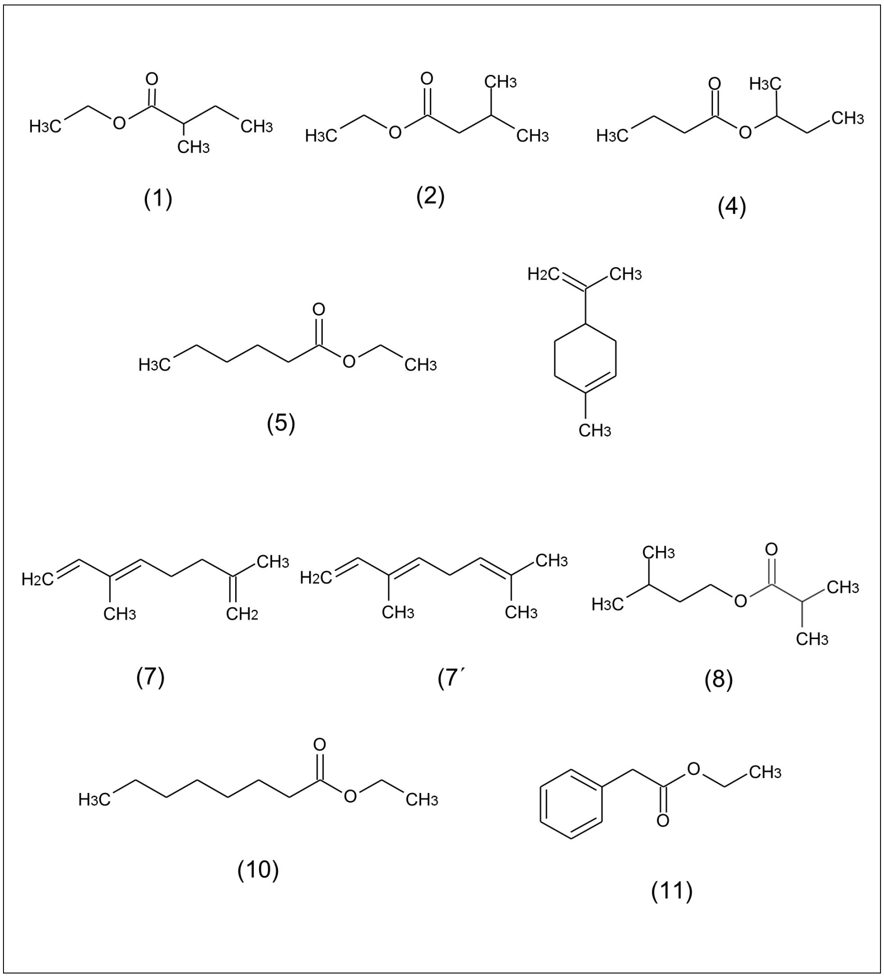


Figure 2: Chemical structures of compounds identified from essential oil of pequi PEO.

Of the 58.3% of compounds identified in the PEO as an ester, one is ethyl 2–methylbutanoate and ten is ethyl octanoate, and 25.0% of the seven monoterpenes are β–ocimene. In the work of Cordeiro *et al.* (2013) and Cordeiro (2012), who also analyzed the PEO, identified the compound's ethyl 2–methylbutanoate (1), β–ocymene (7') and ethyl octanoate (10). Recently, several compounds from the ester group with nematicidal activity against *Meloidogyne incognita* were identified (Silva, *et al.*, 2021). Based on the results, the esters and monoterpenes identified have great potential for nematicidal effect and have been responsible for the effect on the nematode.

Of the esters identified were ethyl 2-methylbutanoate, ethyl 3-methylbutanoate, sec-butyl butanoate, ethyl hexanoate, isopentyl 2-methyl propanoate, ethyl octanoate, ethyl 2-phenylacetate; and monoterpenes D-limonene, α-ocimene, β-ocimene. According to the work of Passos *et al.*, (2002), ethyl hexanoate (5) and ethyl octanoate (10) showed an antifungal effect in in vitro tests against *Cryptococcus neoforman*. β–ocimene (7′) is reported as a flavoring agent responsible for the smell of several flowers, as well as being produced by certain plants that have been attacked by herbivores (Lima & House, 2001). Such action occurs as a form of defense that repels insects that are harmful to plants at this moment of sensitivity.

Regarding the nematicidal activity of the PEO, the data from the analysis of variance and the Tukey's test of means at 5% of significance are shown in Table 2. All concentrations of pequi essential oil (2, 4, 8, and 16 mg L^{-1}), analyzed showed a positive effect ($p \leq 0.05$), compared with the control (distilled water) on the mortality of J2 of *M. javanica*. There was a difference between treatments ($p \leq 0.05$), where treatments T3 (4 mg L^{-1}) and T5 (16 mg L^{-1}) resulted in a higher percentage of mortality of 66 and 82% of J2, respectively.

The concentration with 4 mg L^{-1} was enough to cause the death of 66% of the nematodes, while that of 2 mg L^{-1} corresponded to a level of 58% in the control of J2 of *M. javanica*. The highest concentration analyzed (16 mg L^{-1}) resulted in a mortality of 82% of J2.

At the concentration of 8 mg L^{-1} (T2) the results showed a lower mortality rate of *M. javanica* J2. Probably, intrinsic biological factors related to the concentration of PEO and its interaction with the nematode. In the control treatment (T0), few dead J2 were observed 24%, since the water did not contain any active compounds. Probably these juveniles already hatched with little body energy or with little metabolic activity and then died. Treatments with pequi essential oil showed positive results with a high mortality rate of nematodes. The treatments with the highest concentration obtained more effective results, causing up to 82% mortality of *M. javanica* J2 at the highest concentration of PEO. In the study by Rocha *et al.* (2009), the six-day storage period of J2 of *M. incognita* and *M. exigua* resulted in losses of more than 50% of the neutral lipid content in relation to the original level, representing the threshold period of infectivity in tomato, while for reproduction, this period was reduced to three days of storage.

In the current work, 58.3% of the compounds identified were esters and 25% were monoterpenes. In a study carried out in 2013, the authors identified 21 chemical constituents in pequi pulp, in which esters with 55 to 87% were the main chemical class identified, followed by terpenes, mostly represented by monoterpene hydrocarbons 10-28%, and other constituents, such as non-terpene alcohols 1-14%. The main constituents identified were ethyl hexanoate (mean value = 55.92 ± 25.10%), (E)-β-ocimene (17.65 ± 11.88%)

Table 2: Mean values of second stage juveniles (J2) of *Meloidogyne javanica* mortality in the *in vitro* test with application of essential oil from the inner mesocarp of the pequi fruit (*Caryocar brasiliense*), carried out with 2 mL of the solution containing 80 nematodes after 120 h of incubation

Concentrations (mg L^{-1})	**J2 Deads**	**% mortality**
0	9.60 a	24% a
2	23.20 bc	58% bc
4	26.40 cd	66% cd
8	16.00 ab	40% ab
16	32.80 d	82% d
SMD	7.59	-
CV(%)	18.58	-

SMD = Significant Minimum Difference, CV = Coefficient of variation, means followed by the same lowercase letter in the column do not differ statistically from each other at the 5% probability level by Tukey's test.

and ethyl octanoate (4.79 ± 5 .07%) (Cordeiro *et al.*, 2013). Pequi pulp and almonds contain phenolic acids, these being the highest concentration of ellagic acid, p-coumarinic acid, gallic acid and 4-OH benzoic acid (Do Nascimento, 2018). The chemical compounds (E)-ocimeone, ethyl octanoate and terpenes were shown to be nematicides (Massuh *et al.*, 2017; Abdel-Rahman *et al.*, 2019), and also these same compounds were found in the PEO and this confirmed the nematicidal effect. of the PEO in the J2 of *M. javanica*.

The concentration with 16 mg L^{-1} of the PEO was enough to cause the death of 82% of the J2 of *M. javanica*, 4 mg L^{-1} 66% and 2 mg L^{-1} 58% of nematode mortality. The use of aqueous extract and powder of pequi fruit residue showed efficacy in reducing the hatching rate and increasing the mortality rate of second-stage juveniles of *M. javanica*, but showed signs of phytotoxicity under in vivo conditions (Ribeiro *et al.*, 2012). The ethanolic extract of pequi caused a mortality rate of *M. javanica* of 20% of juveniles, that is, a lower rate than the pequi essential oil (16 mg L^{-1}, T5) of 82% and (4 mg L^{-1}, T3) 66% mortality of *M. javanica* J2 (Lopes, 2017).

The *in vitro* results obtained in the present study with PEO were satisfactory, as was expected since in the work carried out in a greenhouse, the effect of incorporating the exocarp of the pequi fruit into the soil, the dose of 0.020 kg of the fruit caused a reduction of 56% in the reproductive rate of *M. javanica* compared to the control treatment, without the pequi fruit residue (Peixoto, 2019). The doses of 0.015 and 0.030 g of pequi peel powder and external mesocarp per pot (5 L) reduced the number of *M. javanica* egg masses per root by 47.8 and 95.8% in relation to the control (Ribeiro *et al.*, 2012).

Natural plant substances have the potential to be used in the alternative control of plant diseases, especially in organic agriculture. Alkaloids, fatty acids, isothiocyanates, phenolic compounds and tannins are substances with known nematotoxic activities, and as the pequi mesocarp contains tannins and phenolic acids, the nematicidal effect observed in the present study comes from the substances identified from the PEO (E)-ocimeone, ethyl octanoate and terpenes (Coimbra *et al.*, 2006; Gardiano *et al.*, 2011; Mateus *et al.*, 2014; Neves *et al.*, 2008; Abdel-Rahman *et al.*, 2019). pequi essential oil showed a high percentage of mortality of J2 in the treatment T5 (16 mg L^{-1}) of 82% and T3 (4 mg L^{-1}) of 66%, respectively. It is worth mentioning of the compounds identified, 77.8% were esters and 22.2% monoterpenes. Some studies under laboratory conditions (Abdel-Rahman *et al.*, 2019; Ferreira & De Paula Júnior, 2019; Ribeiro *et al.*, 2012; Lopes, 2017; Massuh *et al.*, 2017; Silva *et al.*, 2021) demonstrate that terpenes, (E)-ocimeone, ethyl octanoate and phenolic acid have nematicidal action by reducing the rate of eclosion and cause the death of J2 of *Meloidogyne* spp., corroborating with the compounds present in the pequi peel and pulp found in the present study.

In the present study, PEO at a concentration of 16 mg L^{-1} caused the mortality of 82% of *M. javanica* J2. *Tagetes minuta* TmV3 essential oils with high (E)-ocimeone content showed strong suppression of J2 root penetration (LC50: 0.1 mg/mL) (Massuh *et al.*, 2017). Therefore, for the present study with PEO, soil application should be higher compared to the concentrations obtained in the in vitro study, due to the influence of environmental factors and soil biota.

The essential oils and plant residues such as pequi, marigold, rosemary, pepper and citronella grass have been widely used. Various analyzes of these oils have proven the effectiveness of these compounds in controlling several species of nematodes (Moreira *et al.*, 2015, Massuh *et al.*, 2017). The range of pest and pathogen controls that can be obtained through vegetable oils is extensive due to the diversity of plants existing in Brazil, and this present study is of paramount importance so that future research can be carried out with the most varied types of oils. or even vegetable residues, making the control effective and low cost, which has been much sought after by producers.

The compounds found in essential oils such as esters (ethyl 2-methylbutanoate, ethyl 3-methylbutanoate, sec-butyl butanoate, ethyl hexanoate, isopentyl 2-methyl propanoate, ethyl octanoate, ethyl 2-phenylacetate) and monoterpenes (D-limonene, α-ocimene, β-ocimene) can act directly on the pathogen or be resistance inducers, in this case involving the activation of latent defense mechanisms of plants. Regarding the mechanism of action, previous works with essential oils indicate that the secondary metabolites contained in them interact with the cytoplasmic membrane, promoting the rupture of polysaccharides, phospholipids and lipids, causing the depolarization of some membranes of the cytoplasmic organelles, altering the permeability of these membranes. (Marino *et al.*, 2012).

The contribution of this work was to demonstrate the importance of using a native fruit and alternative management with pequi essential oil (PEO) in the control of *M. javanica* in vitro. The results provided showed a high nematicidal effect to the J2 of *M. javanica*, with concentrations of 16 mg L^{-1} 82%, 4 mg L^{-1} 66% and 2 mg L^{-1} 58% allowing the producer to apply in the field to manage root-knot nematodes.

Based on the results obtained in the present study, the recommendation for a producer who is suffering from damage caused by phytonematodes and who is looking for a more sustainable way to combat these organisms is that PEO has high nematicidal activity of *M. javanica*. This more sustainable form would be the encapsulation of pequi oil, which reduces the loss of volatile nematicidal compounds and allows greater contact of the product with phytonematodes.

CONCLUSION

Of the compounds identified by the GC-MS process, 58.3% had the ester (ethyl 2-methylbutanoate, ethyl 3-methylbutanoate, sec-butyl butanoate, ethyl hexanoate, isopentyl 2-methyl propanoate, ethyl octanoate, ethyl 2-phenylacetate) functional group and 25.0% of the compounds identified are terpenes (D-limonene, α-ocimene, β-ocimene), groups that are known to contain substances with nematicidal activity.

The results obtained in the experiment demonstrated a high percentage of mortality of J2 in the treatment T5 (16 mg L^{-1}) of reaching 82% control of *M. javanica.*

Pequi essential oil has the potential to be used as another new control strategy in the management of *M. javanica*.

REFERENCES

Abdel-Rahman AA, Kesba HH & Al-Sayed AA (2019) Activity and reproductive capability of Meloidogyne incognita and sunflower growth response as influenced by root exudates of some medicinal plants. Biocatalysis and Agricultural Biotechnology, 22:101418.

Adams RP (2007) Identification of essential oil components by gas chromatography/ quadrupole mass spectroscopy. Carol Stream, Allured Bussiness Media. 804p.

Almeida AS, de Macedo E, da Silva DCG, da Silva IJM, de Farias ED & Santos CRO (2018) Óleo de pequi (Caryocar brasiliense Camb.) métodos de extração, constituição química e propriedades medicinais. Diversitas Journal, 3:557-563.

Baermann G (1917) Eine einfache methode zur auffindung Von ankvlostomum (Nematoden) larven in erdproben. Nederlands Indie, 57:131-137.

Bellé RB & Fontana DC (2018) Patógenos de solo: principais doenças vasculares e radiculares e formas de controle. Enciclopédia Biosfera, 15:28:779.

Boneti JIS & Ferraz S (1981) Modificação do método de Hussey e Barker para extração de ovos de Meloidogyne exigua de raízes de cafeeiro. Fitopatologia Brasileira, 6:553.

Carneiro RMDG & Almeida A (2001) Técnica de eletroforese usada no estudo de enzimas dos nematóides das galhas para identificação de espécies. Nematologia Brasileira, 25:35-44.

Chaul LT, Rodríguez EC, Conceição EC, Alves VF & Paula JR (2013) Identificação de compostos presentes em óleo essencial de Rosmarinus officinalis por cromatografia gasosa acoplada a espectrometria de massas (CGEM). Revista de Biotecnologia & Ciência, 1:01-01.

Coimbra JL, Soares ACF, Garrido MS, Sousa CS & Ribeiro FLB (2006) Toxicidade de extratos vegetais a Scutellonema bradys. Pesquisa Agropecuária Brasileira, 41:1209-1211.

Cordeiro MW (2012) Caracterização física e química de frutos de pequizeiro (caryocar brasiliense camb.) de diferentes regiões do estado de mato grosso. Master Dissertation. Universidade Federal de Goiás, Goiânia. 51p.

Cordeiro MWS, Cavallieri ÂLF, Ferri PH & Naves MMV (2013) Características físicas, composição químico-nutricional e dos óleos essenciais da polpa de Caryocar brasiliense nativo do Estado de Mato Grosso. Revista Brasileira de Fruticultura, 35:1127-1139.

Correia ÉCSS, Neves MIRS, Silva LS, Santos DS & Neto FJD (2017) Estratégias e desafios no manejo de nematoides formadores de galhas (Meloidogyne spp.) em cultivos de olerícolas: Uma Revisão. Revista Mirante, 10:19-33.

De Carvalho LS, Pereira KF & de Araújo EG (2015) Características botânicas, efeitos terapêuticos e princípios ativos presentes no pequi (Caryocar brasiliense). Arquivos de Ciências da Saúde da UNIPAR, 19:147-157.

Do Nascimento LM (2018) Óleo de pequi – um nutracêutico com propriedades antioxidante: uma revisão de literatura. Trabalho de Conclusão de Curso em Farmácia. Universidade de Brasília, Brasília. 54p.

Favoreto L, Meyer MC, Dias-Arieira CR, Machado ACZ, Santiago DC & Ribeiro NR (2019) Diagnosis and management of phytonematodes in soybean. Agricultural Informe, 40:306:18-29.

Ferreira DF (2011) Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia, 35:1039-1042.

Elyemni M, Louaste B, Nechad I, Elkamli T, Bouia A, Taleb M, Chaouch M & Eloutassi N (2019) Extraction of Essential Oils of Rosmarinus officinalis L. by Two Different Methods: Hydrodistillation and Microwave Assisted Hydrodistillation. The Scientific World Journal, 2019:01-06.

Ferreira TS & De Paula Júnior W (2019) Caracterização fitoquímica da polpa e amêndoa de Caryocar brasiliense Cambess. Brazilian Journal of Health and Pharmacy, 1:19-25.

Gardiano CG, Muramotto SP, Krzyzanowiski AA, Almeida WP & Saab OJGA (2011) Efeito de extratos aquosos de espécies vegetais sobre a multiplicação de Rotylenchulus reniformis Linford & Oliveira. Arquivos do Instituto Biológico,78:553-556.

Hussey RS & Barker KRA (1973) comparison of methods of collecting inocula of Meloidogyne spp., including a new technique. Plant Disease Reporter, 57:1020-1028.

IBGE - Instituto Brasileiro de Geografia e Estatística (2020) Produção da Extração Vegetal e da Silvicultura: Quantidade produzida e valor da produção na extração vegetal, por tipo de produto extrativo. Available at: <https://cidades.ibge.gov. br/brasil/pesquisa/16/0?tipo=grafico&indicador=21632&localidade1=22&localidade2=21>. Acessed on: March 2nd, 2022.

Leite JF, Feitosa AC, Zuniga ADG, Guida LM & da Silva DX (2020) Qualidade do fruto do pequi (Caryocar Brasiliense Camb.) armazenado sob vácuo em diferentes temperaturas / Quality of pequi fruit (Caryocar Brasiliense Camb.) stored under vacuum at different temperatures. Brazilian Journal of Development, 6:21951:21958.

Lima IS & House PE (2001) Volatile Substances from Male Anastrepha fraterculus Wied. (Diptera: Tephritidae): Identification and Behavioural Activity. Journal of the Brazilian Chemical Society, 12:196-201.

Lorena O & Bicas L (2017) Terpenos, aromas e a química dos compostos naturais. Química nova na escola, 39:120-130.

Lopes LNS (2017) Controle de Meloidogyne javanica: Efeito in vitro de extratos de plantas nativas do cerrado. Master Dissertation. Instituto Federal de Educação, Ciência e Tecnologia Goiano – Campus Morrinhos, Morrinhos. 47p.

Marino RH, Gomes LAA, Cruz EMO, Silva AC, Bianchini FG, Meneses TN, Santos HR & Blank AF (2012) Controle de Meloidogyne incognita raça 1 com óleo essencial de Lippia Alba. Scientia Plena, 8:01-08.

Mateus MAF, Fariam CMDR, Botelho RV, Dallemole-Giaretta R, Ferreira SGM & Zaluski WL (2014) Extratos aquosos de plantas medicinais no controle de Meloidogyne incognita (Kofoid e White, 1919) Chitwood, 1949. Bioscience Journal, 30:730-736.

Medeiros FHV, Júnior Silva MB, Pereira PF, Cardoso AMS, Faria AF, Gadaga SJC, Lima PP, Juliatti BCM, Luz ALF, Santos GS, Nicolli CP, Cardoso AMS, Siqueira CS, Ogoshi C, Lobo Junior M, Lima PP, Pereira PF, Costa SS, Moreira SI, Figueiredo YF & Bettiol W (2016) Controle biológico de doenças de plantas: integrando técnicas para entregar resultados. Lavras, NEFIT. 254p.

Moreira FJC, Santos CDG, Innecco R & Silva GS (2015) Controle alternativo de nematoide das galhas (Meloidogyne incognita) raça 2, com óleos essenciais em solo. Summa Phytopathologica, 41:207-213.

Massuh Y, Cruz-Estrada A, González-Coloma A, Ojeda MS, Zygadlo JA & Andrés MF (2017) Nematicidal Activity of the Essential Oil of Three Varieties of Tagetes minuta from Argentina. Natural Product Communications, 12:705-707.

Neves WS, Freitas LG, Lopes EA, Coutinho MM, Dallemole-Giaretta R & Ferraz S (2008) Ação nematicida de óleo, extratos vegetais e de dois produtos à base de Capsaicina, Capsainóides e Alil Isotiocianato sobre Juvenis de Meloidogyne javanica (Treub) Chitwood. Nematologia Brasileira, 32:93-100.

Oliveira CMG, Kubo RK & Harakava R (2009) Diagnose de Pratylenchus spp. de cafezais paulistas pela aplicação do código de barras do DNA. In: 6th Simpósio de pesquisa dos cafés do Brasil, Vitória. Proceedings, Embrapa Café. CD-ROM.

Passos XS, Santos SC, Ferri PH, Fernandes OFL, Paula TF, Garcia ACF & Silva MRR (2002) Atividade antifúngica de Caryocar brasiliensis sobre Cryprococcus neoformans. Revista da Sociedade Brasileira de Medicina Tropical, 35:623-627.

Peixoto FR (2019) Controle de Meloidogyne javanica em jiloeiro (Solanum gilo) com resíduo do fruto de pequi (Caryocar brasiliense). Trabalho de Conclusão de Curso (Bacharelado em Agronomia). Instituto Federal Goiano, Morrinhos. 39p.

Pinheiro JB (2017) Nematoides em Hortaliças. Brasília, Embrapa. 194p.

Rani A, Kumar P, Kumar A, Shukla G & Singh R (2022) Management of Insects/Nematodes for Improving the Crop Productivity. In: Sengar RS, Chaudhary R & Bhadauriya HS (Eds.) Handbook of Research on Green Technologies for Sustainable Management of Agricultural Resources. IGI Global, United States. p.200-214.

Ribeiro HB, Xavier AA, Campos VP & Mizobutsi EH (2012) Resíduos de frutos de pequi no controle do nematoide das galhas em tomateiro. Horticultura Brasileira, 30:453-458.

Rocha FS, Campos VP, Canuto RS & Souza RM (2009) Efeito do armazenamento na energia corporal de juvenis do segundo estádio de Meloidogyne incognita infestados por Pasteuria penetrans. Summa Phytopathologica, 35:15-19.

Santos AMM, Costa KDS, Oliveira TRA, Silva JW, Souza ÊGF & Carvalho Filho JLS (2018) Progeny coriander resistant root-knot nematode. Revista Verde de Agroecologia e Desenvolvimento Sustentável, 13:2:150-155.

Silva MCL, Santos CDG & Silva GS (2016) Espécies de Meloidogyne associadas a vegetais em microrregiões do estado do Ceará. Revista Ciência Agronômica 47:710-719.

Silva MSG, Campos VP, Terra WC, Pacheco PVM, Paula LL, Barros AF & Pedroso MP (2021) Volatile fatty acids from whey volatilome as potential soil fumigants to control Meloidogyne incognita. Crop Protection, 143:105567.

Somavilla L, Gomes CB & Quecini VM (2012) Registro da Ocorrência de Meloidogyne incognita no porta-enxerto 'IAC 766-Campinas' no estado de pernambuco e reação de porta-enxertos e de cultivares copa de videira a Meloidogyne spp. Revista Brasileira de Fruticultura, 34:750-756.

Zhang CM, Xu MJ, Gong Y, Li XW, Huang JJ, Zhou SF, Xing K & Qin S (2020) Identification and characterization of nematicidal activity of organic volatiles from a Pseudomonad rhizobacterium. Rhizosphere, 16:100244.