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BIODEGRADABLE FILMS MADE FROM CASSAVA STARCH: AN ANALYSIS OF SUSTAINABLE INNOVATIONS

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ABSTRACT

The search for alternatives to the use of plastic as packaging has been driving the adoption of new materials, has motivated the use of materials from renewable sources and biodegradables. The objective of this work was to carry out a descriptive bibliographic survey on research that focused on the use of cassava starch in the production of biodegradable films. The survey was carried out by consulting four data platforms: Web of Science, ScienceDirect, Pub med and Scopus. Having as search keywords the English terms "Cassava starch and biodegradable film". Articles published in the years 2018 to 2024 were selected, in journals with Qualis A1 classification with CAPES, with open access to the articles and the survey was carried out until the nineteenth day of November 2024. After consulting the platforms, 15 published studies with relevance to the theme developed were selected. They individually report the incorporation into the film made with cassava starch in different concentrations of materials such as yerba mate extract, cassava peel and bagasse, corn and cassava starch, bagasse from the production of blueberry juice, kappa caragenin (red algae extract), metakaolin, lignocellulose nanoparticles from cassava bagasse, nightshade extract, application of nanocompounds of metals such as zinc and cerium, Ocimum tenuiflorum and propolis by-product. And that after being tested and characterized by different techniques, such materials proved to be interesting as a way to promote the improvement of cassava starch films in relation to applicability as biodegradable packaging.

Keywords: Starch. Bioplastic. Sustainability. Packing.

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INTRODUCTION

The continuous growth of the world's population inevitably leads to an increase in the demand for food, thereby driving the global packaging materials market (Mueller *et al*., 2024). And currently, non-biodegradable petroleum-based polymer plastic packaging represents a significant environmental problem (GUO *et al*., 2024).

The food packaging industry is the one that most needs the use of plastics and consequently generates a high amount of waste, thus requiring the development of new biodegradable materials (CEBALLOS *et al.,* 2020).

For Barizão et al. (2020), biodegradable films have been a great alternative to non-renewable sources due to their cytocompatibility and biodegradability. The authors also mention that these properties can increase the shelf life of food, reducing costs and economic losses, in addition to reducing environmental pollution promoted by packaging.

There has been increasing awareness among consumers regarding their health, nutritional value of food, and food safety. As an alternative to reverse these problems, these biopolymers from renewable sources are considered an attractive alternative due to their characteristics.

Starch is an abundant polymer in nature, its characteristics, such as low cost and biodegradability, make it an alternative to petroleum derivatives (Guo *et al*., 2024). In addition, it has the ability to form colorless, odorless, and non-toxic films (THUPPAHIGE *et al*., 2023).

Cassava starch can act as a carrier for antioxidants and antimicrobial agents, enabling the development of active packaging (LUCHESE *et al*., 2018).

Due to its versatility and relevance in the current scenario, cassava starch applied in biofilms will be the basis for this study, with the objective of evaluating the scientific production in the period from 2018 to 2024, in journals with an A1 classification, with a higher impact factor and free access and in synthesis what has been scientifically produced on the subject in this space of time and definitions.

METHODOLOGY

SURVEY BY DATABASE SEARCHES

Descriptive research was carried out through bibliographic surveys in four databases (Figure 1). The English words defined for the searches were "biodegradable films" and "cassava starch", which in Portuguese mean "biodegradable films" and "cassava starch".

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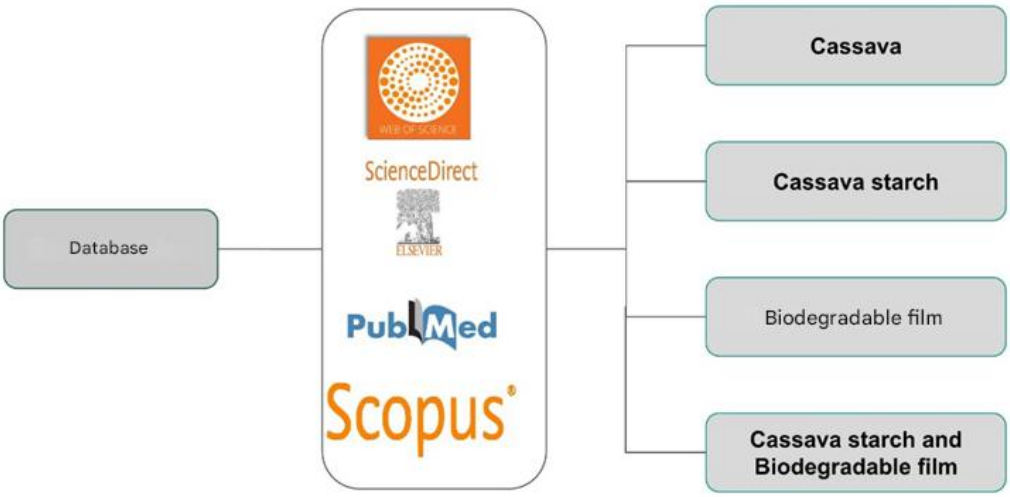
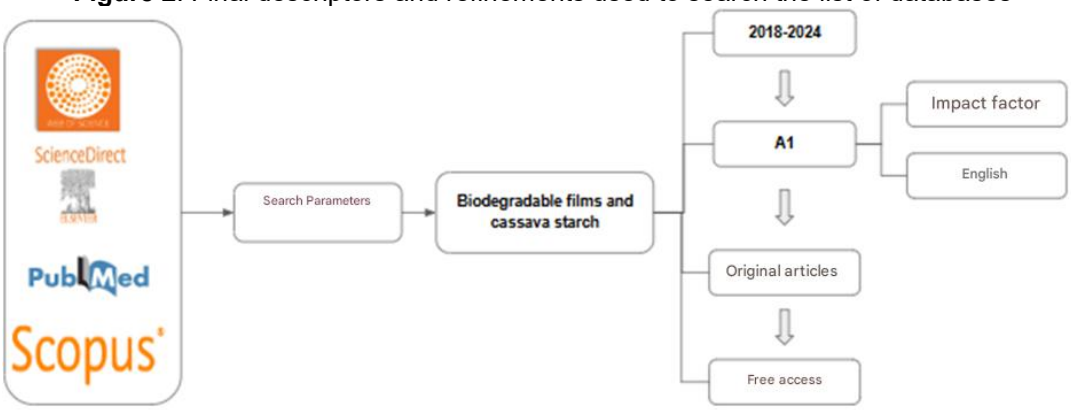
Figure 1. Descriptors and terms used to search searches in databases.



The periodicity of publications selected for the research covered the years 2018 to 2024. As parameters, only research articles in English, published in scientific journals with Qualis A1 classification, according to the Sucupira CAPES Platform - quadrennium 2017 – 2020 (Figure 2), with open access and with a higher impact factor, were selected.

Figure 2. Final descriptors and refinements used to search the list of databases



RESULTS

The search carried out through the four different platforms using the words "cassava"; "starch"; "biodegradable film"; "cassava starch and biodegradable film" is shown in Table 1.

Table 1 - Results obtained from the consultation of four different databases according to the search terms.

Databases	Impeached	Cassava starch	Biodegradable Film	Cassava starch and Biodegradable film
Web of Science	7493	3174	9688	456
ScienceDirect	33.992	15.264	109.258	3.653

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Pubmed	5067	1383	17206	61
Scopus	20381	8987	2884	9035

Source: Sucupira Platform (2024).

Table 2 presents the results obtained from the database searches, which met all the search parameters and their final delimiters using the words "biodegradable film and cassava starch", as well as those relevant to the research theme.

Table 2 - Results obtained that meet the search parameters and relevance to the theme in the consulted databases.

Keywords	Databases	Open access articles	Qualis A1	Relevance to the topic
Biodegradable films and cassava starch	Web of Science	191	32	3
	ScienceDirect	226	50	3
	PubMed	33	5	5
	Scopus	78	7	6

Source: Sucupira Platform (2024).

By searching for the keywords "biodegradable film" and "cassava starch" in the period from 2018 to 2024, in the Web of Science database, a total of 456 articles and only 191 with open access were obtained that were selected and evaluated. Graph 1 shows the 191 articles and their respective years of publication.

In 2018, there were 23 articles published, followed by 2019 with 18 articles published, 2020 with 26 articles, 2021 with 32 articles, 2022 with the highest number of publications with 44 articles published, 2023 with 29 articles, and 2024 with 19 articles published, taking into account that the survey survey was carried out until the nineteenth day of November.

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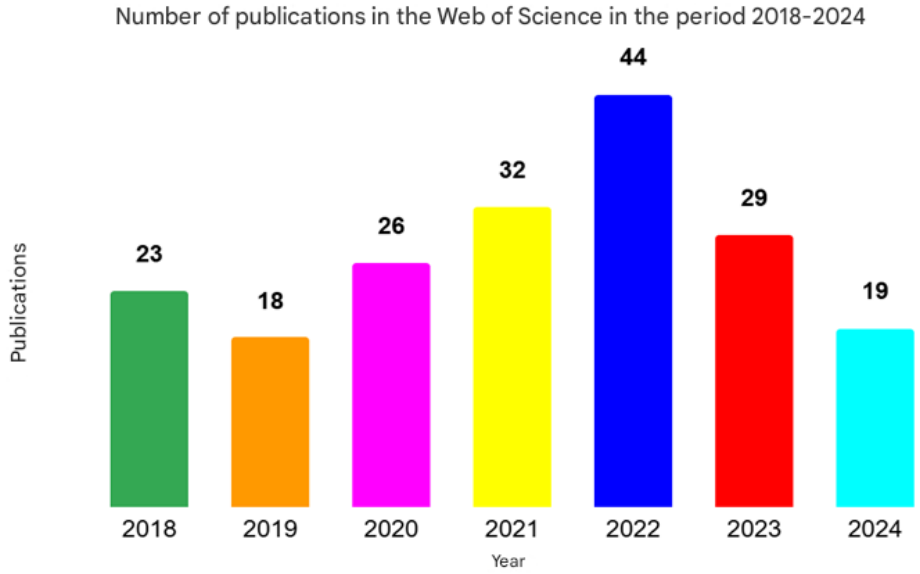
Graph 2 - Number of open access articles in the Web of Science database



The 32 Qualis A1 articles from the Web of Science database selected through open access were published in journals according to the classification of journals of the 2017-2020 CAPES quadrennium, as observed in Chart 1.

Table 1 - Number of A1 articles with open access in the Web of Science database

Newspapers	Articles
ACS Sustainable Chemistry e Engineering	2
Carbohydrate Polymers	2
Environmental Chemistry Letters	1
European Polymer Journal	1
Express Polymer Letters	1
Food Chemistry	3
Foods Hidrocolloids	4
Green Chemistry	1
International Journal of Biological Macromolecules	4
Journal of Applied Polymer Science	4
Journal of materials research and technology	2
Journal of Molecular Liquids	1
LTW-Food Science and Technology	3
Polymer Testing	1
Scientific Reports	1
Trends in food Science e Technology	1

Source: Sucupira Platform (2024).

Among the 32 articles above, only three were selected because they were in accordance with the research's intentions, with a 2020 article published in the journal Carbohydrate Polymers with an impact factor of 11.2; LTW- Food Science and Technology journal article with an impact factor of 6 published in 2021 and in the journal Food Chemistry with an impact factor of 8.8 published in 2023.

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In the study by Ceballos et al. (2020) they produced films based on cassava starch, glycerol, water and different concentrations of yerba mate extract obtained by extrusion and followed by compression. After 4 weeks, both chemical and specific analyses of film properties were performed (CEBALLOS *et al*., 2020).

The above study highlights that the film produced from native starch (TPNS) exhibited a smooth surface, no holes or cracks, decreased lubrication, moisture and water vapor permeability values, higher modulus and rupture stress values than TPHS.

The incorporation of yerba mate extract led to active and intelligent biodegradable materials, as they were released in different media and causing the color change of the films when exposed to different pH values (CEBALLOS *et al*., 2020).

The second selected paper, Ordonez et al. (2021) analyzed the effect of incorporating 1-2 % different proportions of cinnamic and ferulic acids into cassava starch thermoplastic films. They sought to analyze functional properties of the films as packaging material as well as the antimicrobial action of the films.

The incorporation of phenolic acids did not cause notable changes in the oxygen and water vapor permeability of starch films, but these became less soluble in water (13-25% reduction), more extensible, and less resistant to breakage, especially with the higher concentration of ferulic acid (ORDONEZ *et al*., 2021).

Films with 2% of either of the two acids inhibited the growth of *E. coli* and *L. innocua* in tests carried out in culture medium; cinnamic acid was more effective than ferulic acid and *L. innocuous* was more sensitive than *E. coli*. In foods such as chicken breast and melon, films with cinnamic acid against *L. innocua*, in chicken breast and fresh-cut melon (ORDONEZ *et al*., 2021).

Ordonez et al. (2021) state that starch films with 2% ferulic or kinnamic acid could be used as active layers for food contact combined with complementary properties in order to obtain active laminates that could provide remarkable antimicrobial capacity and, in particular, antilisterial activity (ORDONEZ *et al*., 2021).

Thuppahige et al. (2023) investigated the potential for valuing cassava peel and bagasse as fibrous reinforcing agents, as well as an alternative rich in matrix starches for the development of biodegradable food packaging. These materials were characterized by MEV, EDS, XRD, FTIR, TGA, thermal analysis (THUPPAHIGE *et al.,* 2023).

The above study highlights that the morphology of residual starch granules in cassava peel and bagasse were almost similar to commercial cassava starch granules.

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The main crystalline phase of α-amylose suggested the presence of starch, while quartz (SiO2) and whewellite (CaC2O4 H2O) in shell and bagasse suggested Si and Ca in the samples (THUPPAHIGE *et al*., 2023).

These results also encourage further research on its direct use and starch extraction in terms of the development of biodegradable food packaging (THUPPAHIGE *et al.,* 2023).

The query to the ScienceDirect platform presented 2,661 results focused on the terms "biodegradable film and cassava starch". However, 770 were review articles, 60 Encyclopedia, 509 book chapers, 1 conference abstracts, 4 case reports, 1 data articles, 2 discussion, 1 erratum, 1 mini reviews, 1 News, 4 shorts communications and 51 classified as Other.

As previously mentioned for the refinement of this study, only articles related to experimental research were considered, resulting in a total of 1,256 articles. After the analysis, it was observed that only 495 were published in journals classified as Qualis A1, according to the classification of journals of the 2017-2020 quadrennium of CAPES. However, only 46 of these articles were freely accessible.

Chart 2 - Journals identified and published with Qualis A1, according to the classification of journals of the 2017-2020 CAPES quadrennium

Newspapers	Qualis A1	Free access
International Journal of Biological Macromolecules	328	21
Carbohydrate Polymer	78	12
Food Chemistry	57	4
Food Research International	16	-
Food Control	10	-
Polymer Testing	11	4
Ultrasonics Sonochemistry	3	3
South African Journal of Chemical Engineering	2	2
Total	495	46

Source: Sucupira Platform (2024)

In Graph 3, it is possible to see the distribution of open access articles according to the ScienceDirect research platform for the years 2018 to 2024.

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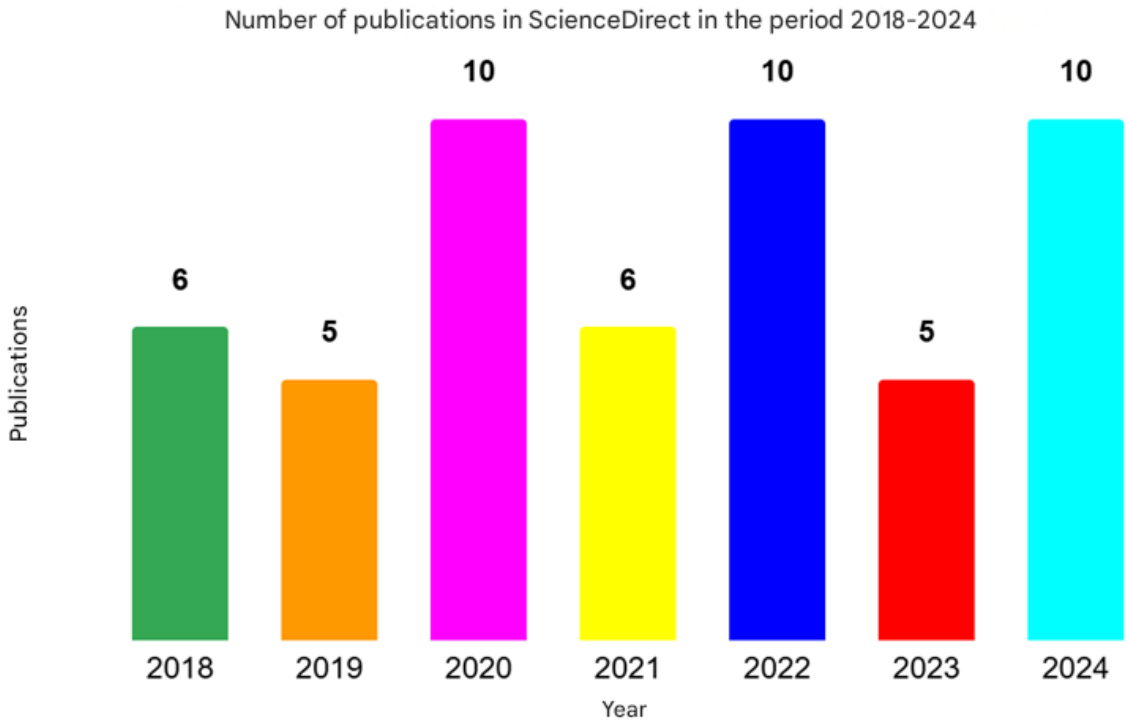
Graph 3 – Number of articles with open access, with Qualis A1 in the ScienceDirect database.



Of the 46 articles, only 4 (four) were selected, because the others had their respective contents, without agreement with the study. The research is published in the South Africa Journal of Chemical Engineering (2022) and the International Journal of Biological Macromolecules (2018 and 2020). The journals have as an impact factor the grades 8.4 and 7.7.

Luchese et al. (2018), wanted to develop a film that would have renewable and biodegradable characteristics and that would value waste from the food processing industries. So they made a film from cassava starch incorporated with different concentrations of blueberry bagasse, from the manufacture of juice, and studied the functional properties (thermal, optical and physicochemical) of the films.

The authors further noted that blueberry pomace films showed good barrier properties against light, indicating their beneficial effect in preventing food spoilage caused by UV radiation and that they could be applied to food packaging. They attributed these results to the presence of aromatic compounds in blueberry pomace.

According to Luchese et al. (2018), after analyzing the CS and BP biofilm, the results showed greater stability of the biofilm maintaining its integrity after 24 hours of immersion in water, with little resulting swelling, release of the bioactive compound in a

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period of 10 days with better response in acetic medium than ethyl resulting in a product with good effectiveness for larger-scale production and for the consumer market.

Travalini et al. (2019), produced lignocellulose nanofibers (LCNF), using cassava bagasse, a by-product of starch processing. The nanofibers were incorporated into cassava starch biofilms, and the product obtained was evaluated in its structural, mechanical and thermal properties and the results were compared with the control films reinforced with commercial nanoclay (Nclay).

Five different types of cassava starch biofilms were produced, which included: 1 control (without reinforcement), 2 with LCNF reinforcement and 2 reinforced with Nclay, each with 0.65 and 1.3% w w1. The films were analyzed for: thickness and deity, opacity and moisture content, water absorption and solubility, permeability and water vapor, FT-IR/ATR, SEM, XRD, DSC and TGA.

Travalini et al. (2019) report that all films made with cassava starch reinforced with LCNF or NClay were cast with a solution with starch, glycerol, and water and were transparent, flexible, and bubble-free. And TEM micrographs revealed that the nanoparticles had a characteristic nanofibril shape (diameter between 3-15 nm and high aspect ratio >85).

The authors above also mention that the values of opacity and water absorption were significantly reduced for all films with reinforcements, the value of water vapor permeability was reduced for the LCNF 0.65% and Nclay 1.3 films, and a lower concentration of LCNF resulted in the lowest WVP value.

The mechanical and barrier properties of the films showed that lignocellulose nanofibers from cassava bagasse can be employed to reinforce starch films with potential uses in food packaging (TRAVALINI et al., (2019).

Barizão *et al.* (2020), produced biodegradable films from different concentrations of kappa caragenin (red algae extract) and cassava starch and evaluated their physical, thermal, and mechanical properties, as well as apparent opacity and color.

From the results, they observed that the films presented high transparency and that the sample without K-Caroenan presented high solubility in water (39.22%) and low degree of absorption (391.6%). The lowest water vapor permeability (PVA) was observed for the sample with 50κ-c (3.01 × 10−8 g (Pa·m·s) −1.

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The sample with 100κ-c and 75κ-c films (with high κ-carrageenan content) showed higher stiffness (19.23 and 25.88 MPa, respectively) than the 25κ-c and 0κ-c films with elongation at break (ε) of 21.60 and 67.65%, respectively.

Méité et al. (2022), studied the incorporation of metakaolin in cassava starch-based bioplastics plasticized with glycerol, as they sought to form a biopackaging material that, in addition to being biodegradable, represented an alternative to the use of synthetic polymers, simultaneously presenting good water barrier properties and mechanical performance.

The bioplastics were elaborated through the casting-evaporation method and named according to the different concentrations of metacaulin (MKB) applied to them (0, 5, 10 and 15%) being: BP (0% bioplastic), BPMKB5 (bioplastic with 5% metakaolin), BPMKB10 (bioplastic with 10% metakaolin) and BPMKB15 (bioplastic with 15% metakaolin) respectively.

The authors observed that the increase in the concentration of metakaolin in the material under study favored the retrogradation of the gels, consequently, drying, in addition to providing rigidity to the films, improvement of mechanical properties and water resistance, with the formulation with 10% metakaolin BPMKB10) being the most significant with Young's modulus (195.78%) and mechanical strength (34, 54%).

Thus, Méitë et al (2022) suggest that the concentration of 10% by weight of metakaolin would be suitable for the elaboration of bioplastic with stiffness and moderate ductility, as it generated a bioplastic with acceptable mechanical resistance for use in biodegradable food packaging.

The query carried out on the PubMed platform presented 35 results focused on the terms "biodegradable film and cassava starch" between the years 2018 and 2024. However, 1 was a review, that is, a review article, which was excluded, because one of the characters adopted for the refinement of this study would be the use of only those related to experimental research.

When the search was refined to open access articles, the number remained at 35 articles. In Graph 3 we can see these 35 articles and which years they were published. We highlight the year 2022 with 9 articles published, followed by 2023 and tied 2021 and 2024 with 6 articles published each, 2020 and 2018 with 3 articles published each and 2019 with no research-related publications.

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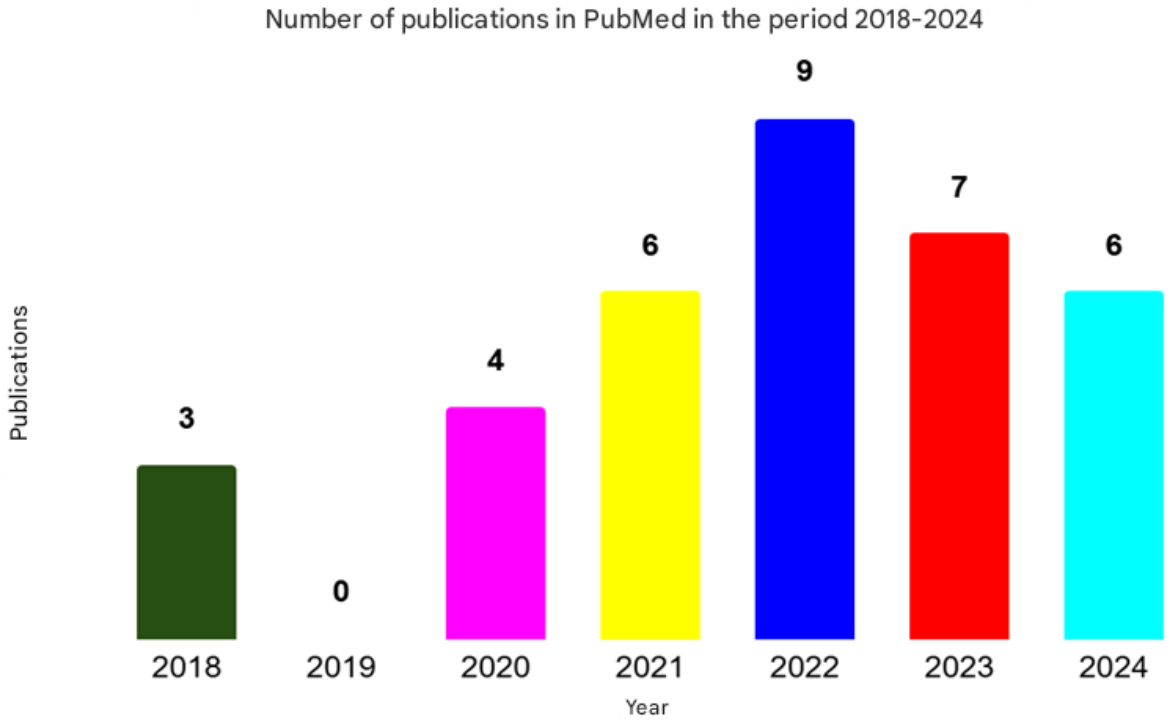
Graph 4 - Number of open access articles in the PubMed database



Of these, after consultation, it was found that only 5 were published in journals with Qualis A1, according to the classification of journals of the 2017-2020 quadrennium of CAPES, as shown in Table 3.

Among the articles obtained after publication research in Qualis A1 journals, 4 articles were selected as well as the other researches, standardizing and refining the search platform, thus, they are of great relevance for open searches whether in pubMed or in other platforms. The chosen articles were published from 2018 to 2024, in the journal Food Chemistry with an impact factor of 8.5 and the International Journal of Biological Macromolecules with an impact factor of 7.7.

Table 3 - Number of Qualis A1 articles with open access in the PubMed database

Newspapers	Qualis A1	Free Access	
Food Chemistry	3	3	
International Journal of Biological Macromolecules	21	2	

Source: Sucupira Platform (2024).

La Fuente et al. (2019), evaluated in Ozonation of cassava starch to produce biodegradable films, the ozonation process of cassava starch in biofilms compared to

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biofilms without the procedure, regarding its mechanical, barrier and functional properties, morphology, crystallinity, color and opacity.

Using the techniques for structural evaluation and their properties relevant to the study, analyses of tensile strength, Young's modulus, water vapor permeation and oxygen permeation were applied, in two ionization conditions, not described in the methods, resulting in three comparative products (native starch, condition 1 and condition 2) for the tests described above (LA FUENTE *et al* (2019).

After evaluating the data obtained, La fuente et al (2019), concluded that the ozonation process is effective for the formation of a biofilm with greater resistance with a more hydrophilic surface and lower solubility in the time of 24 h, resulting in biofilm with greater permeability of water vapor and oxygen.

In Characterization and application of active films based on commercial polysaccharides incorporating ZnONPs, produced by Bruni et al (2023), they seek to apply zinc oxide nanoparticles (ZnONPs) for the purpose of an antimicrobial biofilm using different formulations for the casting method.

Using physicochemical and mechanical analysis parameters for biofilms of different nanometric formulations and comparing the results obtained in X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and Dynamic light scattering (DLS) with Tukey's test in all results being applied to strawberries for antimicrobial evaluation (BRUNI *et al* (2023)).

As a result, Bruni et al. (2023) obtained an 11-day antimicrobial response for fresh strawberries coated with the biofilm incorporated with ZbONPs, where 1.5 and 2.0 % of nanoparticles showed the best resistance response and antimicrobial activity, where a UV barrier was obtained, curbing the ripening process of fresh fruit.

The article by Jafarzadeh et al. (2024), evaluates the improvement of cassava starch biofilm incorporated into hydrophobic cerium metal-organic structure nanoparticle (Ce-MOF), at concentrations of 0.5% to 4% w/w of the total solid through solution casting for biodegradable packaging purposes.

For the study Jafarzadeh et al. (2024), morphological, thermal and physicochemical analyses of the biofilms produced were applied, using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), Zeta potential, scanning electron microscopy (SEM), thermogravimetric analysis and atomic force microscopy (AFM).

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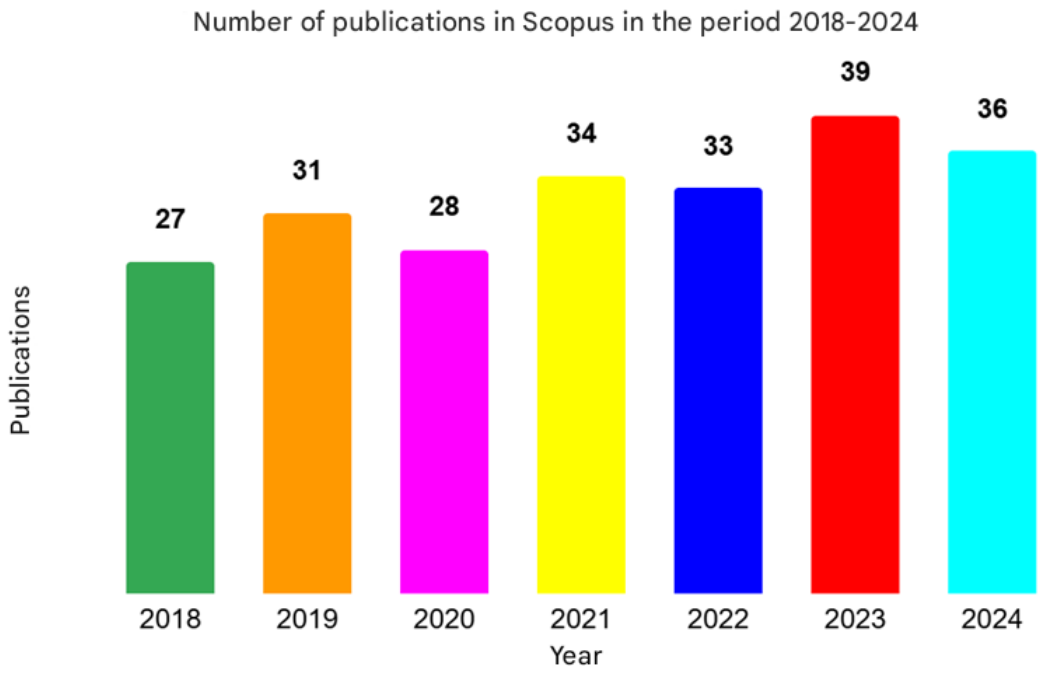
Comparative studies of the different concentrations of Ce-MOF demonstrated good effectiveness regarding the dispersion of the compound's nanofillers, resulting in a significant improvement in crystallinity, thermal stability, antioxidant activity, hydrophobicity, and can be applied with very positive results in active food packaging (JAFARZADEH *et al* (2024)).

The search carried out in the Scopus database using the keywords "cassava starch and biodegradable film" found 280 results, this number was reduced between the years 2018 and 2024, making a total of 228 documents, as can be seen in Graph 4.

Graph 4 - Articles published between 2018 and 2023 in the Scopus database



The journals selected from Qualis A1 of the Scopus database are shown in Chart 4, according to the classification of journals of the 2017-2020 CAPES quadrennium.

Chart 4 - Journals identified with Qualis A1 with open access, according to the classification of journals of the 2017-2020/CAPES quadrennium.

Newspapers	Articles
Food Chemistry	3
International Journal of Biological Macromolecules	2
LWT	1
Food Hydrocolloids	1

Source: Sucupira Platform (2024).

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Evaluating the open access articles, 3 articles were selected, where they are outside the list already described on another platform and have a high impact factor, thus resulting in three LWT articles with an impact factor of 6.0, Food Chemistry with an impact factor of 8.5 and Food Hydrocolloids with an impact factor of 11.0 for description.

Faced with the need to place products on the market that can replace products that are produced based on petroleum, several researchers have been developing biodegradable films that offer greater resistance to water in their research; good oxygen barrier capacity, at a low cost, among other benefits.

Garcia, Vargas, Chiralt (2021) decided to produce and analyze the physical and microstructural properties of melted and compression-molded starch films of corn and cassava, influenced by the incorporation of xanthan gum or gellan gum. Also according to the authors, Poly(lactic acid) (PLA) and Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) are biodegradable polyesters obtained from natural resources that can be used for food packaging purposes.

For the preparation of the monolayer films of corn starch (MS) and cassava (CS), the researchers used poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) ENMAT Y1000P with 3% hydroxyvalerate, amorphous PLA 4060D, density of 1.24 g/cm3 and average molecular weight of 106,226 D with 40% low molecular weight fraction (275 D), corn starch (MS, 27% amylose) and cassava starch (CS, 9% amylose), xanthan gum (X) (high molecular weight,~106 Da), low acyl gellan gum (G) KELGOGEL F (MW 3-5x105 Da), negatively charged. The plasticizer, poly(ethylene glycol) with a molecular weight of 1000 Da (PEG1000), and glycerol (GARCIA; VARGAS; CHIRALT, 2021).

The gums were only partially miscible with starch and the gum-rich domains appeared dispersed in the starch-rich continuous phase. The different cryofracture behavior of the continuous starch phase of the films reveals the partial miscibility of the gums in the starch phase, which reinforced the starch matrix, as revealed by the higher structural toughness deduced from the tensile parameters of the mixing films (GARCIA; VARGAS; CHIRALT, 2021).

The results obtained from cassava starch films were more stable in their mechanical properties over time, especially those that incorporate xanthan gum. In their conclusions, the authors state that the incorporation of gums in starches slightly reduced the water adsorption capacity of corn-based films, as well as improved the mechanical properties,

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even though the cassava starch film reached the highest values of EM and TS (GARCIA; VARGAS; CHIRALT, 2021).

The incorporation of gellan or xanthan gum decreased the water vapor and oxygen permeabilities of starch films, with cassava starch films with gums being the least permeable to oxygen. Also taking into account the adhesion of the layer, the bilayer formed with cassava starch with gellan gum and the PLA-PHBV sheet appeared as the best option for food packaging purposes (GARCIA; VARGAS; CHIRALT, 2021).

Gunathilake and Somendrika (2024), evaluated in Development of a biodegradable packaging with antimicrobial properties from cassava starch by incorporating *Ocimum tenuiflorum* extract, where methane extract of the *Ocimum tenuiflorum* leaf is incorporated in concentrations ranging from 0 to 3% in biofilms produced with cassava.

The biofilms were analyzed for their tensile, rupture, Young's modulus, thickness, color, transmittance, water solubility, moisture content, water vapor transmission rate, antimicrobial effect, biodegradability, thermal stability, cyanide content, compound analysis, and migration tendency of compounds were evaluated in these films compared to a control sample (GUNATHILAKE, SOMENDRIKA (2024)).

After statistical treatment, the insertion of the extracts has significance ($p<0.05$), regarding the elongation of rupture and transmittance, but there was no significant change for the traction and Young's modulus when compared to the control biofilm, in the microbial issue the extracts were efficient in the protective barrier for covering fresh fruit used in the test (GUNATHILAKE, SOMENDRIKA (2024)).

Bertotto et al. (2022), seeking to add value to the propolis byproduct, used methane extract of the material to increase the antioxidant and antibacterial properties of biofilms produced from cassava starch for biodegradable food packaging. The study used mechanical and chemical tests for the bioactives and material composition with microbiological tests (BERTOTO *et al* (2022)).

Evaluating the mechanical properties, the extract was inserted up to a concentration of 4% in the biofilm, because according to the authors, the by-product has a significant value of fibers that affect the traction of the dry biofilm, controlled concentration, the mechanical tests showed improvements in its traction and elasticity (BERTOTO *et al* (2022)).

From a chemical and biological point of view, Bertoto et al (2022) had very positive results with the insertion of the propolis by-product extract, as it fought free radicals,

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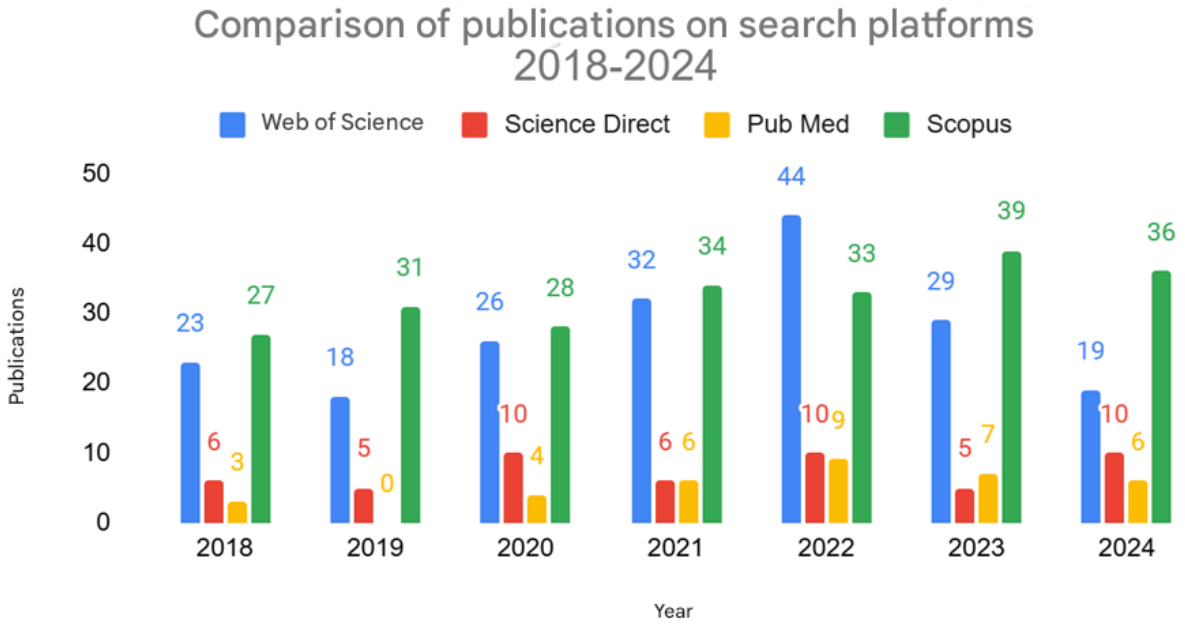
increased the bactericidal property and presented a range of volatile compounds of great impact in the studies of propolis by-products and how the use of this material can bring benefits to society.

After evaluating all platforms, it was possible to observe that both Web of Science and Scopus have the largest library of articles linked to their platforms, with 2023 being the most expressive year in Scopus and 2022 the most significant for the other journals surveyed for the article, using the term "cassava starch and biodegradable film" (Graph 5).

Graph 5 - Articles published between 2018 and 2023 in the database studied.



CONCLUSION

Interest in the development of biodegradable films has grown considerably. The results of studies and experimental research prove this. Having free access to Qualis A1 articles was of great importance, as it contributed to obtaining better information about the use of cassava starch in the production of biodegradable films.

Evaluation of how analyzes and characterizations of the material can be made in the construction of multidisciplinary knowledge, respond to society's need for products that help in improvements in the coating of fruits, meat foods, chicken, as in the maturation process and how we can discard films without degrading the environment, combined with waste treatment and nanotechnology.

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The use of cassava starch, as well as the blends developed by some researchers, enabled the innovation and creation of new formulations for the production of biodegradable films, with satisfactory results. Investing in science and technology will contribute so that in the future non-biodegradable products are replaced by biodegradable packaging, the studies and results are promising, the articles researched here prove this.

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REFERENCES

1. Barizão, C. M., Crepaldi, M. I., Junior, O. O. S., Oliveira, A. C., Martins, A. F., Garcia, P., & Bonafé, E. G. (2020). Biodegradable films based on commercial κ-carrageenan and cassava starch to achieve low production costs. International Journal of Biological Macromolecules, 165, 582–590. [Accessed November 19, 2024]. Available at: https://www.sciencedirect.com/journal/international-journal-of-biological-macromolecules.

2. Bertotto, C., Bilck, A. P., Yamashita, F., Anjos, O., Siddique, M. A. B., Harrison, S. M., et al. (2022). Development of a biodegradable plastic film extruded with the addition of a Brazilian propolis by-product. LWT, 157, Article 113124. https://doi.org/10.1016/j.lwt.2022.113124

3. Bruni, A. R., de Souza, A., Friedrichsen, J., de Jesus, G., da Silva, E., da Costa, J. C. M., Souza, P. R., de Oliveira Santos Junior, O., & Bonafé, E. G. (2023). Characterization and application of active films based on commercial polysaccharides incorporating ZnONPs. International Journal of Biological Macromolecules, 224, 1322–1336. https://doi.org/10.1016/j.ijbiomac.2022.10.219. [Epub 2022 Oct 25]. PMID: 36306900.

4. Ceballos, R. L., Yepesa, O. O., Goyanesa, S., Bernalb, C., & Famaa, L. L. (2020). Effect of yerba mate extract on the performance of starch films obtained by extrusion and compression molding as active and smart packaging. Carbohydrate Polymers, 244, 1–12. [Accessed September 20, 2023]. Available at: https://www.sciencedirect.com/journal.

5. Garcia, E. H., Vargas, M., & Chiralt, A. (2021). Thermoprocessed starch-polyester bilayer films as affected by the addition of gellan or xanthan gum. Food Hydrocolloids, 113, 1–12. [Accessed September 20, 2023]. Available at: https://www.sciencedirect.ez3.periodicos.capes.gov.br/science/article/pii/S0268005X20328836?via%3Dihub.

6. Gunathilake, I., & Somendrika, M. (2024). Development of a biodegradable packaging with antimicrobial properties from cassava starch by incorporating Ocimum tenuiflorum extract. Food Chemistry, 100658.

7. Guo, X., Wang, X., Wei, Y., Liu, P., Deng, X., Lei, Y., & Zhang, J. (2024). Preparation and properties of films loaded with cellulose nanocrystals stabilized Thymus vulgaris essential oil Pickering emulsion based on modified tapioca starch/polyvinyl alcohol. Food Chemistry, 435, 1–12. [Accessed November 19, 2024]. Available at: https://www.sciencedirect.com/journal/food-chemistry/vol/435/suppl/C.

8. Jafarzadeh, S., Golgoli, M., Azizi-Lalabadi, M., Farahbakhsh, J., Forough, M., Rabiee, N., & Zargar, M. (2024). Enhanced carbohydrate-based plastic performance by incorporating cerium-based metal-organic framework for food packaging application. International Journal of Biological Macromolecules, 265(Pt1), 130899. https://doi.org/10.1016/j.ijbiomac.2024.130899. [Epub 2024 Mar 13]. PMID: 38490375. [Accessed November 19, 2024].

9. La Fuente, C. I. A., de Souza, A. T., Tadini, C. C., & Augusto, P. E. D. (2019). Ozonation of cassava starch to produce biodegradable films. International Journal of Biological Macromolecules, 141, 713–720. https://doi.org/10.1016/j.ijbiomac.2019.09.028. [Epub 2019 Sep 5]. PMID: 31494157.

10. Lucese, C. L., Garrido, T., Spada, J. C., Tessaro, I. C., & La Caba, K. (2018). Development and characterization of cassava starch films incorporated with blueberry pomace. International Journal of Biological Macromolecules, 106, 834–839. [Accessed November 19, 2024]. Available at: https://www.sciencedirect.com/journal/international-journal-of-biological-macromolecules.

11. Méité, N., Konan, L. K., Tognonvi, M. T., & Oyetola, S. (2022). Effect of metakaolin content on mechanical and water barrier properties of cassava starch films. South African Journal of Chemical Engineering, 40, 186–194. [Accessed November 19, 2024]. Available at: https://www.sciencedirect.com/journal/south-african-journal-of-chemical-engineering/vol/40/suppl/C.

12. Ordonez, R., Atárez, L., & Chiralt, A. (2021). Physicochemical and antimicrobial properties of cassava starch films with ferulic or cinnamic acid. LWT-Food Science and Technology, 144, 1–12. [Accessed November 22, 2024].

13. Thuppahige, V. T. W., Moghaddam, L., Welsh, Z. G., Wang, T., & Karim, A. (2023). Investigation of critical properties of cassava (Manihot esculenta) peel and bagasse as starch-rich fibrous agroindustrial wastes for biodegradable food packaging. Food Chemistry, 422, 1–12. [Accessed November 22, 2023]. Available at: https://www.sciencedirect.com/journal.

14. Travallini, A. P., Lanmsal, B., Magalhães, W. L. E., & Demaite, I. M. (2019). Cassava starch films reinforced with lignocellulose nanofibers from cassava bagasse. International Journal of Biological Macromolecules, 139, 1151–1161. [Accessed November 24, 2024]. Available at: https://www.sciencedirect.com/journal/international-journal-of-biological-macromolecules/vol/139/suppl/C.