# CHAPTER 90

## Organic-based material as an alternative for packaging food products

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**ABSTRACT**
Contemporary society is increasingly being marked by discourses on the environment, sustainability and the need for sustainable and ecologically correct consumption. For this discourse, organic food has gained more prominence in the Brazilian and world scenario. With the growing demand for these products, thechanges arise on the packaging. Knowing that the world's plastic industry has been increasing, causing serious environmental problemsdue to its inability to biodegrade; the use of renewable resources has been exploited, which can reducewaste disposal costs. Consequently, the development of biodegradable materials of organic base emerge as an alternative to this andmbalagem. Therefore, this study aims to present a narrative bibliographic survey addressing the theme related to organic food and biodegradable and organic packaging. For the narrative review, research was conducted in databases such as: SCIELO, Science Direct, PubMed and national and international websites related to the theme. Based on the study, among the alternatives for the production of an organic-based film, starch is one of the bases that are researchedand considered a good substitute for traditional packaging. However, there is a need to add a plasticizer in its formulation, logo, the incorporation of a natural stifying pla, which may be organic, should be in vestigada by future research. This organic-based material can be used in different food products.

**Keywords:** organic food; alternative packaging; organic packaging; sustainability; sustainable consumption .

## 1 INTRODUCTION

"Organic farming" (or "organic" or "ecological" agriculture is a complete system approach based on a set of processes that result in a sustainable ecosystem, safe food, good nutrition, animal welfare and social justice (IFOAM, 2009).

A food is considered organic when it is produced in an environment based on agroecological production processes that make responsible use of soil, water, air and other natural resources, while also respecting social and cultural relations. Differing from the conventional by the absence of pesticide residues keeping the soil healthy and observing the controllable levels of pests to increase their crops (Boobalan et al., 2016).

The consumption of organic food has been proposed as a way to a more sustainable society. As a result, the purchase and consumption of organic food has been increasing worldwide. According to (FiBL and IFOAM, 2022), the organic market in the world expanded from 15.1 billion euros in 2000 to 120.6 billion in 2020 (Dorce et al., 2021).

The packagingact in its context and functions is of great importance to organic foods mainly, both in transportation and in its protection against contaminantagents, andit is an integral part of this growing demand and has been exerting great changes in industries. Organic products have in their concept the concern of reducing the impact of their productionon the environment, porém, it is known that the composition of traditional packaging, are not mostly sustainable (Boobalan et al., 2016).

In the daily life of the population, disposable plastic materials, such as plastic bags, among others, for packaging for food use are in every corner of society and become important and indispensable items. However, due to the non-biodegradability of most of these plastic products, since they are discarded at random, they will cause environmental pollution being a short- and long-term concern, also known as "white pollution". Therefore, more and more countries are restricting the use of non-biodegradable disposable plastic products (Dai et al., 2019).

In recent years studies on biodegradable and edible films, such as protein, lipid and polysaccharides, are being carried out. In particular, starch has been the focus of a series of investigations because it is biodegradable, renewable, low cost, edible in nature and with wide availability (Cui et al., 2021; Gutiérrez et al., 2015).

Starches have the ability to form transparent and odorless films with good barrier to oxygen, which is extremely beneficial for food preservation. Of the starches, cassava starch stands out, because it is a very common raw material, besides having reduced cost and has wide availability. When compared to other starches, their extraction generates fewer impurities, which improves extraction efficiency (Caetano et al., 2018; Li et al., 2020) Thus, a bibliographic narrative survey was carried out, in which it has the purpose of describing and punctuating biodegradable materials that can be organically based as a packaging alternative for food products.

## 2 METHODOLOGY

The review was carried out through a narrative bibliographic survey. Narrative review articles are publications with the purpose of describing and discussing the state of the art of a given subject. Given the scope of the theme and the difficulty in establishing a precise research question, the narrative review was used because it allowed an expanded discussion (Lopes et al., 2022; Martinelli et al., 2019).

For the research, a survey of scientific articles in the literature was conducted through online databases: Scopus, Science Direct, Scientific Electronic Library Online (SCIELO), PubMed Central (PMC), national and international sites with reference to organic foods, websites of Brazilian government agencies and Brazilian Agricultural Research Company (Embrapa).

The search of the articles for review was carried out by combining the terms: organic food, organic agriculture, biodegradable material, film and starch-based coating and demand for organic foods. The inclusion criteria defined for the selection of articles were: publications in Portuguese and English, which portrayed the theme related to organic products and biodegradable packaging. There were no specific dates for searching, so archives published and indexed were obtained in the databases between 2005 and 2022, totaling 166 articles and after reading the manuscripts 94 were excluded for not meeting the purpose of the research, as exemplified in Figure 1.

## 3 ORGANIC FOOD PRODUCTION

Organic agriculture was driven by movements at the end of the 19th century that opposed traditional food production systems and the environmental damage they brought. Thus generating the beginning of a chain for a healthy diet and a better quality of life (Moraes, 2017).

According to IFOAM (*International Federation of Organic Agriculture* Movements), organic farming is a production system that sustains the health of soils, ecosystems and people. Combining tradition, innovation and science. Its role ranges from production, processing, distribution, to consumption. It thus guarantees the sustainability and health of the ecosystems and organisms that compose it (IFOAM, 2020; Moraes, 2017) .

According to its definition, organic farming is one of the alternatives for the production of a safe food within the standard of food safety, and also of food safety. The international standard in organically produced foods comes from the "*Codex Alimentarus*", originated from the United Nations Food and Agriculture Organization (Efing et al., 2019).

In the literature, several definitions of organic foods are found, among which are presented as: "Foods considered organic are those produced in an environment where agroecological principles are used as the basis of the production process, contemplating the responsible use of soil, water, air and other natural resources" (Boobalan et al., 2016). Under Brazilian legislation, an organic food, *fresh or processed* , is one derived from an organic system of agricultural production or a sustainable extractive process, being not yet harmful to the local ecosystem (BRASIL, 2020).

Currently in the world, there is a growing demand and acceptance for organic products, mainly due to the harms that pesticide residues and chemical fertilizers can cause to the health of the consumer in the food chain, paving the way for awareness of the use of these chemical agents the addition of preservatives during the manufacture of food by companies (Boobalan et al., 2020; F. Silva et al., 2016).

According to *the Research Institute of Organic Agriculture* (RIBL), an independent European non-profit institution, data from the 2018 organic world production from 178 countries show that the sector occupies 71 million hectares (Table 1), about 1.2% of the world's producing areas. The market is led by the United States, both in exports (£2.9 billion), imports (£1.8 billion) and sales (£40 billion), followed by Germany (£10 billion), France (£9 billion), China (£8 billion) in sales (RIBL, 2020).

South America has a total of 8 million hectares, with Brazil touted as the leader of the organic market, but in an extension of land destined for organic agriculture, the country is in third place in the region, followed by Argentina and Uruguay (FIBL, 2020).

The country with the highest number of organic producers is India (835,000), according to Bruno et al. (2019). While in South America the largest number of organic producers is concentrated in Peru

(91,771).

## 4 LEGISLATION FOR ORGANIC PRODUCTS

The first movements of organic certifications took place in Europe in the 1920s, where the Demeter system of biodynamic organic products was created, whose seal is found to this day (ABD, 2021; Moraes, 2017).

In Brazil, the certification follows the line defined by the Ministry of Agriculture and Livestock (MAPA), being recognized by IFOAM. Its culture and commercialization of organic products began in 2003, however, its regulation occurred only on December 27, 2007 with the publication of decree No. 6,323 (BRASIL, 2020).

Based on Law No. 10,831 of December 23, 2003, all those who intend to market organic products in Brazil must have registration with MAPA, more specifically through the Brazilian Organic Compliance Assessment System (SisOrg). The law established the use of the SisOrg seal for certified products. It is defined, therefore, that certification can be carried out in three ways: by audit, by participatory guarantee system, and by social control in direct sales (BRASIL, 2020).

Abroad, the international body that accredits the certifiators is IFOAM, which is the international federation that brings together the various movements related to organic agriculture.

The labeling in Brazil, specified as organic, is regulated by federal law no. 10,831 of 2003. In 2007, Decree No. 6,323 established the rules of certification and supervision.

Through Article 119 of Annex I of Normative Instruction No. 19 of 2009, MAPA in Brazil established for the domestic market that organic quality information must be stamped on the front of the label, with specific terms for "Organic" or "organic product" for those with 95% or more of organic ingredients; and "product with organic ingredients" for products with 70% to 95% of organic ingredients, among more variants, when with less than 70% of organic ingredients can not have any expression to organic quality (BRASIL, 2020).

The production, processing, labelling and marketing of organic products, for example, in the European Union are governed by Reg. 834 of 2007 and its implementing regulation - Reg.889 of 2008, which covers primary or processed products of plant or animal origin; in the United States, they are governed by the USDA-NOP (*National Organic Program*), section 205 (7 CFR 205), Japan, the legislation governed by jas (*Japan Agricultural Standards*), while in China it is governed by the National Regulation of the Republic of China for organic products (Ecocert, 2020).

## 5 CONSUMER PERCEPTION

Since the growing demand for organic crops in the world, through the sale of large retailers, as well as creation of its own brand for organic, at least two barrea have been removed for their consumption: high price and low availability. The consumer reacted positively to the spread of organic products. Its characteristics meet the needs of more naturalness and sustainability, demonstrating more respect for animal welfare, and giving importance to human and cultural values (Carfora et al., 2019).

According to literature, it is unanimous to verify the main perceptions of consumers regarding organic foods. The main drivers of buying and consumption are due to the fact that they are said to be healthy and less harmful to the environment than conventional foods and promote support to the local economy and the community (Dorce et al., 2021).

Trust between the consumer and food is a factor that can be added as a buying motivator. The organic product is made through process certification. Trust in the certification system is critical to the integrity of organics. Thus, trust becomes loyalty to the brand, so the consumer has a greater willingness to pay for the product (Carfora et al., 2019; Castaldo et al., 2009; Menozzi et al., 2015; Pivato et al., 2012).

Koklic et al. (2019), through their study, pointed out areas that can directly shape the intention to purchase organic products: attitudes towards the consumption of organic foods, past consumption and personal norms. That is, the consumer's intention to buy organic food becomes stronger with more positive attitudes, an increase in the frequency of organic food consumption in the past and stronger personal standards. In addition to the study of past behavior being an important predictor of future actions and intentions, directly affecting the norms and personal attitudes regarding the purchase of organic. Moral influences influence the intentions of buying, for example, environmental concern exerts an effect via moral or personal norm.

Lamonaca et al. (2022) in their research, cited other characteristics as intention to purchase organic products, such as nutritional information on the packaging, sympathy through a label with carbon footprint and organic and quality labels.

## 6 ALTERNATIVE PACKAGING FOR ORGANIC AND CONVENTIONAL FOODS

It is a fact that packaging can influence the impression of consumer taste, generating emotional responses and predisposing the same to buy the product. It presents itself as an integral part of a system. In the literature, three functions for traditional packaging are covered: (1) containment and handling, (2) protection and preservation and (3) information and communication (Becker et al., 2011; van Herpen et al., 2016). Traditionally, plastics, papers, glass and metal containers have been used to pack food. However, when performing these functions generates a cost, both monetary of the packaging material itself and the environmental load that it causes (Amin et al., 2021; Roper et al., 2013).

According to the IFOAM principle, the packaging of organic products should have minimal impacts on food or the environment. As a recommendation, these should be packed in reusable, recyclable, recycled or biodegradable packaging when possible (IFOAM, 2009).

Retailers' preference is common in marketing organic products in plastic bags, so that they can be clearly distinguished from conventionally grown ones and ensure that the consumer buys the product at the correct price. In addition, some supermarkets also prefer plastic bags to ensure the organic integrity of the product. The organic claim is, in fact, about how the product is grown, however, supermarkets are responsible for maintaining the separation between organic and conventional. Violation of regulations in place to protect this problem can result in severe fines to the retailer (Dole, 2020).

However, in a study conducted in Europe, researchers concluded that removing the primary packaging (plastic packaging) of organic fruits and vegetables would be a promising intervention in attempts to increase sales of organic vegetables, since it would fit better with the environmental image of the product (Van Herpen et al., 2016).

Alternatively, great advances in the packaging area have come since its creation in the 18th century, among them are biodegradable packaging, which can be active and intelligent.

In the literature, several studies developing and applying different types of biodegradable packaging can be found. Produced from renewable sources, such as starch, protein, lipids and developed from agro-industrial waste, as unused parts of fruits and vegetables, which have bioactive compounds and that can provide interaction with the packaged product, bringing additional advantages in food preservation (Miglioranza et al., 2021)

Biodegradable films arise due to environmental concerns and the need to protect consumer health. Through biomaterias (natural materials) of food quality, these packages can extend the life of the product acting as a selective barrier against moisture and oxygen. They reduce lipid oxidation by controlling oxygen transmission and synthesis of volatile compounds, factors responsible for the production of unwanted odors and flavors (Amin et al., 2021; Enujiugha et al., 2018).

To control food quality and improve food safety standards, i.e. expand the functionality of biodegradable packaging, bioactive and functional substances such as antimicrobials, antioxidants, vitamins, flavonoids, etc. can be incorporated. Thus, these materials can be used as carriers of bioactive compounds, increasing the nutritional value of food products or to extend the shelf life of the packaged product (Lu et al., 2019; Salgado et al., 2015).

To this type of packaging, Glicerine et al. (2021), conceptualize as active packaging, where there is a system in which the packaging, product and environment actively interact prolonging the shelf life and / or increasing the safety and sensory properties of food products during storage.

Miglioranza et al. (2021), compared the application of a biodegradable film, based on grape seed flour extract and PVA (Polyvinyl alcohol), as a packaging for dehydrated fruits, using raisins of the crimson variety without seeds, with conventional poly film (ethylene) packaging, obtaining higher phenolic contents and antioxidant activity for raisins packed with biodegradable film after 182 days of storage.

Motta et al. (2020) developed films based on non-ionic, cationic and anionic starches incorporated with the cationic surfactant LAE, aiming to provide an alternative to extend the shelf life of food products.

Nakashima et al. (2016), studied the development of collagen-based films with concentrations of clay, plasticizer and essential oil of clove on the characteristics of color, opacity, tensile strength, solubility, water vapor permeability and film thickness. Concluding that collagen films obtained good mechanical properties, adequate visual appearance and easy handling, as well as low permeability to water vapor and solubility in water. The addition of essential oil was effective in the structure of the film, improving the appearance and handling.

Costa et al. (2020) developed and characterized edible films produced by polymerblends, composed of natural polysaccharides, aiming at their use as edible coatings for fruits. Polymeric films from Quitosana, Pectina, Cassava Starch, Chiscan + Pectina, Chitosana + Cassava Starch, Pectina + Cassava Starch and Chitosana + Pectina + Cassava Starch were developed.

## 7 STARCH-BASED PACKAGING MATERIALS

Renewable raw materials such as polysaccharides (starch, pectin, alginate, carboxymethylcellulose and chitosan), proteins (wheat gluten, whey protein isolate, caseinate and soy protein) and lipids (waxes and fatty acids) or a combination of these have been studied to prepare biodegradable edible films and coating. However, several studies report that polysaccharides from different sources are promising materials for the preparation of films and coatings with bespoke behavior, considering that they are natural, non-toxic and biodegradable polymers (Enujiugha et al., 2018; Guimarães et al., 2020; Schmid et al., 2018).

Starch has been reported as a cheap material, besides having excellent film forming capacity (Hassan et al., 2018; Kang et al., 2020).

It is a polymer that occurs widely in plants such as potatoes, corn, rice and cassava. In all these plants, starch is produced in the form of granules, which vary in size and composition depending on the plant. In general it is formed by two types of glucose polymers: amylose and amylopectin, with different structures and functionality. The proportion between amylose and amylopectin is variable with the botanical source, conferring specific characteristics to the starch paste. In food use, both fractions are readily hydrolyzed in acetal bonding by enzymes (Chandra et al., 1998).

Starch films are one of the most effective bio-based packaging materials in terms of performance, adaptability, processability and cost. Through the composition of starch, amylose and amylopectin, effects on the formation and properties of film occur. The linear structure of amylose promotes high-level hydrogen, through the bond between its molecules forms a crystalline structure. Amylose chains are relatively long linear chains, this allows a better interaction between polymer chains due to better approximation or accommodation of chains. While amylopectin chains result in films with weak and brittle characteristics due to intermolecular bonds disadvantaged by the existence of short chains and branches (Jha, 2020; Suh et al., 2020).

However, starch films have some limitations, such as strong hydrophilic behavior, which makes high sensitivity contact to moisture and low mechanical properties (Jha, 2020).

Aiming to serve the consumer in the search for improvement of quality, safety and the extension of shelf life of the product, biodegradable materials based on starch has been studied for the food industry as packaging materials (Table 2).

Several studies have been conducted to analyze the properties of starch films produced from different botanical sources, such as corn, wheat, cassava, yams and potatoes (Cui et al., 2021; Galdeano et al., 2009).

Among the starches of various botanical sources, cassava starch stands out for being an excellent raw material for the production of biodegradable materials and is useful for industrial applications. When compared to other starches, it is easily extracted, resulting in a white product without the need to use bleaching agents. Most of the granules are rounded, with the flat surface on one side and a cavity on the other. According to the variety and the harvest period exhibit great variation in their size (5 to 40 μm) (Chollakup et al., 2020; Dai et al., 2019).

In addition to being biodegradable, films and coatings produced from cassava starch are odorless, tasteless, colorless and non-toxic. Furthermore, the films have good mold resistance and permeability, are flexible and extensible materials of homogeneous and smooth surfaces. The production of films from the starch is based on its gelatinization, which occurs above d and70°C, followed by cooling (Cortés-Rodríguez et al., 2020; Dai et al., 2019; Lim et al., 2020; Luchese et al., 2021; Suh et al., 2020). However, pure starch films have more fragile mechanical properties, consequently it is necessary to use additives, such as plasticizers, to improve their characteristics (Chen et al., 2019).

Plasticizers are additives necessary for the manufacture of films, such as starches, because films that comprise only starch are rigid, brittle and inflexible. Generally glycerol and sorbitol are used as plasticizers. These improve the flexibility of starch film by reducing the hydrogen bond between macromolecules and increasing intermolecular spacing between chains (Lim et al., 2020).

Although hydrophilic compounds, such as polyols (glycerol and sorbitol), are commonly used in starch films, some sugars, amino acids, carbamides and fatty acids can also be used (Maniglia et al., 2019). In the literature can be found studies with the development of starch-based films and different plasticizers, as exemplified in Table 2.

## 8 NATURAL PLASTICIZER TRENDS

As the alternative packaging industry grows, the proportion of demand for new plasticizers also increases. Since the use of phthalates (the most used nowadays), has been questioned due to toxicity problems, which are related to the migration of these compounds. Therefore, alternatives to traditional plasticizers are sought, which come from biological sources and that meet requirements such as low toxicity, low migration and biodegradability (Liu et al., 2020; Rocha, 2019; Vieira et al., 2011).

In the search for new biodegradable packages of natural and organic source, the option of sugars, honey and lipids can be studied.

Sugar is a generic term for edible candied carbohydrates, mainly sucrose, lactose and fructose. It is produced by all chlorophyllvegetables, through photosynthesis. Of the different types of sugar, brown, organic or not, stands out, once produced from sugarcane, does not go through any kind of refinement process, so there is no chemical additive in its composition. Thus maintaining its nutritional quality, vitamins and minerals (Bettani et al., 2014).

The use of sucrose as a plasticizer is recommended in cassava starch films and may increase elongation at rupture, however crystallineity has been observed during storage, changing the material from malleable to brittle (Veiga-Santos et al., 2007). For example, Santos (2004), observed crystallization after 10 days of storage in films based on cassava starch and sucrose as plasticizer. It is then indicated to use a wetting as propylene glycol to avoid crystallization of the films. If sucrose is added to the filmogenic solution, all granules should be completely homogenized so that there are no crystallization nuclei, affecting the final structure of the eriais mat along the stocking.

Honey, considered a natural product, is composed predominantly of sugars such as fructose and glucose, in addition to enzymes, minerals, organic acids, hydrocarbons, amino acids, B vitamins, vitamins (C, D and E), antioxidants, water and substances that give it aroma and flavor, being a replacing resource of sugars (Garcia et al., 2018; M. G. C. da Silva et al., 2018). As for the possibility of using organic honey, it would qualify as a product free from undesirable chemical and biological contamination. In literature, several studies addressing antioxidant properties ( Beiranvand et al., 2020; González-Ceballos et al., 2020) and honey antimicrobial (Alvarez-Suarez et al., 2010; Estevinho et al., 2008).

Santagata et al. (2018), for example, used pectin-honey coating in dehydrated fruits (apple, melon, mango and pineapple) to explore the antimicrobial activity of mel. However, there are still no studies as a possible contribution to plasticization.

Lipids are compounds that originate from natural sources such as animals, insects and plants, the diversity of lipid functional groups is composed of phospholipids, phosphatides, mono, di and triglycerides, terpenes, cerebrosides, fatty alcohol and fatty acids. In films and coatings lipids can provide some characteristics such as brightness, minimizes moisture loss and alters packaging complexity (Mohamed et al., 2020). Biological-based plasticizers can be obtained from plant or animal sources, in this set are oils obtained from agricultural plant sources, by-products of them, or even from residues. Vegetable oils, as well as coconut oil, appear in this group as highly available, low-cost, non-toxic alternatives from renewable and non-volatile sources (Liu et al., 2020; Rocha, 2019).

Coconut oil is useful in several sectors, such as food, pharmaceutical, cosmetic and also in biofuels, since there is the presence of methyl esters present in the oil. In packaging research, it is evaluated as antioxidant and antimicrobial, since it contains polyphenols in its composition, and can inhibit oxidation. In addition to having a free fatty acid content of less than 0.1%, fatty acids with a normal distribution of the carbon chain and a reasonable composition of saturated and unsaturated fatty acids. The addition of coconut oil can reduce water permeability in films and food coating (Fangfang et al., 2020; Neto et al., 2020). As for the possibility of this also having influence on the mechanical characteristics of films has not been reported.

It is important to highlight that a good plasticizer usually provides high plasticization in low concentration and promotes rapid diffusion and interaction; while its efficiency is defined as the amount of plasticizer required to produce the desired properties of the film. Therefore, to optimize the properties of final use of the materials, it is important to study the effect of plasticizer concentration on mechanical resistance. (Versino et al., 2019).

## 9 FINAL CONSIDERATIONS

This article surveyed the concept and increased demand for organic foods, addressing traditional packaging and alternatives for food products. Being able to develop biodegradable organic materials closing the cycle of the chain of food and organic products.

Many studies show increased consumer awareness of products that meet environmental protection, health and food safety. Given environmental protection, biodegradable packaging based onnatural resources has received considerable attention.

Busing an organic packaging has the possibility of using an organic starch as raw material for its production. This is a base of low ass, besides abundant, biodegradable and even edible. And emphasizing that all the insums used in the production of this packaging are of organic origin, it makes the concept of this packaging more challenging.

Future research is necessary, both bibliographical and experimental, where the objective is to study the possibility of incorporating natural and organic plasticizers into a filmogenic solution in order to obtain organic and biodegradable base materials. Going according to the ideology of organic foods and this material can be used for other products.

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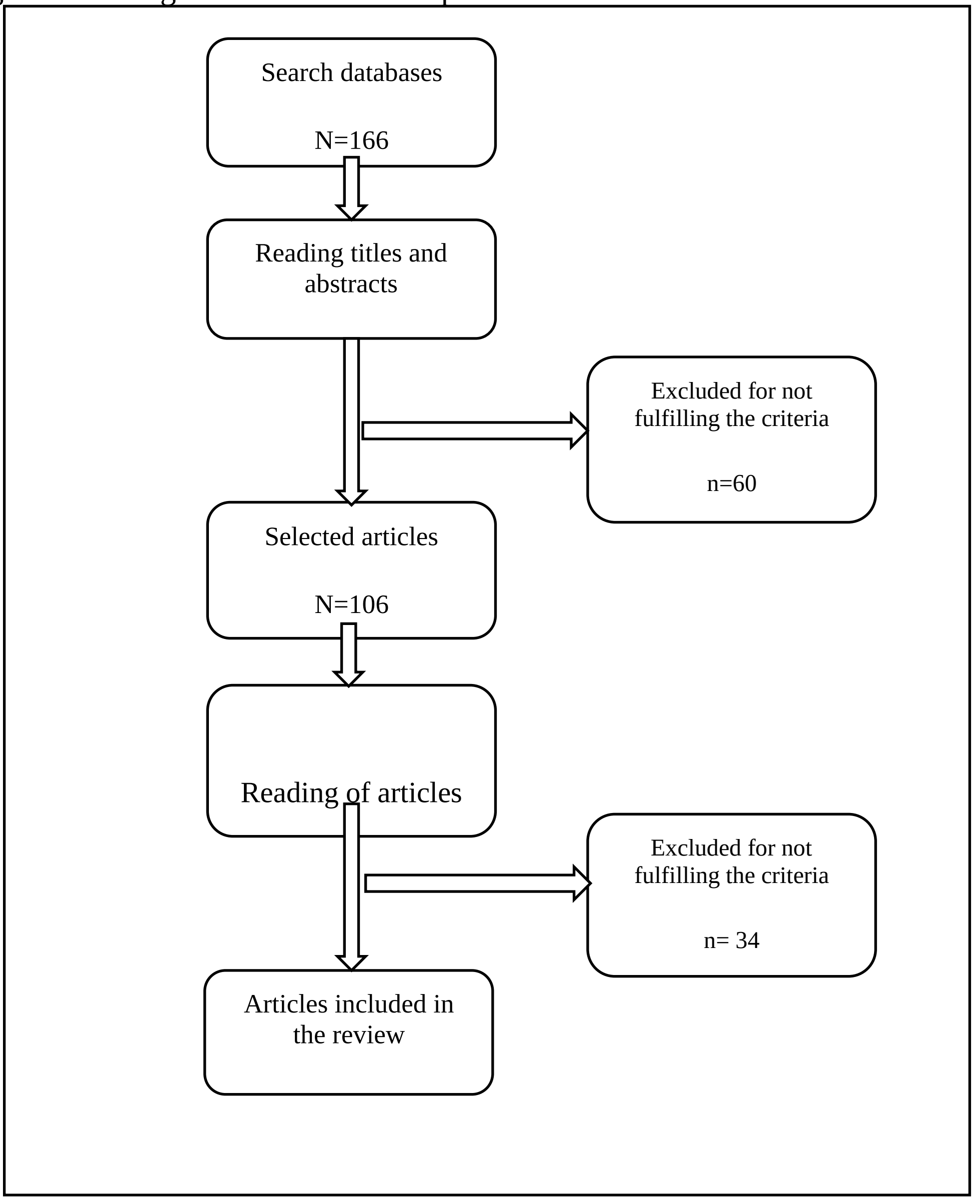
Figure 1: Fluxogram of the inclusion process of the articles in the narrative review




Source: Authors

Table 1: Area in the world by organic regions

| Country | Year | Organic area (agricultural land) [ha] | Percentage of organic area in total agricultural land [%] |
|---|---|---|---|
| Africa | 2018 | 1'984'132.28 | 0,18 |
| Asia | 2018 | 6'537'225.85 | 0,41 |
| EFTA* | 2018 | 233'637.14 | 5,96 |
| EU | 2018 | 13'790'384.08 | 7,71 |
| Europe | 2018 | 15'635'504.61 | 3,12 |
| Latin America | 2018 | 8'008'580.69 | 1,06 |
| North America | 2018 | 3'335'001.81 | 0,82 |
| Oceania | 2018 | 35'999'373.49 | 8,57 |
| World | 2018 | 71'494'738.75 | |

*EFTA: European Free Trade Association (Switzerland, Norway, Iceland and Liechtenstein)

Source: FiBL, 2020

Table 2: Development of starch-based food packaging with different plasticizers

| Characteristic | Developed material | Plasticizer | Applied food | Reference |
|---|---|---|---|---|
| Shelf life extension | Coat based on cassava starch and chitosan with tamarind seed extract | Glycerol | Guava | (Rodrigues et al., 2020) |
| Shelf Life Extension Antioxidant Property | Edible film based on cassava starch with *Lactobacillus plantarum*, *Pencococcus pentosaceus* and carboxymethylcellulose sodic | Glycerol | Banana | (Li et al., 2020) |
| Biodegradable | Biodegradable foam based on cassava starch incorporated with grape stem | Glycerol | English cake | (Engel et al., 2019) |
| Antioxidant and antimicrobial property | Film based on starch, citrus pectin and Acca sellowiana residue | Glycerol | Apple | (Sganzerla et al., 2020) |
| Shelf life extension | Film based on arrowroot and yota-carrageenan starch | Glycerol | Cherry tomato | (Abdillah and Charles 2021) |
| Biodegradable Use of industrial waste /natural sources and | Cassava starch-based film with orange juice residues | Glycerol | N/A | (Leites et al., 2021) |
| Shelf life extension | Film based on cassava starch, whey protein and beeswax | Glycerol | N/A | (Cortés-Rodríguez et al., 2020) |
| Active agricultural films for controlled release of fertilizer | Cassava starch and bagasse materials containing urea | Glycerol and Urea | N/A | (Versino et al., 2019) |
| Antioxidant and antimicrobial property | Cassava starch and whey protein mixing films containing rambutan bark extract and cinnamon oil | Glycerol | Salami | (Chollakup et al., 2020) |

| | | | | |
|---|---|---|---|---|
| Plasticizing study Biodegradable | Cassava starch film | Glycerol and Sorbitol | N/A | (Lim et al., 2020) |
| Plasticizing study | Oatstarch Films | Glycerol, Sorbitol, Urea and Sucrose | N/A | (Galdeano et al., 2009) |
| Biodegradable | Cassava starch and gelatin film | Inverted sugar and sucrose | N/A | (Veiga-Santos et al., 2007) |

*N/A: Not Applied

Source: Authors