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Study the Classification, Chemical, Physical, Methods Modification and Starch Applications in Some Industrial Processes. Review

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Abstract – **Starch is increasingly used in industrial applications and as a renewable energy resource. Commercial preparations of resistant starch are also produced to be used as food additives. Starch can be modified to enhance its positive attributes and rid of the negative characteristics. In this article, the state of knowledge on starch and their Physical and chemical characteristics. This paper covers physical modification methods (pre-gelatinization, hydrothermal, and non-thermal processes), some chemical modifications and a combination of both. In addition to the various applications of starch in industries.**

Keywords – **Starch, Classification, Processing, Starch Modification, Applications, Chemical, Physical, Properties.**

I. INTRODUCTION

Starch is a naturally occurring, biodegradable, cheap, renewable, and abundantly available polysaccharide molecule. The different botanical sources of starches are cereal (wheat, corn, rice, barley, oat, sorghum, millet, and rye), legume (lima bean, garbanzo bean, lentil bean, red kidney bean, navy bean, faba bean, mung bean, pinto bean, adzuki bean, field pea, cowpea, beach pea, green pea, grass pea, soybean, and groundnut), some under-utilized legume (sword bean, jackbean, and pigeon pea), root and tuber (cassava, potato, yam, cocoyam, and sweet potato), and unripe fruit (banana, plantain, mango, and pawpaw). Starch granules are mainly found in seeds, roots and tubers, as well as in stems, leaves, fruits and even pollens [1].

Starch is the most abundant carbohydrate reserve in plants and is found in leaves, flowers, fruits, seeds, different types of stems and roots. Starch is used by plants as source of carbon and energy [2]. Starch is a natural polymer occurring in all plant organisms. It is the major component of most of plant-originated foodstuffs and feedstuffs and of numerous industrial raw materials. Being synthesized from glucose, which is formed from dioxide and water, starch is an indirect product of photosynthesis, hence it is called renewable raw material [3].

as a source of energy during periods of dormancy and regrowth. Many of these starch-storing organs — for example, the grains of maize and rice or the tubers of cassava and potatoes — are staple foodstuffs in the human diet. Increasingly, starch is also used as a renewable raw material, as a source of energy after conversion to ethanol, and for many different industrial applications [4].

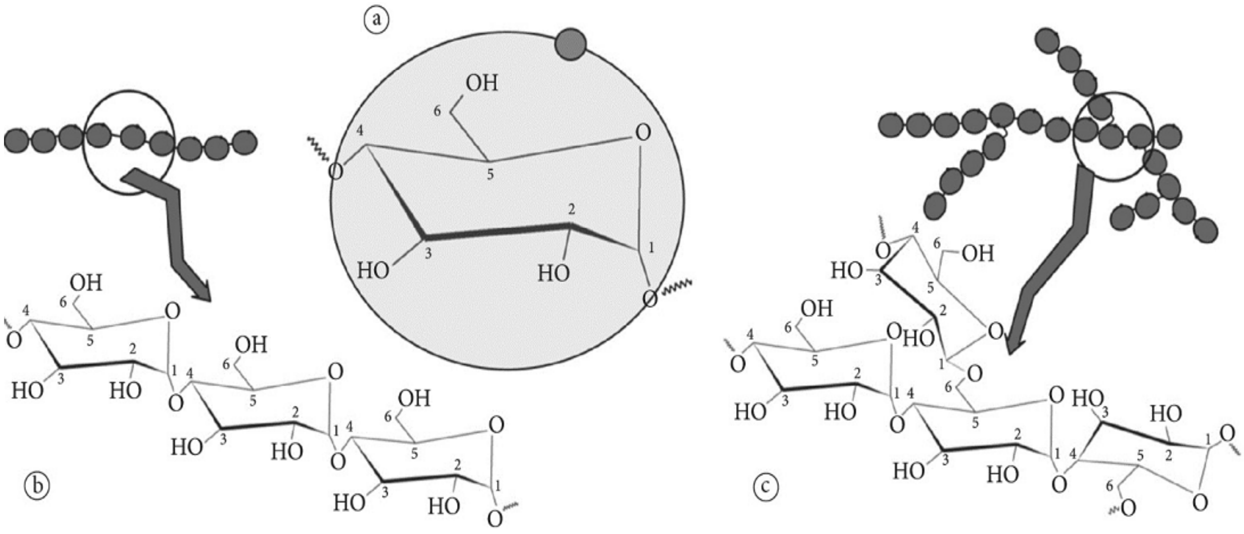
The main location of starch synthesis and storage in cereals is the endosperm. Major starch sources are cereals (40 to 90%), roots (30 to 70%), tubers (65 to 85%), legumes (25 to 50%) and some immature fruits like bananas or mangos, which contain approximately 70% of starch by dry weight [5]. The accumulation pattern of starch granules in each plant tissue, shape, size, structure and composition is unique to each botanical species [2].One of the unique characteristics of starch-based polymers is their processing properties, which are much more complex than conventional polymers. The processing (in particular extrusion) of starch-based polymers involves multiple chemical and physical reactions, e.g. water diffusion, granule expansion, gelatinization, decomposition, melting and crystallization [6]. Using starch of various sources to manufacture products in noodle shapes has been practiced for centuries in China and subsequently spread to neighboring countries. These products are called ‘‘starch noodles” or ‘‘cellophane noodles” because of their translucent or transparent appearance of pre- or post-cooking [7]. The biochemical chain responsible for starch synthesis involves glucose molecules produced in plant cells by photosynthesis. Starch is formed in the chloroplasts of green leaves and amyloplasts, organelles responsible for the starch reserve synthesis of cereals and tubers [2, 8].

II. CLASSIFICATION OF STARCH

The two main components of starch are amylose (AM) and amylopectin (AP) and they differ significantly intheir properties and functionality. AM has a high tendency to retrograde and produce tough gels and strong films. In contrast, AP, when dispersed in water, is more stable and produces soft gels and weak films [1].

The polymodal distribution of α-glucans chains of different sizes and the grouping of branch points in the amylopectin molecule allow the formation of double helical chains. Amylose and amylopectin can be arranged in a semi-crystalline structure forming a matrix of starch granules with alternating amorphous (amylose) and crystalline (amylopectin) material, which is known as the growth rings in superior plant starch [9]. There are three types of crystalline structures: A-type characteristics from cereal starches, B-type found in tubers and C-type present in legumes [10]. Starch synthesized by plant cells is formed by two types of polymers: amylopectin and amylose. Amylopectin consists of linear chains of glucose units linked by α-1,4 glycosidic bonds and is highly branched at the α-1,6 positions by small glucose chains at intervals of 10 nm along the molecule's axis; it constitutes between 70 to 85% of common starch [11].

Starch is a polysaccharide composed of the chains of glucose residues bound with a glycosidic linkage, however the structures formed are spatial in character. It contains two fractions: amylose and amylopectin. Amylose is a linear (rather poorly-branched) fraction with a medium degree of polymerization (reaching 102–103) [12]. Several types of starches are known as "waxy" starches due to the waxy appearance of the endosperm tissue from which they are derived; these tissues contain a minimal amount of amylose in their granule composition (<15%). Waxy starch requires high energy for gelatinization due to its high crystallinity [13].



Basic structural design of:
(a) glucose units.
(b) amylose.
(c) amylopectin.
along with the labeling of the atoms and torsion angles. Extension of the basic units to macromolecular structures was adapted from [14].

III. PHYSICOCHEMICAL PROPERTIES OF STARCH

Starch granules have microscopic sizes with diameters ranging from 0.1 to 200 µm, and its morphology varies between different shapes, such as oval, ellipsoidal, spherical, smooth, angular and lenticular, depending on the botanical source [15,16,10]. Size distribution can be uni-, bi-, or polymodal. In amyloplasts, starch granules are present individually or in groups [14]. The length of the α-glucan chains, amylose-amylopectin ratio and branching degree of amylopectin define the size, structure and particular utility of starch granules in each plant species. Other characteristics associated with the granule such as form, surface type and phosphate groups influence the starch's properties and uses (Smith, 2001).individually or in groups [17,14] Common cereals such as wheat, barley and rye contain two types of starch granules: (i) A-type, lenticular shape and large size and (ii) B-type, spherical shape and small size [18,19]. The physicochemical properties of certain native starches. Starch granules are typically isolated before microscopic observation, and the isolation method is important because it can potentially affect the starch's original size [20,21] Granule morphology typically contains a central line known as the hilum or "Maltese cross". Each starch granule may contain one or more Maltese crosses, and this characteristic reduces the birefringence ability of the starch granule [22]. The amount of amylose present in the granule significantly affects the physicochemical and functional properties of starch. The amylose content can vary within the same botanical variety because of differences in geographic origin and culture conditions [20].

Researchers have highlighted the role of amylose in the initial resistance of granules to swelling and solubility, as swelling proceeds rapidly after leaching of amylose molecules. The capacity of amylose molecules of form lipid complexes prevents their leaching and consequently the swelling capacity [10]. Amylose is anhydrous and can form excellent films, which are important characteristics for industrial applications. Films formed by amylose are very strong, colorless, odorless and tasteless [23]. Crystalline structures are based on the double helix formed by the amylopectin molecule. In A-type structures, the amylopectin branches are short (polymerization degree of 6-15) and linked by α-1,6 bonds. A-type is characteristic of amylopectin ramifications. In B-type, the glucose chains are more polymerized and can act as bases where the branches are A-type or form branched amylopectin molecules. B-type chains are subdivided into B1, B2, B3 and B4. B1 chains have a polymerization degree between 15 and 25, and B2 chains are typically between 40 and 50;

B3 and B4 are the highest. C-type crystallinity is a combination of the A- and B-types and consists of amylopectin molecules with non-reduced ends [24].

The characteristics of the native starch, the effects of the physical or chemical modifications of the granules, the process parameters and the botanical sources of the starch are all critical factors governing the behavior and characteristics of the starch paste. The transformation of starch during manufacturing depends on the temperature-time-mixture ratio and the modification ratio during processing. One of the most important structural characteristics of starch is that it passes through several different stages from water absorption to granule disintegration. Water absorption and consequent swelling of the starch granule contribute to amylopectin-amylose phase separation and crystallinity loss, which in turn promotes the leaching of amylose to the inter-granular space [25].When starch molecules are heated in water excess, the semi-crystalline structure is broken, and water molecules associate by hydrogen bonding to hydroxyl groups exposed on the amylose and amylopectin molecules. This association causes swelling and increases granule size and solubility [10]

The extent of this interaction is influenced by the amylose-amylopectin proportion and is characteristic of each molecule depending on the polymerization degree, length and grade of chain branching, molecular weight and molecular conformation [16, 26]

The swelling stage of starch granules is the initial step of all other paste characteristics. Initially, granule swelling is reversible, increasing its volume up to 30% (Gryszkin et al., 2014). Water absorption and heating of the starch dispersion breaks the hydrogen bonds responsible for granule cohesion, partially solubilizing the starch (Hoover, 2001).Water penetrates the interior of the starch granule, hydrating the linear fragments of amylopectin [27].

IV. STARCH MODIFICATION

Modification of starch is carried out to enhance the positive attributes and to eliminate the shortcomings of the native starches. Various methods have been developed to produce a range of modified starches with a variety of characteristics and applications. Physically modified starches are simple and inexpensive because they can be produced without chemicals or even biological agents. In contrast, chemical modification is possible due to ubiquitous hydroxyl groups in starches that have been exploited for over a century, principally in the preparation of starch esters and ethers, but also in more subtle alterations, e.g., in order to tune the structure of starches for specific applications [1].

Starch is rarely consumed in its intact form and frequently used by industry in its native form. Most native starches are limited in their direct application because they are unstable with respect to changes in temperature, pH and shear forces. Native starches show a strong tendency for decomposition and retro gradation [28]. Additionally, some starch granules are inert, insoluble in water at room temperature, highly resistant to enzymatic hydrolysis and consequently lacking in functional properties. Native starches are often modified to develop specific properties such as solubility, texture, adhesion and tolerance to the heating temperatures used in industrial processes [29, 30]. Starch is a versatile and useful polymer not only because it is a cheap, natural material but also because of the ease with which its physicochemical properties can be altered through chemical or enzyme modification and/or physical treatment. In recent years, our understanding of starch structure and our knowledge of the enzymes that are involved in starch biosynthesis has increased greatly, many of the genes that encode these enzymes have been cloned [31]. Several methods have been developed to produce modified starches with a variety of characteristics and applications. All of these techniques alter the starch polymer, making it highly flexible and changing its physicochemical properties and structural attributes to increase its value for food and non-food industries [32]. The starch modification industry is constantly evolving. Modifications of starch include physical, chemical and enzymatic methods [33]. Physical methods involve the use of heat and moisture, and chemical modifications introduce functional groups into the starch molecule using derivatization reactions (e.g., etherification, esterification, crosslinking) or involve breakdown reactions (e.g., hydrolysis and oxidation) [29].

V. PREPARATION METHODS OF MODIFICATION

Physical Modification of Starch

Physical modifications of starch can improve its water solubility and reduce the size of the starch granules. Physical methods to treat the native granules include: different combinations of temperature, moisture, pressure, shear and irradiation. Physical modification of starch granules is simple, cheap and safe. These techniques do not require chemical or biological agents, and are therefore preferred when the product is intended for human consumption [1].

Jet Argon Plasma Treatment under Atmospheric Pressure

The schematic diagram of jet atmospheric argon plasma setup Argon plasma was induced by supplying sufficient input power and high frequency (HF) to argon gas under atmospheric pressure. In this study, the input power supplied for generating plasma was 50 or 100 W. The HF of power supply was about 600 MHz. The starch slurry was treated by jet argon plasma for 5 min. During the treatment, slurries of both granular and cooked starch were continuously stirred using a magnetic stirrer to prevent sedimentation. Two forms of starch slurry were prepared as granular and cooked starch. For granular starch, 0.4 g of starch was dispersed in 1.6 g of distilled water to obtain a starch concentration of 20% (w/w). The slurry was thoroughly mixed using a magnetic stirrer. For cooked starch, 0.1 g of starch was dispersed in 4.9 g of distilled water to obtain a concentration of 2% (w/w), the slurry was then boiled for 2 min with stirring. The cooked starch was cooled to room temperature (25˚C) for 7 min before subjecting to plasma treatment [34].

Pre-gelatinized Starch (PGS)

Pre-gelatinized starch (PGS) is starch that has undergone a cooking process until complete gelatinization and a simultaneous (or subsequent) drying process. Drying methods include drum drying, spray drying and extrusion. The main consequence of this treatment is the destruction of the granular structure, resulting in complete granular fragmentation, and the absence of birefringence properties. The principal properties of PGS are an increase in swelling capacity, solubility and cold water dispersion. PGS functionality depends on the cooking conditions, drying and the starch source [1]. The physically modified starches, PGS is primarily used as a thickener in many instantaneous products, such as baby food, soups and desserts, due to its ability to form pastes and dissolve in cold water. The use of PGS is preferred in sensible foods because it does not require heating to form a paste [35].

Hydrothermal Modification

This physical modification involves changes in the physical and chemical properties of the starch without destroying the granule structure [36]. Structure is ANN and HMT. Both physical modifications occur at temperatures above the glass transition temperature (Tq) but below the gelatinization temperature of the starch granules. Essentially, hydrothermal modification can only take place when the starch polymers in the amorphous phase are in the mobile rubbery state of the semi-crystalline region. A few minute is sufficient to bring about detectable changes in the physicochemical properties of the starch. Both HMT and ANN occur below the onset temperature of gelatinization and have been shown to modify starch structure and properties to different extents. There is a need to distinguish between the two terms (ANN and HMT). Both HMT and ANN involve storage of starch at a specific temperature and at a certain moisture level during a certain time period. The term HMT is used when low moisture levels (less 35% w/w) are applied. In contrast, ANN refers to treatment of starch in excess water (less 65% w/w) or at intermediate water 40–55% w/w [1].

Essentially, hydrothermal modification can only occur when starch polymers transition from the amorphous region to the semi crystalline region. Starch in its native form exhibits amylopectin ramifications by forming a double helix chain, and this behavior imparts a crystalline structure to the starch molecule. Heat treatment involving temperatures between the (Tg) and melting temperature (Tm) may not alter the double helix conformation or degree of starch crystallinity; these conditions are present when starch pastes are drying. Physical modification of starch performance improves starch paste characteristics such as texture and plasticity by reducing (Tg) and consequently relaxing the hydrogen bonds and polymer-polymer interactions. The presence of water reduces the (Tm) [25].

Non-thermal Physical Modification

Some processes in food production are applied to extend the life of a product using thermic treatments at boiling temperatures (or even higher) for seconds or minutes. Traditional treatments cause a loss of some vitamins and nutrients and alter their organoleptic properties. Non-thermal modification is an alternative to traditional processes that also eliminates pathogenic microorganisms and spores. Non-thermal techniques involve the use of high pressure, ultrasound, microwaves [37], [38], [39]. The high pressure technology in industry uses pressure from 400 to 900 MPa. High pressure generally restricts the swelling capacity and consequently decreases paste viscosity. Other technologies use pressure several times bellow atmospheric pressure (vacuum pressures); this technology uses gas in a plasma state and is the most recent technology used for starch granule modification [40], [34] Modification of starch using microwaves involves several interacting mechanisms, such as irradiation, furnace dimensions and the characteristics of the starch. In the microwave irradiation process, the most important parameters are moisture and temperature, which influence the dielectric properties of the starch [38]. Starch modification by microwaves results from the rearrangement of starch molecules that generates changes in solubility, swelling capacity, rheological behavior, Tge$_l$ and enthalpies [41], [42]. Depending on the starch source and moisture, modification by microwave also produces variations in morphology and crystallinity in the granule [38].The use of ultrasound is also considered a physical modification treatment. This treatment is applied to starches in suspension and starches that have undergone previous gelatinization [41], [42].

Ultrasound primarily affects the amorphous region, while maintaining the granule’s shape and size. The starch surface becomes porous, and properties such as the swelling capacity, solubility and viscosity of the paste are modified [43]. Ultrasonic modification depends on the sound, frequency, temperature, process time and the starch suspension properties (i.e., concentration and botanical source of starch) [42].

VI. CHEMICAL MODIFICATION OF STARCH

Chemical modification involves the introduction of functional groups into the starch molecules, resulting in markedly altered physicochemical properties. Such modification of native granular starches profoundly changes the proximate compositions, gelatinization, retro gradation, and pasting characteristics. Chemical modification is intended to facilitate intra- and inter-molecular bonds at random locations in the starch granule for their stabilization. The chemical and functional properties achieved by modified starches depend, inter alia, on starch source, reaction conditions (reactant concentration, pH, reaction time, and the present of catalyst), type of substituent, degree of substitution (DS), and the distribution of the substituents in the starch molecule [1]. Chemical modification involves the introduction of functional groups on the starch molecule without affecting the morphology or size distribution of the granules. Chemical modifications generate significant changes in starch behavior, gelatinization capacity, retrogradation and paste properties [32].

Cationic Starch

Cationic starches are generally produced by reacting Starchwith compounds containing tertiary or quaternary ammonium, imino, amino, sulfuric or phosphate groups. Free hydroxyl ions present in the native starch molecule are commonly altered using cationic monomers such as 2,3-epoxypropyl trimethylammonium chloride (ETMAC) or 3-chloro-2-hydroxypropyl trimethyl ammonium chloride (CTA) in dry or wet processes. In dry cationic modification, in the absence of a liquid phase, the reactive is sprayed onto the dry starch during extrusion. The semi-dry method for cationization involves a mixture of starch and spray reagent prior to the thermal treatment. Wet cationization includes a homogeneous reaction with dimethyl sulfoxide (DMSD) or a heterogeneous reaction in alkaline solution. The physicochemical properties of the starch and granular structure are altered after the cationic process, particularly when the process involves a high degree of substitution. The cationic reaction reduces the paste temperature, increases the viscosity peak and results in various changes in starches from different sources. Among modified starches, cationic starch materials are preferred by the textile industry because the positive charge introduced in the molecular chains conform to the electrostatic bonds between the negative charges of the cellulose fibers [43].

There are several applications for cationic starches (i.e., in water treatment as flocculants and as additives in textile products, paper and cosmetics), preferred for their low cost, excellent fit, biocompatibility and rapid degradation [44].

Cross-linked Starch

Crosslinking of a polymer occurs when linear or branched chains are covalently interconnected and is known as cross-linking or cross-ligation. The reagents used form ether or ester bonds with hydroxyl groups in the starch molecules [29].

This modification increases the polymer’s rigidity by formina three-dimensional network. Crosslinking in starch increases the degree of polymerization and molecular mass; starch molecules lose water solubility and become soluble in organic solvents. Several agents are used to crosslink native starch: sodium trimetaphosphate (STMP), sodium tripolyphosphate (STPP), epichlorohydrin (ECH) and phosphoryl chloride (PDCl3), among others [45].

Depending on the reagent used for crosslinking, the final product is classified in one of three types: i) monostarch phosphate produced by starch esterification with orthophosphoric acid, potassium or sodium orthophosphoric or STPP; ii) distarch phosphate produced when native starch reacts with STMP or PDCl3; or iii) phosphateddistarch phosphate, resulting from combined treatments of monostarch and distarch phosphates [46], [47].

The source of starch granule, methods and parameters used for crosslinking modification has an important influence on the properties of the final product. Starch properties affected by cross linking modification include the paste clarity and swelling capacity. Some authors suggest that both properties are linked, and a reduction in swelling is responsible for the decrease in paste clarity [48].

The degree of crosslinking also reduces the moisture, lipids and proteins associated with the native starch granule; these changes are produced by all of the aforementioned crosslinking agents in different proportions [49].In the food industry, cross-linked starch is associated with formulations of frozen products due to its stabilizing, thickening, clarity and retrogradation resistance properties of the pastes formed. Its uses also extend to other industries such as plastics [32].

Modified Starch using Acetylation

Acetylation is one of the common chemical method of starch modification, it is achieved by esterification of native starch with either acetic anhydride or vinyl acetate in the presence of alkaline catalyst, e.g., NaOH, KOH, Ca(OH)2, Na2CO3. The acetylation reactions are typically carried out in water, though organic solvents also have been shown to be effective [1]. Acetylation is a modification of polymeric starch molecules through the introduction of functional acetylated groups (CH 3CD) that react with free hydroxyl groups present in the branched chains of the starch polymer to produce a specific ester [30]. Acetylation is the more common chemical modification method, resulting in native starchesterification using reactive reagents such as anhydrous acetic acid, vinyl acetate or DSA in the presence of an alkaline catalyst (NaDH, KDH, Ca(DH)2, Na2CD3) [50].

Starch modified with DSA is an effective emulsifier used in the food, pharmaceutical and cosmetic industries; in this modification, DSA adds hydrophobic chains to the hydrophilic structure of starch [51]. The introduction of acetyl groups reduces the resistance of bonds between the starch molecules. Acetylated starch increases the swelling capacity and solubility compared to native starch [28]. The presence of hydrogen bonds in acetylated starch is restricted due to electrostatic repulsion forces on the starch molecule [52].

In acetylated starch, hydroxyl groups and anhydrous glucose have been converted to acetylated groups (Huang et al., 2010). Acetylated starch with a low degree of substitution (0.01-0.2) has several applications in conforming films, adherents, thickeners, stabilizers, texturizers and encapsulation agents [53].

VII. STARCH APPLICATIONS

The biological function of starch in plants is as a reserve of carbon and energy. As food, starch is the most abundant and important digestible polysaccharide. The starches in food are commonly derived from grains or seeds (wheat, corn, rice, and barley), tubers (potato) and roots (cassava) [15], [54]. Starch provides 70 - 80% of the calories consumed by humans worldwide. As food, starch functions as a structural agent because of the modifications introduced during manufacturing. Starch is used in the food industry mainly as a modifier of texture, viscosity, adhesion, moisture retention, gel formation and films [54]. In the food industry, edible films are barriers that prevent moisture transfer, gas exchange, oxidation and the movement of solutes, while maintaining their organoleptic properties. The basic materials used to produce edible films are cellulose, starch, gums and chitosan; the linear configuration of polymers can produce films with flexible, transparent and oil resistant properties. For these reasons, amylose is the most important fraction in starch granules. Typically, the starch granule is composed of 25% amylose and 75% amylopectin. Edible films require starches with a high amylose content (≥ 70%). The amylopectin molecule cannot adequately form films; the branched structure imparts poor mechanical properties to the film, reducing its tensile strength and elongation. Polysaccharides are typically hygroscopic and therefore are poor barriers to moisture and gas exchange. The use of plasticizers in the film composition improves the barrier against moisture exchange and restricts microbial activity. The starch used in edible film preparation is incorporated to partially or completely replace the plastic polymers. Native starch does not produce films with adequate mechanical properties and requires pretreatment, the use of a plasticizer, mixture with other materials, genetic or chemical modification, or a combination of these treatments. Among the plasticizers, for hydrophilic polymers, such as starch, are glycerol and other low-molecular weight polyhydroxy-compounds, polyether, and urea. Processes such as extrusion adjust the parameters of temperature and mechanical energy over the starch paste, making it a thermoplastic material that is also suitable for the production of edible films [55]. Plastics obtained from oil are being replaced by natural polymers; starch is known for its ability to form films in food packaging applications [56]. Edible and biodegradable starch films can be obtained from native starch or its components amylose or amylopectin by two main techniques: a wet method that includes a starch suspension and posterior drying or a dry method that involves a thermoplastic process [57]. Modified starches can also be used in film production [23], [55], [32]. For new industrial applications of starch, especially in plastic polymer production, the hygroscopicity of starch is a disadvantage because the main feature of plastics films is their hydrophobic property. Starch granule size, its form and associated molecules influence film production. Wheat starch is typically associated with a significant amount of protein, which may result in a Maillard reaction and cause bleaching; therefore, this type of starch is not used in to manufacture biodegradable plastics films [58].

In the textile industry, starch films are also used during textile production as fiber coatings. Native starch forms rigid and brittle films due to its cyclic structure. Brittle films are not advantageous because they reduce protection, increase friction and thus damage the thread. The polarity of native starch minimizes the adhesion of synthetic fibers, affecting the tensile strength and abrasion. Starch is commonly modified to improve the physical properties, emulsifying ability and film formation [59]. Many industrial processes use starch after partial or complete destruction of its structure. When this occurs, the properties of its components and the relationships between them increase their importance. Differences between the amount and type of lipids originally present in the native starch may cause two starches with the same amylose-amylopectin ratio to have different physical properties, such as viscosity. Starch solutions are viscous, and the ability of starch to change the viscosity of other solutions and pastes is well known and exploited in the food industry. This property is also used in the oil drilling industry, where starch is used to adjust the viscosity of the mud used during drilling operations. Highly viscous starch solutions are desirable for industrial processes involving starch pastes for mechanical manipulation, such as the paper, corrugated and textile industries [58].

The production of biodegradable plastics is still young when compared to the petrochemical plastic industry. Starch will play an important role in its growth in container production and in the form of biodegradable materials that conform to suitable matrices because it is a relatively inexpensive material compared to other polymers [55]. In recent years, starch has been studied for the production of nanoelements as nanocrystals that result from the breakdown of the amorphous region in semicrystalline starch granules by acid hydrolysis or for the production of nanoparticles from gelatinized starch [60].These nano compounds have unique properties due to their nano size compared to conventional size materials. Nanoparticles can be used as fill material in filtration and form effective barriers in flexible packaging [61].

VIII. CONCLUSIONS

Starch has a major role in the food industry in for its nutritional value**.** The amylose and amylopectin polymers, lipids, proteins and phosphorus present in granules have significant effects on the physicochemical properties and functionality of starch. Starch is rarely consumed in its native form; this form is also not commonly used in industry because native starches have restricted solubility in water, which limits industrial applications. Modification processes can greatly improve the characteristics of native starch by altering its physicochemical properties and structural attributes and increasing its technological value. Physical modification of starch can enhance its water solubility and reduce the size of the starch granules. Physical methods for the treatment of native granules include combinations of temperature and moisture, pressure, shear and irradiation and. These modification techniques are preferred because they do not require chemical or biological agents that may be harmful to health. Chemical modification of starch involves the introduction of functional groups to the starch molecule without affecting the morphology or granule size distribution. Determining the required characteristics of starch for each process is necessary to select the best modification method according to the application requirements, market trends, availability, structural characteristics and cost.

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