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Other Names for this SubstanceStarchAmylumArrowroot starchW-GumMarantaDeleted or Replaced CAS Registry Numbers9057-05-0, 42616-76-2, 53112-52-0, 53262-79-6, 60496-95-9, 67674-80-0, 75138-75-9, 75398-82-2, 85746-25-4, 118550-61-1, 131800-97-0, 152987-55-8, 154636-77-8, 730985-55-4, 730985-56-5, 730985-57-6, 939768-85-1, 955949-61-8, 1017902-96-3, 1152489-70-7, 1309960-29-9, 1374255-25-0, 2075820-73-2, 2168558-67-4, 2247144-19-8, 2416312-53-1, 2835497-61-3, 2919713-18-9, 2919713-41-8, 2982930-99-2 Starch is a mix of 2 different polysaccharides:1) Amylose: a long chain of α-glucose monomers joined by 1,4-glycosidic bonds. The chain coils in a spiral shape, held together by hydrogen bonds. This shape makes starch well suited to energy storage as it is compact, so takes up little space in the cell, and not very soluble in water, so does not affect the water potential of the cell. 2) Amylopectin: branched chains of α-glucose monomers joined by 1,4-glycosidic bonds and 1,6-glycosidic bonds. The 1,6-glycosidic bonds form the links which make branches.The branches mean there are many glucose molecules accessible on the end of chains which can be easily broken off by hydrolysis for use in respiration. Therefore amylopectin can provide a rapid supply of energy. Branching also makes it compact, it takes up little space in the cell. Starch, a polysaccharide, is a biodegradable natural carbohydrate that acts as an energy store in plants and serves the plant as a reserve food supply. It is a staple carbohydrate in the human diet and plays a crucial role in quality and nutritional value improvement in the food industry. Starch consists of glucose molecules synthesized by the green leaves of plants during photosynthesis and found in the form of granules in plants. When photosynthetic activity is inadequate, It breaks down to glucose and helps in nourishing the plant. Starch is present in the leaves of green plants, stems (sago), roots of the cassava plant, all vegetables, fruits (banana, plantain), tubers (potatoes, cassava), cereals (such as wheat, corn, maize, sorghum and, rice), and some algae. Starch or amylum is a homopolymer (each yields only one type of monosaccharide (glucose) after complete hydrolysis) composed of D-glucose units linked by α-(1→4) glycosidic bonds. The α-(1→4) glycosidic linkage between the glucose units is formed by starch synthases. It is also called glucosan or glucan. α, β -amylases specifically act on catalyzing the degradation of α-1,4 linkages. Starch hydrolyzes to liberate dextrins and then maltose and glucose units with the help of an amylase enzyme. It constitutes two polysaccharide components: water-soluble amylose (20-30%) and water-insoluble amylopectin (70-80%). Both components are present in the starch granules. Structure of Amylose and Amylopectin in Starch Amylose, a linear molecule, is a long unbranched chain with 200- 1,000 α-D-glucopyranosyl units linked by α (1-4) glycosidic linkages. Amylose is amorphous in nature. Amylose leaches out of the granules, allowing water to enter and swell upon heating. Amylose compound produces a blue color when starch reacts with iodine. It is less soluble in water and does not form gel when hot water is added. The common source of amylose is a hybrid corn containing 50 % up to 70 % amylose. Other sources are rice and potato starches (up to 30%), quinoa, beans, bananas, and lentils. Amylopectin is a highly-branched polymer with 50,000 to 5,00,000 α-D-glucopyranosyl units linked by α (1-4) linkages everywhere and by α (1-6) glycosidic bonds at the branching points. It has a molecular weight of 107 to 108 daltons. Each branch constitutes 20-30 glucose units, and each molecule possesses hundreds of these branches. Amylopectin is crystalline in nature. The branching points in amylopectin join together to facilitate the formation of allomorphs. The bond formed in amylopectin is weaker than the linear amylose molecules. It is more soluble in water and forms a gel when hot water is added. It influences viscosity changes due to water and heating. A maximum of three hydroxyls are present in each glucose unit and are available for chemical substitution. It gives a purple color when reacting with iodine. The higher amount of amylopectin is present in grain rice, waxy potato starch, waxy corn, and glutinous rice, whereas lower in long-chain rice, amylomaize, and russet potatoes. The properties depend on the molecular and structural composition of amylose and amylopectin, percent composition, and arrangement of these two homopolysaccharides in starch granules. It has good iodine-binding ability. It has good swelling power. It lowers water absorption capacity. It has high viscosity. It acts as Emulsifiers. Encapsulants Gelling ability or clouding agent Gelatinization Freeze-thaw and cold storage stabilities Binders Confectioneries, cough syrups- Act as anti-crystallizing Beverages- Act as a sweetening power Dairy Products- Act as a Bulking agent and improve texture Bakery Products- Act as moistening Soups and sauces- Act as a thickening and binding agent Paper- Increase strength Corrugated board- Acts as an adhesive agent Use for ethanol, polyurethane, and bioplastics production Act as a binding capacity in glues and adhesives Cosmetics- Act as Emulsifier Jams- Act as a preservative agent Freezing point depression in ice creams Provide nutritional quality in baby food and clinical nutrition Animal Feeds- Palatability for pet food, high digestibility for piglets starter feed, milk powder replacement in calf milk, and yellow pigmentation for egg yolks There are two types of starch. They are: Native Starch Processed/ Modified Starch Native Starches are long-chain carbohydrates which are pure forms of starch. It exists in plant sources such as corn, maize, rice, wheat, potato, cassava, and tapioca. The extraction of pure starches from sources produces white, tasteless, odorless, either powder or liquid. They are insoluble in cold water and swell to different degrees depending on type and temperature. In this group, starch has not altered to any other treatments, like physically, chemically, or enzymatically. Despite being used in the food industry for decades, its industrial application is limited because of its inherent properties, such as resistance to high temperature or acid (starch breaks down when reheated or in an acidic environment) and poor thermal stability. Native starches have tremendous properties such as thickening, texturizing, gelling, moisture retention, antistaling properties, stabilizing, film forming, dusting, and dough binding. Bakery mixes Frozen cakes Sheeted snacks Batters & breadings Brewing adjuncts Licorice confections Dry mix soups and sauces Pet foods Processed meat Pudding powders Cold Process Salad dressings and dips Frozen prepared entrée sauces Fruit Preps The physiochemical and functional properties of native starch have been altered or modified with any other treatments like physical, chemical, enzymatic, or combination of these as per the Good Manufacturing practices for improved physiochemical characteristics, functionalities, and nutritional qualities and to change, strengthen, or impair new properties by molecular cleavage, re-arrangement is known as modified starch. Due to this, there will be changes in the properties such as gelatinization temperature, viscosity, retrogradation (a reaction occurs in gelatinized starch when the amylose and amylopectin chains realign themselves), gel clarity, texture, and taste of native starch. Modified starch fulfills the flaws of native starch. In food industries, unprocessed or original native starches are less preferred due to low thermal and shear resistance, poor resistance to acid and alkali, resistance to freeze/thaw, instability shear stress, viscosity loss while processing, and higher retrogradation tendency. Because of this limitation, the quality of food products deteriorates. That is why modification of starch is needed to improve nutritional quality and to increase shelf life. The most common sources of native starch used in this modification are various roots, tubers, cereals, and legumes. The most common types of modified food starch obtained from corn, wheat, potato, and tapioca are as follows: Modified corn starch Modified waxy maize starch Modified tapioca starch Modified potato starch Modified wheat starch Modified rice starch Modified starches have properties like thickening, stabilizing, emulsifying, texturizing, taste, gel clarity, resistance to acid and alkali, shear, resistance at different temperatures (excessive heat, freezing), retrogradation (expel water from the polymer network), and increased shelf life. There are three types of modification methods: Physical modification Chemical modification Enzymatic modification Genetic modification Based on physical factors (moisture, temperature, pressure, pH change, radiation treatment, and ultrasonic treatment), it changes the functional, morphological, physical, and structural characteristics of starch, such as solubility, crystallinity, swelling power, viscosity, thermal snd stability properties. It helps starch to swell and to be soluble in cold water. The commonly used methods are superheating of starch, thermal inhibition treatment, UV and gamma irradiation, microwave treatment, high pressure, osmotic pressure, instantaneous controlled pressure treatment, mechanical activation by stirring ball mill, pulsed electric field treatment, micronization in vacuum ball mill, annealing, and freeze-thaw treatment. Applications of Physically modification It helps in the production of modified starch and hydrolyzed starch. It acts as a thickening and binding agent. It helps in controlling moisture. Salad dressings Toppings Syrups Yogurt It also modifies the physiochemical characteristics of starch by adding new chemical or functional groups in starch despite not altering the shape and size of starch granules (starch deposited in plants in the form of granules). Each anhydroglucose unit (AGU) consists of three hydroxyl groups adjacent to the carbon atoms at positions 2, 3, and 6. This arrangement renders the ability to alter starch easily through a chemical reaction with different functional groups. The chemical modification includes esterification and etherification, emulsification, cationization, oxidation, acid treatment, and cross-linking (making a starch more heat resistant). Conventional chemical methods use acids and acetates, hypochlorites, and phosphates. Mostly, stabilized and cross-linked starch is implemented in food. These modifications greatly expand the field of potential applications in the food industry. However, this treatment can be pernicious to the environment and requires recycling. So, the enzymatic method is preferred more. Functions of Chemical Modification Improve the gel setting performance and lower gelatinization temperature Increase the stability during frozen storage Reduce retrogradation Applications of Chemical Modification Additives for medicine, cosmetics, coatings, oil exploiting Drug delivery Packaging biofilm (green packaging) edible films Food additives (like stabilizers and thickeners such as hydroxypropyl starch and acid-treated starch) Papermaking Fat replacers in ice cream, salad dressings, cheese, baked foods, icings, mayonnaise eliminate oil uptake by the foods Improve dough characteristics Canned foods, bakery and frozen foods, sauces, ketchup, jam, and jellies- act as pectin replacers in these food products Enzyme treatment is a direct modification of starch structure, which means there will be changes in molecular size and weight, the ratio of amylose to amylopectin, and branch chain length distribution. When activation energy gets lower and the reaction is mild, the complex chains of starch converts into simple sugars like maltose with the help of enzymes. This process is also called enzymolysis. The enzyme can be retrieved and reused. This method replaced the physical and chemical methods in producing the modified porous starch. Moreover, It is innocuous to the environment as well as food consumers. For example, Starch retrogradation referred to as staling, which is a core problem of starchy-based foodstuffs such as bread and rice cake. To limit the retrogradation rate, improving instability of the gelatinized starch structure, viscosity loss, various enzymes, emulsifiers, oligosaccharides, and polysaccharides have been initiated. Functions of Enzymatic Modification Lowers energy cost Offers higher yield specific reactions for starch substrate Starch-modifying enzymes are classified into two families. They are Glycoside hydrolase and transglycosylase for starch functionalization. Glycoside hydrolase: It is also known as glycosyl hydrolases or glycosidases. These enzymes catalyze the hydrolysis of glycosidic linkage of glycosides, which leads to the formation of a sugar hemiacetal (glucose) or hemiketal and the free aglycon. The glycosyl enzyme intermediate can react with water to cause hydrolysis is called glycoside hydrolase activity. It includes enzymes such as α-amylase (hydrolases that hydrolyze α-1. 4-glycosidic linkage of starch to produce oligosaccharides), β-amylase (hydrolyzes α-1,4-glycosidic linkages in starch and glycogen with an inversion of configuration on the C (1) position of the glucose from α to β forming maltose.), branching enzyme (glucan transferase), de-branching enzymes (pullulanase, isoamylase), cyclodextrin glycosyltransferase, amylomaltase and 4-α-glucanotransferase. Transglycosylase: These enzymes catalyze the transformation of one glycoside to another. The activity in which glycosyl enzyme intermediate reacts with a sugar acceptor to cause transglycosylation is called transglycosylase activity. These starch-modifying enzymes are isolated from micro-organisms including Thermus thermophilus, Thermus scotoductos, Thermus aquatieus, Bacillus stearothermophils, Bacillus acidopullulyticus, Aspergillus niger, Bacillus subtilis, Bacillus magaterium, Alkalophilc Bacillus, Neisseria polysaccharides, Deinococcus geothermalis, Rhodothermus obamensis, Aquifex aeolicus, Deinococcus radiodurans Some enzymes (usually β-amylase) are also isolated from various plant sources such as Ramie leaf and Barley (malt). Applications of Enzymatic Modification Production of organic acids (citric, lactic, and malic acid) Production of sweeteners such as maltodextrin, corn syrup, dextrose syrup, oligosaccharides, crystalline dextrose, and fructose Production of Polyols (mannitol, sorbitol, maltitol, and xylitol); Amino acids (cysteine, threonine, lysine, tryptophan, and methionine); alcohol (ethanol) Baking industry such as bread or rice cake for improving quality (crumb softness in bread, increases shelf life, production efficiency) Genetic modification employs amylose-free starch, high amylose starch, and starch with altered amylopectin structure. In a genetic modification of starch, transgenic technology is implemented to specifically target the enzymes involved in the pathways leading to the biosynthesis and degradation of starch in plants. Canned food Frozen prepared foods Meat products: sausage, canned meat Bakery: bread, cake, biscuits Confectionary: soft candy, gelling candy, jelly- forming a hard shell Beverage Dairy desserts: yogurt, ice cream, pudding Fruit pie and cream fillings dressings- act as an emulsifier and stabilizer Sauce (flavored sauce, cheese sauce) and Gravies- decrease lumpy consistency when mixed Instant food: noodles Soups- act as a thickener About Author Open, fast, peer-reviewed 3 STEP PROCESS 3 Months to Publication Always Open for Submissions 26 Book Series Covering Diverse Scientific Fields ISSN + ISBN Our authors span the globe, including emerging researchers at science’s cutting edge and esteemed Nobel Laureates. Contribute to this shared scientific journey and join us shaping the future. 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Explore our latest gallery of Editors’ Picks.Browse Editors' Favorites Starch is a polymeric carbohydrate that is composed of numerous glucose monomers. It is an organic substance that is produced by all the green plants and is stored as reserve food in chloroplasts. Given below is the molecular structure of starch. Starch – Diagram Structure & Features The molecular formula of starch is (C6H10O5)n. It is composed of n number of glucose monomers joined by α (1,4) linkage in chains and α(1,6) linkages at branching point. Two glucose molecules combine together to lose one molecule of water (H2O) for the formation of a starch polymer. Starch molecules exist in two forms – a simple linear polymer called amylose and a more complex branched form called amylopectin. Amylose is a linear polysaccharide chain that is made up of glucose monomers joined by α (1,4) glycosidic linkage. Amylose makes upto 30% of the total starch molecule. It has a helical structure and is more resistant to digestion. Amylopectin is a highly branched polymer made up of glucose subunits. It is made up of linear chains of glucose units that are linked by α (1,4) glycosidic linkage along with a number of side chains that branch the structure by α(1,6) glycosidic linkages. Amylopectin makes upto 70% of the starch molecule. It is insoluble in water. Physically, starch appears as a white, odourless and tasteless powder. It is insoluble in both water and alcohol. It is the most common form of energy storage in plants. In plants, starch is also stored in storage organs like roots (cassava plant), tubers (potato), stems (sago plant) and seeds (wheat, rice and corn). This starch can be broken down by a certain set of enzymes when required by the plant into glucose monomers and is supplied through diffusion across the plant tissues. Starch polymer is one of the most important components found in the staple diet of humans in the form of cereals and root vegetables. Commercial Uses Commercial starch is extracted from the roots and tubers of tapioca, sago, wheat and potato plants. It is used as a thickening agent in baking goods and confectionaries. It is used in the manufacturing of paper to increase its strength. It is also used to make tape, paper boxes and bags, gummer paper and corrugated paperboard. It also finds its use in the textile industry during warp sizing that imparts strength to threads at the time of weaving. ’ It is also used in pharmaceuticals as a binding agent, as an excipient and tablet disintegrant. Visit BYJU’S Biology for more updates. Also Read: About, Contact Us, Copyright, Privacy, AccessibilityU.S. Food and Drug Administration, 10903 New Hampshire Ave, Silver Spring, MD 20993-0002U.S. Food and Drug Administration, Health & Human ServicesFreedom of Information ActPowered by Starch can be obtained from a variety of plant sources. The specific source of starch, the environmental conditions during starch maturation, and the age of the plant affect the physicochemical composition of the starch. This is because of the effect they have on critical factors especially the amylose amylopectin content of the starch as well as their relative quantities. These factors also affect the starch granule size and size distribution and the levels of minor components such as phosphates, lipids, and the nature of these interactions with amylose and amylopectin. In its wide use as a pharmaceutical excipient especially as binder and disintegrant, unmodified starch is affected in its functionality by the physicochemical properties of the starch. These factors especially by their influence on the swelling power and gelatinization as well as granule size and shape determine the properties of dosage forms in which the starches are used. This results in dosage forms that, although meeting compendial standards, differ in specific properties. The source of starches therefore affects the properties of pharmaceutical dosage forms. This should be taken into consideration in the choice of excipients in drug formulation and before the substitution of one starch for another in a formulation. starch source amylose amylopectin swelling viscosity pharmaceutical excipients In its native form, pure starch is a white, amorphous relatively tasteless powder which is odorless and is insoluble in water and other common organic solvents. It is one of the most widely distributed chemical substances in nature being the energy storage form of plant materials. Microscopically, starch consists of colorless, highly refractive particles whose size and shape depend on various factors most important of which is the source of the starch. A starch granule involves alternating regions of amorphous and crystalline lamellae seen as rings which are essentially the crystalline portion. Starch is chemically a carbohydrate composed of two similar carbohydrate molecules—amylose and amylopectin. Amylose is a straight chain α-1,4-glycosidic bonds, while amylopectin is a branched polymer also made of α-1,4-glycosodic with branched chain linked by α-1,6-glycosidic bonds. This conformational difference confers different properties on each of these polymers. For example the short branching of amylopectin at the α-1,6-glycosidic bonds is responsible for the crystalline region of the granules [1, 2, 3]. In the natural state, starch is approximately 20–30% amylose and 70–80% amylopectin. Amylose which is rigid due to packing resulting from its straight chain is insoluble in water but soluble in hot water without gel formation. Amylopectin is, however, nonrigid in structure and soluble in water and forms a gel in hot water. Starch which is largely synthesized in the amyloplast of the storage organs of plants and/or the chloroplast of plant leaves also contains traces of lipids and phosphate groups. Advertisement Starch is one of the most widely used pharmaceutical excipients because it is one of the few natural products that, with minimal processing, meet most of the requirements for excipients. It is nontoxic, odorless, inexpensive, widely available, and biocompatible. In its native form, starch is used in the formulation of a number of dosage forms where its particular functions depend on the specific dosage form. This section discusses the most commonly utilized functions of starches as an excipient. Starch is widely used as a binder in the wet granulation process of massing and screening which is an important step in the production of tablets, capsules, and other solid dosage forms. The granulation process is used to improve the flow of APIs which tend to be very cohesive. Flow is critical to the maintenance of dosage form weight consistency in high-speed manufacturing equipment, to avoid the dose variation that can result from irregular flow and powder segregation. In this process, starch is used as a liquid binder to create agglomerates with good flow properties. The paste produced on heating a suspension of starch is used to cause the “sticking together” of the particles in the formulation to create larger sized agglomerates that will reduce cohesiveness and encourage flow. This is achieved by the creation of bonding between particles in the powder bed which become solid bridges on drying. The more viscous the paste, the stronger the bridges formed, and the larger the size of the particles formed up to a limit [4]. It would therefore imply that any factors that affect the viscosity of the starch paste would affect the functionality of the starch as a binder. Studies have shown that the source and by implication the chemical composition and nature of starches influence their viscosity [5]. A disintegrant is an excipient included in a pharmaceutical formulation to achieve the breakup of solid dosage forms such as tablets or granules into smaller discrete particles. Disintegration is a critical step in the process of drug release and absorption as it exposes a larger surface area for the drug to more easily and quickly go into solution. This accelerates the dissolution process, drug release, and absorption to achieve the desired therapeutic activity of the drug. Starch is a cheap and convenient disintegrant which is thought to exert this action as a result of the swelling properties of its particles in the presence of water leading to the disruption of the solid bridges and other binding forces in the dosage form. The extent of swelling is a function of the source or type of the starch which is reflective of the relative proportion and conformation of the amylose and amylopectin in the particular starch [6, 7]. Weak associative forces in a starch could be an indication of its potential as a disintegrant [1]. Disintegrant action could also be due to the formation of channels through which fluids are able to penetrate the solid dosage form allowing the dissolution of the drug. Some drugs are used at very low doses thus making it very difficult to process them and eventually compress them into tablets and other required dosage forms. In such cases, inert materials that do not exert the pharmacological effect of the drug can be included in the formulation to bulk it up to allow for the normal formulation processes. Because it is bland, odorless, and digestible, starch is used for this purpose. Starch is hygroscopic and can absorb moisture up to 10–17% when equilibrated at normal atmospheric conditions [8]. It therefore finds use as an absorbent in drug formulations to keep powders dry and ensure the stability of drugs that are liable to deteriorate by hydrolysis and other similar chemical reactions. Starches have been studied for use as lubricants and glidants [9] because of their slippery nature and ability to adhere to surfaces. In its native form, the uses of starch are limited by its inability to withstand some processing conditions such as high temperatures, varying pH, freeze-thaw cycles, its tendency for retrogradation and decomposition, and brittleness. When modified, starch becomes even more versatile in its pharmaceutical applications. For example, acetylation results in improved paste clarity and flow, as well as increased swelling capacity [10, 11], while with carboxylmethylation there is increased water solubility, lowered gelatinization temperature, and paste stability [12, 13]. An important factor in the modification processes and the specific properties of the modified products is the physicochemical characteristics of the particular starch used. Modifications could be physical using heat and moisture, gelatinization, extrusion, spray drying, granulation, or agglomeration. Starch can also be modified chemically by the introduction of functional groups using derivatization techniques such as esterification, cationization, cross-linking, or hydrolysis and oxidation which are usually achieved by the replacement of all or some of the hydroxyl groups. Advertisement Starch is one of the most widely distributed substances in nature and can therefore be obtained from several different plant sources. Starch for use as an excipient is one that meets the official compendial standards of quality in the relevant official books (pharmacopeias) and is generally referred to as official starch. Examples of such are potato, corn, rice, and tapioca starches. Pharmaceutical grade starch can be obtained from several plant sources but generally meet the standards shown in Table 1. Description Starch grains, size, shape and distribution, presence/absence of hilum, and striations depend on the plant material from which the starch is obtained Characteristics Fine to very fine powder, white to slightly yellowish, tasteless, insoluble in cold water and alcohol Identification A translucent whitish jelly is produced on cooling 1 g of the starch mixed with 2 ml of cold water, stirred into 15 ml of boiling water, and boiled gently for 2 min. A reddish violet to deep blue color is obtained on adding iodine to water slurry of the starch Foreign matter Not more than traces of cell membranes and protoplasm should be present Acidity Not >2.0 ml of 0.1 M NaOH should be required to change the color of 50 ml of a solution obtained from shaking suspension of 10 g starch in 100 ml ethanol (70% v/v), previously neutralized to 0.5 ml of phenolphthalein solution, for 1 h and filtered Loss on drying ≤15% determined by drying1g in an oven at 100–105°C Sulfated ash ≤0.6% determined on 1 g of starch Microbial limits Total viable aerobic count