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Functional and Structural Characteristics of Rice Starch: A Review

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Abstract

The functional properties of different rice starches depends upon their morphology characteristics together with amylose content, which have been found unique to each individual variety and shows considerable variations from one other. . Rice starch granules are of the same size as homogenized fat globules; therefore they provide a texture perception similar to fat. Rice starch contains tiny granules (<5 lm) with a narrow size distribution, which makes it ideally suited as a cosmetic dusting powder, a textile stiffening agent, and a fat mimetic in foods. Starch is an important source of carbohydrates in the human diet and serves as a major source of energy. Depending on the in vivo digestion of starch, it is classified into rapidly digestible starch, slowly digestible starch and resistant starch as per its rate of glucose release and its absorption in the gastrointestinal tract.

Keywords: Review; Glucose; Starch

Introduction

Starch is the major constituent of milled rice, which mainly determines the physicochemical, textural and cooking characteristic of rice and thus has the main role in measuring the acceptability of rice. The demand of starch from rice in India has been increased due to its excess production and availability of broken rice at low cost, Rice starch in its gelatinized form possesses excellent property of having bland taste, creamy appearance and easy spreadability. The starch granules of rice are smallest (3–10 lm) than other cereal starches that imparts it texture perception similar to that of fat, retention of excess amount of water, lower syneresis and a substitute for fats in various food formulations Labell, et al. [1]. Also the texture perceptions of starch granules are similar to that of homogenized fat globules. These unique properties of rice starch together with their large diversity makes rice as one of the best source of producing starch for different food and non-food industrial applications [2].

The basic attributes associated with rice starch that have given it merit over other cereal and non-cereal starches include hypo-allergenicity, digestibility, bland flavour, small granule (3-10 μm), white colour, greater acid resistance, greater freeze –thaw stability of pastes and a wide range of amylose/amylopectin ratios. Rice starch in its gelatinized form has bland taste and is creamy, smooth and easily spreadable that makes it ideal for custard. Rice starch granules are of the same size as homogenized fat globules; therefore they provide a texture perception similar to fat. Rice starch contains tiny granules (<5 lm) with a narrow size distribution, which makes it ideally suited as a cosmetic dusting powder, a textile stiffening agent, and a fat mimetic in foods. High purity rice starch with low surface protein-lipid contamination is desired to minimise rancidity during storage and for use as a starting material for chemical modification, fermentation, and industrial applications. Rice starch with high amylase content has a low glycemic index These novel and unique characteristics manifest itself in the different applications of rice starches Sodhi, et al. [3].

There are two main polymers in rice starch granules, i.e. amylose and amylopectin along with some minor constituents like the proteins (0.25%), the lipids (0.1-0.3%) and the compounds of phosphorus. The glutelin, prolamin, globulin and albumin are the four types of proteins present in the endosperm of rice. These proteins adhere to the surface of the starch and are relatively difficulty to remove, so the residual protein of rice starch depends mainly on the method of isolation. Swelling of starch is a property of amylopectin and amylose has been known to restrict it. It is due to this reason, that the difference in swelling and pasting properties of different starches is attributed to variation in amylopectin unit-chain length distribution. In addition to amylopectin, other factors that affect the swelling power and solubility of starch granules include the presence of lipids and differences in morphological characteristics [3].

Starch Morphology

The morphology of starch granules has been found to depend on the biochemistry of the chloroplast or amyloplast, as well as the physiology of the plant. The discrepancy in the size and shape of starch granules is attributed to biological origin. Rice starch granules are very small, ranging from 3 to 10 μm with a unimodal distribution. They are polygonal and angular-shaped with rough or smooth surface. Rice starch has been purified from endosperm by way of alkali, detergent, and protease digestion. Alkali gave high purity starch, but its use commercially would generate an alkaline or salty effluent. Anionic detergent was satisfactory in removing protein and fibre from rice endosperm but detergent also would cause an effluent problem and probably would reduce starch paste consistency. The isolation of starch by protease digestion method has been recommended as an alternate to the alkaline steeping method due to higher yield of starch with properties comparable to that produced by alkaline method and lesser damage to starch granules [3,4] .

The relationship between structural and functional properties of rice starches is very important for consumers to choose a suitable rice variety for health benefits and for optimization in industrial applications. The relation of amylose and amylopectin with functional properties of rice starch has been widely studied. Amylose content has been found to be associated with increasing gelatinization temperature and amylopectin short chains results in decreasing gelatinisation temperature but amylopectin Long Branch chains has been reported to be positively correlated with gelatinisation temperature. Short branch chains of amylopectin could destabilize the crystalline lamellar structure, while the Long Branch chains of amylopectin forms longer double helices that required higher temperatures for complete dissociation. The starch with Long Branch chains in amylopectin along with higher amylose content increased pasting temperature and setback viscosity and decreased peak viscosity and shear thinning [5,6].

The gelatinization behaviour of starches can be determined by a number of techniques including differential scanning colorimetry (DSC), X-ray diffraction, small angle neutron scattering and Kofler hot stage. The transition temperatures and gelatinization enthalpy of starch that are related to crystallinity can be measured by DSC. However, it has been shown by NMR and X-ray diffraction that enthalpic transition in starch is primarily due to the loss of double helical order rather than crystallinity. Rheological and thermal techniques also find application in measuring the aging of starch gels. Starch has been shown to exhibit unique viscosity behaviour with changes in temperature, concentration and shear rate. The starch paste viscosity can be extensively measured by means of Brabender visco-amylograph and rapid visco-analyzers (RVA). Laser light scattering has been used to characterize granule diameter based on the assumption that granules are spherical but this technique may not be accurate for rice starch granules, which are mainly polyhedral [7].

Starch is an important source of carbohydrates in the human diet and serves as a major source of energy. Depending on the in vivo digestion of starch, it is classified into rapidly digestible starch, slowly digestible starch and resistant starch as per its rate of glucose release and its absorption in the gastrointestinal tract. The completely digested starch fractions included rapidly digestible starch and slowly digestible starch while resistant starch is the portion that resists digestion and absorption in the small intestines of healthy individuals and undergo fermentation in the large bowel by human colonic microflora into short-chain fatty acids, mainly propionate, acetate and butyrate. The fermented products of resistant starch help to prevent colorectal cancer, to reduce the risk of cardiac diseases, and to influence metabolic and inflammatory bowel diseases such as diverticulitis and diabetes. The slowly digestible starch fraction has been reported to possess potential health benefits such as diabetes management, glucose metabolism, mental performance and satiety.

The functional properties of different rice starches depends upon their morphology characteristics together with amylose content, which have been found unique to each individual variety and shows considerable variations from one other. Amylose content and granular structure affect the pasting properties that include the changes that occur in rice starch after gelatinization temperature upon further heating. Similarly, amylose content and structural pattern (crystallinity) have a significant affect in determining the thermal properties of rice starch isolated from different cultivars. The differences in the morphology and other physical characteristics of starch are attributed to the biochemistry of chloroplast and different biological and botanical origin of the rice cultivars. The smallest granule size of rice starch along with their different morphology have a significant effect in determining the texture, consistency and other quality attributes of both food and non-food items. Also, the particle size of starch powder has significance in handling, packing, and product formulation and in various foods or other miscellaneous applications [8].

Pasting of starch involves heating of starch granules beyond gelatinization temperature, which include swelling of starch granules, leaching of molecular components and finally disruption of the starch granules. The viscosity parameters during heating cycle of starch are largely influenced by the swelling power and solubility of starch granules. The effect of time and temperature on the starch physicochemical properties such as turbidity, syneresis, gel texture have been explored by researchers to select the desired starches for specific product end use and to avoid different modification techniques. Rice starch with desirable rheological properties is used in number of food products possessing specific characteristics. Rheological properties of starch are affected by its amylose content, lipid contents and branch chain length distribution of amylopectin [9].

Granule size and shape of starch isolated from a germplasm are shown to be primarily affected by the sources of raw material. The other factors having an effect on the starch granule morphology are climatic conditions and agronomic practices. Granule size which is the average diameter of the starch granule can be determined by various techniques like light microscopy, scanning electron microscopy (SEM), electrical resistance, sieving, laser light scattering, and field flow fractionation. However, SEM is mainly used to determine granule size and also provides a more detailed perspective on granule surface characteristics and granule morphology [10]. X-ray photoelectron spectroscopy and SEM have revealed that the granule surface of starch is predominantly (90% to 95%) carbohydrate in nature [11].

Starch granules of all rice types has been shown by scanning electron micrographs to be mainly polyhedral in shape that may be oval, angular, irregular, or smooth in shape. The size of starch granules varies from cultivar to cultivar and between waxy, nonwaxy, and long-grain rice starches. Starch of nonwaxy cultivars has been reported to exhibit greater variation than the waxy cultivars. The size and density of an average rice starch granule has been determined by light scattering techniques to be 14 μm and 1.530 g/cm3, respectively [12]. The granule size of starch has been found to affect the composition, crystallinity, gelatinization temperature, pasting properties, enzyme susceptibility, swelling power, and solubility. However, several other factors including amylose to amylopectin ratio, molecular weight and granule structure have been found to affect the functional characteristics of starch [13].

Retrogradation plays an important role in forming consumer's utility of food products. It is usually described as recrystallization during storage after starch pasting. The change in crystalline structure after pasting involves the formation of double ordered helical structure from amorphous glucans and is induced mainly by low temperature, high amylose content and the presence of polar substances [14]. During storage of starch gel, insoluble fraction of starch especially amylose precipitates at low temperature [15]. Retrogradation is attributed by both amylose and amylopectin fraction in gelatinized granules. Association of linear amylose molecules takes place quickly in the first stage of retrogradation but amylopectin causes slower increase in starch gel rigidity upon crystallization [16]. This process takes place at a faster rate at low temperature. Significant acceleration may be obtained by repeated cycles of freezing and thawing of starch gel. It was found that cereal starches are more prone to retrogradation than potato, and in the cases of bimodal distribution small granules are less susceptible to this process than large granules and non-fractionated starch [17,18].

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