Article ID 4240223

Resistant Starch: A Comprehensive Overview of Modification Methods, Health Benefits and Food Applications

Nongmaithem Seema Chanu[1], Sajesh Chettri[1]*, Hijam Merina Devi[1], Rakesh Kumar Raigar[1] and Said Prashant Pandharinath[2]

[1]Department of Processing and Food Engineering, College of Agricultural Engineering and Post Harvest Technology, Sikkim, Central Agricultural University, Imphal, Manipur, India

[2]College of Food Technology, Central Agricultural University, Imphal, Manipur, India

*Corresponding Author: sajeshchettri20@gmail.com

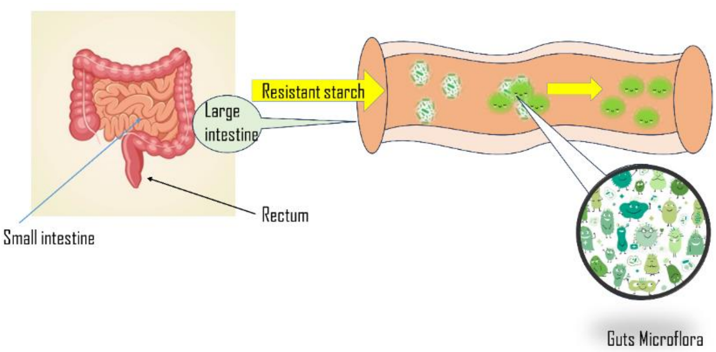
Abstract

A subgroup of starches known as resistant starch (RS) has drawn interest recently due to its potential use and potential health effects. This article explores the categorization of starches, highlighting the function of RS in enhancing digestive health, improving metabolic health, and assisting with weight control. Physical, chemical, and enzymatic starch modification techniques are discussed along with how they affect digestibility and RS content. Moreover, the health advantages of RS are clarified, including its impacts on metabolic systems and gut microbiota. Outlining possible uses for RS in the food industry and emphasizing how adaptable it is as a functional component.

Introduction

In the world of modern nutrition and food consumption, starch plays an integral role that often goes overlooked by the average consumer. As one of the most abundant carbohydrates found in various plant-based foods, starch serves as a fundamental source of energy for both humans and animals. Dietary starches play a crucial role in our nutrition, serving as a primary source of energy and offering significant health benefits. They have garnered considerable attention due to their functional properties and positive effects on human well-being. Nowadays study focuses on the concept of resistant starch as a functional food and its recently discovered health implications. Starch is divided into rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS). Resistant starch can play a crucial role in the global diet by promoting digestive health, aiding in weight management, and supporting metabolic well-being. It can enhance satiety, meaning it can help people feel full and satisfied with their meals, potentially reducing overall calorie intake. Additionally, it has a positive impact on blood sugar control, making it an essential component for individuals seeking to manage or prevent conditions like diabetes and obesity. Resistant starch is known as that fraction of starch that does not break down into small intestine and passes through till large intestine, where the gut mostly ferments its microflora (**Fig. 1**). RS products that are resistant to digestion as they go through the gastrointestinal tract. Resistant starch may not be digested due to its compact molecular structure. The nature of the starch granules themselves prevents the digestive enzymes from breaking them down. It led to four categories of resistant Starch (**Fig. 2**).

Fig. 1 Breakdown of Resistant Starch in intestine



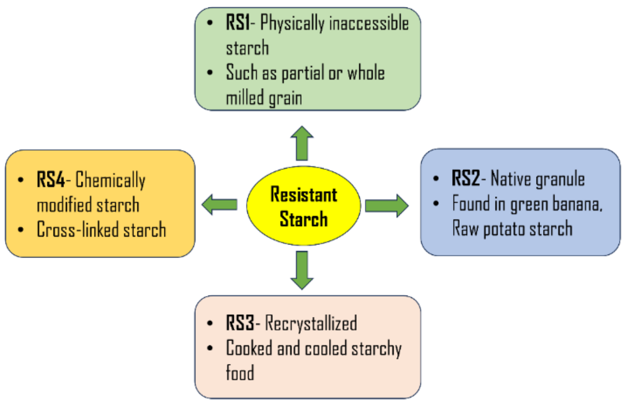


Fig. 2 Types of Resistant Starch

Starch Modification Technique

A variety of techniques are utilized to alter resistant starch, thereby changing its characteristics and functions. These methods encompass physical approaches such as milling and heat treatment, chemical methods like cross-linking and esterification, and enzymatic processes that utilize specific enzymes to modify the structure of starch. Each technique results in unique modifications to the properties of resistant starch, impacting its digestibility and health-promoting properties. Three methods for the modification of Resistant Starch: Physical, Chemical, and Enzyme modification are discussed below in details.

Physical Method

Physical modification is an effective method for increasing the content of resistant starch (RS) in the food industry. It is cost-efficient and does not introduce any harmful components. Physical modification techniques can be categorized into thermal and non-thermal methods. One commonly used thermal method is heat moisture treatment (HMT), which involves treating starch granules at a specific temperature range, typically between the glass transition and gelatinization temperatures, in a solution with limited moisture content. This process alters the digestibility and multi-level structures of starch. Another thermal treatment is annealing (ANN), which promotes interactions and re-associations between amylose and amylopectin chains, leading to the formation of a more organized crystal structure and improved digestibility. Autoclaving treatment (AT), followed by cooling, increases the hydration of the amorphous regions within starch granules under pressure, thereby enhancing the content of RS. Starch dispersion undergoes gelatinization when heated to a specific temperature, causing the swelling of starch granules and the release of amylose and amylopectin molecules. Starch retrogradation is a well-known process where a starch-based gel transforms into a partially crystalline structure upon cooling (Zang and Bao, 2023). Extrusion is an economical modification technique capable of producing large quantities of RS. This versatile method can be adjusted using various parameters to achieve the desired level of RS. The resulting products typically have a high expansion ratio and low density (He et al., 2023). Ultrasonic is a non-thermal processing method that causes starch to physically depolymerize. Improved physicochemical qualities of starch are facilitated by ultrasound. The explanation is that while high ultrasonic power induces retrogradation of RS3 and promotes the rearrangement of double helical structures that are resistant to enzyme digestion, low ultrasonic power disrupts the crystalline structures of starch, making starch granules more susceptible to digestive enzymes.

Chemical Method

Chemical modification can be applied to starch using techniques such as acetylation, oxidation, cross-linking, esterification, and hydroxypropylation. Organic carboxylic acids like malic, tartaric, citric, and glutaric acids are commonly used in esterification reactions with starch to increase resistant starch (RS) content. This reaction forms substituent groups along the α-1,4 glycosidic chains, inhibiting enzymatic digestion (He et al., 2023). For instance, the RS content of high-amylose maize starch can be increased from 66.5% to 84.7% through cross-linking modification using chemicals like sodium trimetaphosphate and sodium tripolyphosphate. This addition of chemical structure can hinder amylase access, resulting in higher RS levels. Similar outcomes are observed with epichlorohydrin cross-linked modified pearl millet starches. Oxidation and acetylation introduce acetyl, carbonyl, and carboxyl groups to starch molecules, leading to higher RS levels and potentially impeding enzyme hydrolysis (Zang and Bao, 2023). These modifications have shown promising results in enhancing the RS content of starches.

Enzyme modification

Enzyme modification, which involves α-amylase, pullulanase, and branching enzymes, offers a systematic and environmentally friendly approach to adjusting starch digestibility. This method alters the composition of starch, increasing the proportion of linear short chains and enhancing the organized semi-crystalline structure. As a result, enzyme-modified starch becomes more resistant to enzymatic hydrolysis during digestion, leading to higher concentrations of resistant starch (RS). Pullulanase (PUL) is commonly used in enzyme modification to break α-1,6 glycosidic bonds in starch, thereby debranching the polymer and generating additional short chains. Additionally, the glucosyltransferase amylosucrase (AS) plays a role in elongating branch chains at the non-reducing ends of amylopectin, contributing to the production of α-1,4-glucans. These enzymatic modifications contribute to the enhancement of RS content in starch. (Zang and Bao, 2023).

Health Benefit

Resistant starch (RS) functions similarly to dietary fiber and offers targeted advantages in reducing the risk of obesity, diabetes, inflammation, and gastrointestinal disorders. When RS levels increase, it can alter the composition of beneficial bacteria in the gut, leading to enhanced synthesis of short-chain fatty acids by the body. These alterations in gut microbiota may influence the activation of genes associated with fat and glucose metabolism. Consequently, this could lead to reduced insulin and glucose responses, as well as a decrease in fat synthesis (Bojarczuk et al., 2022).

Application of RS

RS is considered to have potential use as a functional component in foods high in fibre. When it comes to the final goods' look, texture, and sensory qualities, RS is less influential than other dietary fibers. Applications of RS in food includes, integration of RS in bread, noodles, biscuits, and pasta (Ozturk and Mutlu, 2019). Moreover, resistant starch acts as a thickening agent, and prebiotic, and can be replaced for cassava or potato starch adding health benefit to end product. It can produce gluten-free food products. RS improves coating crispiness and fiber content, enhances texture, appearance, and organoleptic properties, and decreases product calorific value (Sajilata et al., 2006).

Conclusion

Research on resistant starch (RS) and its modification techniques highlights its potential as a functional food with important health benefits. RS provide a range of advantages, including better metabolic health, weight control, and gastrointestinal health. It is possible to modify the qualities and composition of RS physically, chemically, and via enzymes to better suit different dietary uses. Because of its function as a prebiotic fiber, changes in the gut flora may lower the risk of diabetes, obesity, and inflammation. RS is a flexible ingredient that may be used to enhance the texture, appearance, and nutritional value of a variety of food items. Using RS to its full potential in the food sector can result in the creation of more functional and healthful food alternatives for customers.

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