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ORIGINAL PAPER

# Physicochemical properties of cross-linked-annealed wheat starch

**Mahsa Majzoobi · Bahareh Sabery · Asgar Farahnaky · Taewee Tongdang Karrila**

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**Abstract** Starch in its native form, may not be able to provide functional properties such as high or low temperatures and shear forces bearings expected in modern industries. Therefore, it is usually modified to make it compatible for different applications. The main aim of this research was to study the effects of dual modification using cross-linking and annealing on physicochemical properties of wheat starch. Therefore, starch was first cross-linked using different levels of $POCl_3$ (0, 0.1, 0.2, 0.4 %, w/w, starch basis) and then annealed at 40 °C for 72 h. Scanning electron micrographs showed the presence of some spots on the granules of the dual-modified samples. The results of differential scanning calorimetry showed that the onset, peak and conclusion temperatures and enthalpy increased upon dual modification. The X-ray diffraction pattern of the modified samples remained unchanged while water solubility and swelling decreased. The results of rapid visco analyzing showed lower peak, setback, breakdown and final viscosities for the dual-modified samples. These samples produced stronger gels as determined using a texture analyzer. In total, annealing of the cross-linked starch could enhance some of its functional properties for further applications.

**Keywords** Annealing · Cross-linking · Dual modification · Functional properties · Wheat starch

M. Majzoobi (✉) · B. Sabery · A. Farahnaky
Department of Food Science and Technology, School of Agriculture, Shiraz University, Shiraz, Iran
e-mail: majzoobi@shirazu.ac.ir

T. T. Karrila
Department of Food Science and Nutrition, Faculty of Science and Technology, Prince of Songkhla University, Pattani Campus, Pattani, Thailand

## Introduction

Starch is one of the most valuable polymeric carbohydrates due to its functionality that imparts to products in various industries. It is commonly used as a thickener, colloidal stabilizer, gelling, bulking and water preserving agent. The physicochemical and functional properties of starch systems and their exclusivity in a variety of food products differ with starch biological origin. Even though, restrictions such as low shear resistance, thermal resistance and disintegration and high affinity toward retrogradation have limited its utilization in some industrial food applications. These shortcomings can be overcome by starch modification using chemical, physical and enzymatic methods or a combination of them. The latter is called dual modification which has been used when single methods do not provide satisfactory results. Limited work has been published on the effects of dual modification as a combination of chemical and physical methods (i.e., cross-linking and annealing) on the functional properties of starch.

Among different chemically modified starches, cross-linked starch plays an imperative function in food products to thicken, stabilize and give texture [1]. Cross-linking of starch strengthens the hydrogen bonds in the granule with chemical bonds that execute as a bridge between the starch molecules [2]. Chemical composition of the cross-linking agent, reagent concentration, pH, reaction time and temperature are momentous factors in the cross-linking reaction. $POCl_3$ is an efficient cross-linking agent in aqueous slurry at pH 4–11 in the presence of a neutral salt. Thus, hydrophilic phosphorus groups straight away react with the starch hydroxyl groups, forming distarch phosphate [3]. The covalently linked network makes cross-linked starch swells less and shows more stability under shear, high temperature and low pH compared to native starch [4].