



Effects of temperature, starch concentration, and plasticizer concentration on the physical properties of ulluco (*Ullucus tuberosus* Caldas)-based edible films

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ABSTRACT

Ulluco starch could be a promising renewable source for the production of biodegradable or edible films, as an alternative to plastic. This would mitigate the negative impact of plastics on the environment. The aim of this work was to study the effect of the starch concentration (SC), glycerol concentration (GC), and drying temperature (T) of ulluco starch-based films on their physical properties using stepwise regression (SR) and artificial neural network (ANN) approaches. The physical properties, such as the solubility (S), water vapour permeability (WVP), tensile strength (TS), elongation at break (EB), and transparency, of the edible films were satisfactory. The feed-forward and cascade-forward neural networks satisfactorily modelled the effect of the SC, GC, and T on the mechanical, optical, and water-affinity properties (WAP) of the edible films. ANN approach showed better results than SR in all the properties and ANN models were used in the sensitivity analysis and optimization. The global sensitivity analysis showed that the GC had the greatest influence on the physical properties. A desirability function-based optimization including WVP, EB and OP showed comparable values between experimental and estimated data. Based on the results of this study, the use of ulluco starch for the preparation of edible films has enormous potential for the replacement of non-biodegradable plastic packaging.

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1. Introduction

Over the last 50 years, the global production of plastics has increased; therefore, the plastic industry is one of the most successful global industries. Plastic is used in numerous industries, such as the automotive, agricultural, packaging, building, and construction industries. Packaging applications are the largest application sector with regard to the plastics industry, and represent around 39.9% of the total plastic demand [1]. Plastic packaging is in high demand; however, it is a non-biodegradable material, which is synthesized from non-renewable resources. Currently, between 22% and 43% of the global plastic waste is disposed of in landfills, which causes a negative impact on the environment [2,3]. Consequently, there is increased interest in the development of eco-friendly materials based on biopolymers, co-products, and agricultural residues, which can be used to replace plastic packaging.

In the food industry, edible films are potential alternatives to plastics, and could be used to mitigate the negative impact caused by plastics in the environment. A large number of investigations have been conducted regarding this [4,5]. Various film-forming materials have been used for the preparation of edible films, including pectin [6],

gelatin [5], chitosan [7], gums [8], and starch [4]. Among these materials, starch is considered the most suitable candidate for this purpose. This is owing to its specific characteristics, such as biodegradability, low cost, and abundant renewable sources [9]. In addition, starch-based films are transparent, odorless, and tasteless, displaying similar characteristics to those of synthetic polymers [8].

Currently, starch for industrial use is primarily obtained from potatoes and cereal grains. However, other tubers and rhizomes are often used for starch extraction because they contain high contents of this macromolecule. Despite their importance for the food and non-food industries (bio-degradable polymers, adhesives, pharmaceuticals, textiles and others), the industrial demand for starch cannot be met without compromising food security. Therefore, researchers are constantly searching for new starch sources that can be used on an industrial scale [10,11].

Ulluco or chugua (*Ullucus tuberosus* Caldas) is an Andean tuber belonging to the Basellaceae family, cultivated in Colombia, Venezuela, and northern Argentina at 2400–4250 m above sea level [12]. Ulluco is primarily used by the local population for traditional food preparation. Owing to their high starch content (~65%, dry basis), ulluco tubers are considered a potential raw material for industrial use. Previous studies have demonstrated that the starch obtained from ulluco presents appropriate physical, chemical, and functional properties for the food

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