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Impact of ultrasound-assisted osmotic dehydration as a pre-treatment on the quality of heat pump dried tilapia fillets

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Abstract

The dehydration of a tilapia fillet is conducive to its preservation. However, dehydration results in high energy consumption and quality variation. Ultrasound-assisted osmotic dehydration as a pre-treatment combines the advantages of strong permeability by preservatives and the cavitation effect and can improve the quality of tilapia fillets dried by heat-pump drying while decreasing the drying time and maintaining the quality of the dried products. The whiteness, texture, rehydration rate, Ca^{2+} adenosine triphosphate synthase (Ca^{2+}-ATPase) activity and the comprehensive score were used as criteria in single-factor experiment son ultrasound power, ultrasonication and permeate concentration. Based on the results of the single-factor experiment, the Box-Behnken central composite design was adopted to achieve response-surface optimisation. The results indicated Ultrasound-assisted osmotic dehydration as a pre-treatment with suitable ultrasound parameters can significantly improve the quality of heat-pump dried tilapia fillets and provides references for optimising the drying process.

Keywords: tilapia fillet; ultrasound; trehalose osmotic solution; heat pump drying

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1. Introduction

Ultrasound refers to sound waves with a frequency greater than 20 kHz. Under ultrasonication treatment, the treated material continues to contract and expand with repeated tension and compression. This behaviour results in the breaking of the bonds that link the water molecules and surface molecules of a solid, which activates the solid surface and facilitates the removal of moisture tightly bound to the material [1]. The application of ultrasound in food drying pre-treatment can not only change the tissue structure of material but also decrease the material's moisture content. In addition, it decreases energy consumption and variation in the quality of the dried products. Fernandes et al. [2, 3] used ultrasound pre-treatment on bananas and pineapples to increase the moisture migration rate and to decrease the drying times by 11% and 8%, respectively. Ultrasound pre-treatment significantly shortened the drying time of the brown seaweed *Ascophyllum nodosum* under hot-air convective drying [4]. Deng et al. [5] pre-treated apple pieces using a pulsed vacuum chamber or an ultrasound bath and found that the dried products subjected to the ultrasound pre-treatment had a higher glass-transition temperature, lower water activity (aw) and a reduced rehydration ratio compared with products pre-treated using a pulsed vacuum chamber. Thus, ultrasound for food processing offers a substantial number of advantages [6]. Ultrasound was also found to accelerate processes without damaging the quality of foodstuffs in meat processing [7]. As an emerging technology, ultrasound pre-treatment playsan important role in food drying [8], whereby the power, frequency and duration of ultrasound influence the dehydration rate of food materials, different factors have different effects on the drying and the same factor could have different effect on different materials. Ultrasound food drying induces mechanical, physical, chemical and biochemical changes in foods through the cavitation mechanism, thus decreasing the reaction time [9]. However, even at room temperature, the cavitation mechanism may result in local heating, which is associated with whether ultrasound is applied continuously and the power, frequency and time of the ultrasonication treatment. Additionally, these parameters have an uncertain linear relationship with the cavitation mechanism. Therefore, the ultrasound pre-treatment method requires additional investigation.

Osmosis refers to a pre-treatment method in which under specific temperature conditions biological tissues are immersed in concentrated solutions and dehydrated through the semipermeable cell membranes [10]. Commonly used osmotic pre-treatment solutions include sodium chloride, dehydration protectants and solutes used to reduce aw [11]. Sodium chloride can be used together with other macromolecular materials as an osmotic solution, and when complemented with macromolecule materials, the sodium chloride osmotic solution increased the dehydration rate of raw material while controlling the penetration of small molecules [12, 13]. In addition, the effective water diffusivity of an osmotic solution based on a ternary system was higher than that of an osmotic solution based on a binary system [14].Several investigators have studied the mass-transfer process during osmotic dehydration and constructed a number of dynamic models [15,16,17]. Through the investigation of the quality of materials after the pre-treatment, it was found that osmotic dehydration as a pre-treatment could better protect the quality of the materials during the drying process and thus play an important role in the food-drying process [18, 19, 20].

In the drying process, many pre-treatment methods with various mechanisms are used. These methods can be combined to complement one another to increase the dehydration rate while improving the quality of the dried products [21]. The application of ultrasound to the osmotic dehydration of guava slices exhibited improved results [22]. This study investigates the use of ultrasound to assist osmotic penetration as a pre-treatment prior to the heat-pump drying of tilapia fillets. This study's aim is to use ultrasound combined with the penetrating fluid as a pre-treatment method prior to the drying of tilapia fillets to improve quality.

2. Materials and methods

2.1 Materials

Approximately 750g of fresh tilapia was purchased from a local market. Trehalose (food grade) was purchased from Jianuo Food Additive Co., Ltd. The adenosine triphosphate (ATP)activity assay kit and the Coomassie brilliant blue protein assay kit were provided by Nanjing Jiancheng Institute of Biological Engineering.

Bigeye tuna (*Thunnus obeus*) head， was donated by GuangDong GuangYuan Fishery Group CO., LTD., (Guangdong, China). Alcalase 2.4L was purchased from Novo Co. (Novo Nordisk, Bagsvaerd, Denmark). 1,1-diphenyl-2-pycrylhydrazyl (DPPH), reduced glutathione(GSH) and deoxyribose were products of Sigma Chemical