Effect of Atmospheric Plasma on the Surface Area of Powdered Whey Protein Isolate

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Abstract

Plasma-surface modification (PSM) remains an effective technique to alter the surface of inorganic materials, and there is a growing interest in its application on organic materials. To date, research on the use of PSM to promote surface changes of organic materials has focused largely on experiments using aqueous solutions, particularly as they relate to end-use applications in pharmacological development. The purpose of this study is to explore the impact of PSM on dry protein powder, as it relates to surface area. Brunauer-Emmett-Teller (BET) theory analysis was performed to measure the surface area of both a pristine sample of whey protein isolate and a sample of whey protein isolate exposed to atmospheric plasma. In this study, we demonstrate that PSM can successfully increase the surface area of protein powder. Such changes in protein surface area, when delivered at an economical and commercial scale, may prove beneficial to food and nutrition applications.

Introduction

Plasma is an electrically neutral ionized gas composed of highly excited atoms, molecules, ions, electrons, free radicals, and neutral particles. This state of matter can be obtained through excitation and subsequent ionization of different material sources such as gases, metals, and lasers, which can be achieved via radio frequency, microwave, or electrons from a hot filament discharge. Plasma can be applied to the surface of a material to alter physical and chemical properties such as surface area and hydrophilicity, in a process called plasma-surface modification (PSM) [1]. PSM is often used to enhance materials such as titanium, silicon, and ceramics; this is an economical, reliable, and non-toxic method to achieve a range of physical modifications to meet a variety of engineering specifications.

The use of this technology has also become increasingly popular in the development of biomaterials; PSM has been applied to vascular grafts, catheters, heart valves, contact lenses, and surgical tools in order to enhance biocompatibility [1]. Several studies have described improved biomaterial-tissue adhesion after treatment with PSM [2] [3] [4], as well as deactivation of bacterial biofilms on device surfaces [5].

Despite extensive research on PSM inorganic materials, exploration into its use on organic compounds has been limited. In spite of this lack of research, gas based plasma is promising for application on powdered organic material. Specifically, low pressure atmospheric plasma consists of a large uniform area of a well controlled electron density, which is well suited to encompass dry protein powder [1]. This process may be used to enhance the surface area of protein powders to facilitate improved absorption [6]. To date, the ability of atmospheric plasma to directly increase the surface area of an organic powder has not been studied.

Objective

The goal of this study is to investigate whether the surface area of dry powdered whey protein isolate can be modified by atmospheric plasma.

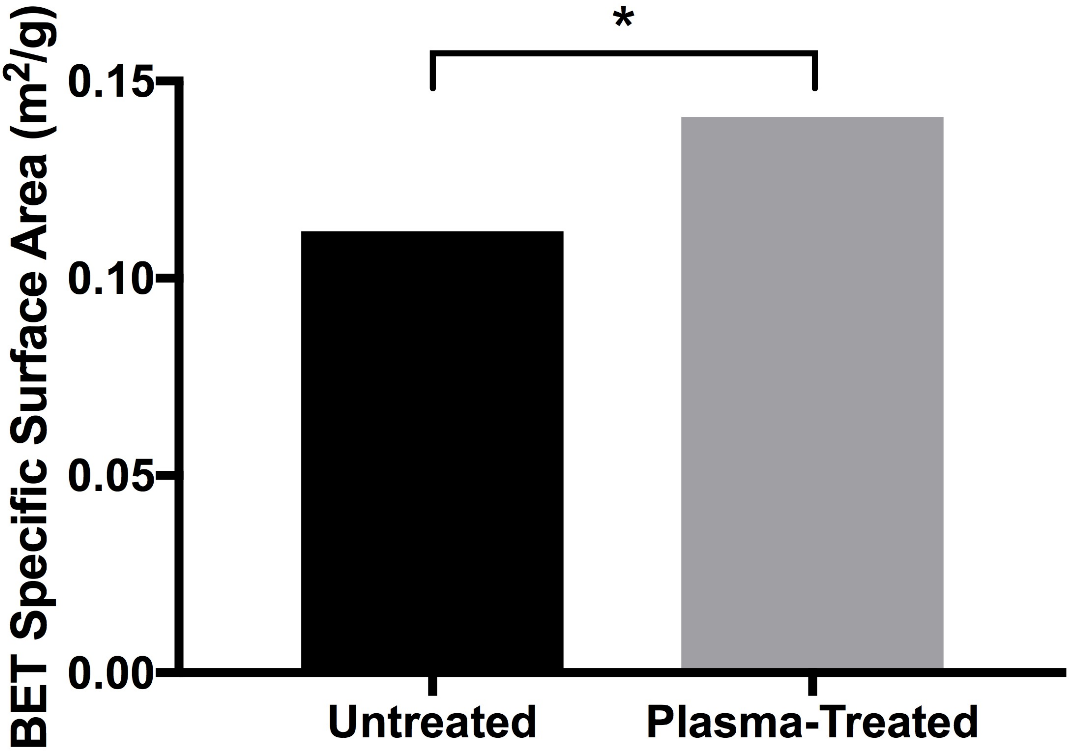

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Figure Legend

Figure 1. Comparison of BET specific surface area measurements of untreated and plasma-treated whey protein powders.

Asterisk (*) indicates 25.89% increase in BET surface area with PSM treatment as compared to untreated control.

A commercially available dry powder whey protein isolate was obtained as the source material for the study. This base source material served as the control for the experiment. A portion of the whey protein isolate from this batch was separated and gravity fed through the reaction chamber at a rate of 0.45 kg/s. The powder was aerated with compressed air before and during exposure to 800 W of atmospheric plasma to allow for maximum area of the protein powder to be exposed during the plasma treatment.

The specific surface areas of both the untreated control and plasma-treated whey protein powders were determined using a BET surface area analyzer (Autosorb iQ, Quantachrome, USA). Approximately 2.2 g of dry powders were degassed at 25℃ for 24 h to remove gases and other contaminants. The samples were analyzed at -195.8℃ using krypton gas as the adsorbate. The adsorption–desorption isotherm data were obtained using eight measurements and fit to the BET equation to calculate the specific surface area of each sample including the pore size distribution.

Results & Discussion

This investigation focused on assessing the impact of PSM on dry powdered whey protein isolate. Proprietary PSM technology (Ingredient Optimized, Plasma Nutrition, USA) was used to effectively mediate the exposure of organic dry powder materials to plasma to enact multiple changes, including surface level alterations.

Multi-point Brunauer-Emmett-Teller (BET) theory analysis was conducted on both a pristine sample of whey protein isolate (control) and a sample of whey protein isolate exposed to atmospheric plasma (experimental) from the same batch. The surface area of the control powder was measured at 0.1120 m^2/g. The surface area of the experimental powder was measured at 0.1410 m^2/g. The exposure of the dry powder whey protein isolate to atmospheric plasma yielded an increase in the powder surface area by 25.89% (Fig. 1).

The surface area of powder-based materials plays a potentially important role in their functional characteristics, including wettability, sinkability, solubility, and dispersibility [7]. In the case of food powders such as whey protein isolate, these characteristics can have a major impact on the use of a specific source material in a given product or application. As such, multiple techniques have been developed to modify the surface area of powder-based materials, generally focusing on two primary targets: particle size and surface morphology [8]. The desire to impact powder surface area is not restricted to food powders. In the area of pharmaceutical development, it is well established that a larger surface area of a drug, that is, surface area to volume ratio, results in its greater availability for solvation, which is a key parameter in the absorption of a compound. Conventional techniques have relied primarily on the reduction of particle size to improve the surface area to volume ratio, [6] but it may be possible that the application of novel PSM techniques can achieve similar improvements to this ratio without altering the particle size.

Conclusions

In this study, we observed an increase in the surface area of a dry powdered whey protein isolate having undergone PSM treatment. This result is consistent with the observations of PSM on other substrates such as metals, glass, ceramics, and biomaterials. We can conclude that organic materials such as whey protein isolate are candidates for surface engineering using atmospheric plasma. This validates the use of PSM to improve solubility and possibly absorption of substances like dry protein powder used in food production.

Limitations

This study investigated the application of PSM on only one source of dry powdered whey protein isolate. While the whey protein isolate source material used in this investigation is commonly found in commercial use, there may be variations between the material used and other market available whey protein isolate powders depending on their processing. Further studies are needed to examine the effect of PSM on a range of dry powder whey protein isolate sources.

Additional Information

Methods

A commercially available dry powder whey protein isolate was obtained as the source material for the study. This base source material served as the control for the experiment. A portion of the whey protein isolate from this batch was separated and gravity fed through the reaction chamber at a rate of 0.45 kg/s. The powder was aerated with compressed air before and during exposure to 800 W of atmospheric plasma to allow for maximum area of the protein powder to be exposed during the plasma treatment.

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Supplementary Material

Please see https://sciencematters.io/articles/201707000006.

Funding Statement

Data collection was financially supported by Plasma Nutrition.

Ethics Statement

All experiments were performed in vitro and did not involve the use of any living subject.

Citations

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