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ScienceDirect
Chemical Engineering and Processing 46 (2007) 420–428
Chemical Engineering and Processing
www.elsevier.com/locate/cep

Development of stickiness of whey protein isolate and lactose droplets during convective drying

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Received 20 April 2006; received in revised form 30 June 2006; accepted 10 July 2006
Available online 16 September 2006

Abstract

The stickiness development of droplets of whey protein isolate (WPI), lactose and their mixture solutions was determined using an *in situ* stickiness testing device at 24, 65 and 80 °C. Stainless steel, Teflon, glass and polyurethane probes were used. At room temperature, the presence of 0.5–1% (w/w) WPI greatly lowered the observed tensile strength of water and lactose solutions due to surface adsorption and led to a weakening of the cohesive strength. At elevated temperatures, lactose droplets remained sticky showing cohesive failure until the surface was completely covered with a thin crystal layer. WPI droplets formed a thin, smooth skin immediately on coming in contact with drying air. This surface became non-sticky early in the course of drying due to the transformation of the surface to a glassy state. The skin forming and surface active nature of WPI was exploited to minimize the stickiness of honey in a pilot scale spray drying trial. Replacement of 5% (w/w) maltodextrin with WPI raised the powder recovery of honey solids from 28% to 80% in a pilot scale drying test. At elevated temperature the magnitude of stickiness on probe materials was in the order of glass > stainless steel > polyurethane > Teflon. The Teflon surface offered the lowest stickiness both at low and high temperatures making it a suitable material to minimize stickiness through surface coating.

Keywords: Stickiness; Tensile strength; Contact angle; WPI; Lactose; Teflon; Polyurethane

1. Introduction

Stickiness of liquid foods in processing equipment and packages is a ubiquitous issue encountered in industry as well as in every day life. Stickiness leads to scale formation and fouling in thermal processes [1,2]. Stickiness of food powders during production, handling and storage has long been recognised as a major problem in powder making industries [3]. This problem not only leads to processing difficulties such as frequent plant shutdowns and cleaning but also results in to low quality products and fire hazards [4].

There is considerable demand for high value particulate products from natural foods such as powdered fruit juices, honey, whey permeates and vegetable soups, especially in developing countries where refrigerated-storage facilities are lacking [5]. Furthermore, these products are important ingredients for ice-cream, yoghurt and non-alcoholic beverage manufacturing. However, the production of powders from these materials through drying is very difficult due to high concentrations of sugars, organic acids and minerals which have a greater tendency to stick to the equipment surfaces [6,7]. The nature of the contact surface can play an important role in food stickiness.

Michalsky et al. [8,9] have studied the adhesion behavior of edible oil and food emulsions to glass, Teflon (PTFE), low-density polyethylene (LDPE), poly ethylene terephthalate (PET) and stainless steel. They allowed the food samples to flow down an inclined substrate surface and measured the amount of sample remaining on the surface after the flow ceased. It was found that surface roughness, the yield stress of the sample and solid surface tension were the key factors responsible for adhesion. Adhikari et al. [7] studied the surface stickiness of droplets of fructose–maltodextrin and sucrose–maltodextrin mixtures during convective drying. They found that the presence of maltodextrin improves the spray drying yield mainly due to its skin forming property. However typically 40–60% (w/w) maltodextrin solids need to be introduced before it is possible to convert these sugar solutions into powders even under mild spray drying conditions [10].

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doi:10.1016/j.cep.2006.07.014

One can think of two possible ways that might more effectively minimize the wall stickiness problem. Firstly, the dryer wall can be coated with materials that do not favor the sticking of the solutions/particles. Secondly the surface of the droplet/particles could be engineered in such as way that they resist coalescence when they come in contact with each other and also decreases their adherence to the dryer wall. The latter approach can greatly reduce the amount of additives required as a drying aid. Hence, this study aims at making a comparative study of the stickiness on stainless steel, glass, polyurethane and Teflon surfaces. Further, it also explores the possibility of using a protein solution to partially replace high molecular weight carbohydrates as drying aids, in order to manipulate the droplet surface property.

2. Materials and methods

2.1. Materials

Spray dried lactose powder (Murray Goulburn Co-Ltd., Australia), hydrolyzed whey protein isolate (ALATAL 817^{TM}, New Zealand Milk Powder, New Zealand) and maltodextrin of dextrose equivalent 6 (Roquette Freres, France) were used without further purification. They were vacuum dried (70 °C 500 mbar) overnight and stored in desiccators over P_2O_5 prior to solution preparation. Capilano floral honey (Capilano Honey Limited, Australia) was used. Dry solid content of honey was determined using AOAC recommended method [11]. A refractometer (RFM 340, Bellingham + Stanley Ltd., USA) was used in this purpose.

2.2. Methods

2.2.1. Contact angle

Contact angle of the test solutions was measured using optical contact angle device (OCA $_{15}$ plus^{TM}, Dataphysics, Germany). A 15 μl of solution was used in all the tests. Sessile drops were formed on the surface of the test surfaces. The reported contact angle values represent the average of three readings.

2.2.2. Tensile strength

Stickiness was measured using an *in situ* stickiness testing instrument. This instrument works on the principle of tack, that is, it mimics the feel when one touches a droplet surface. The working principle and the test protocols are given elsewhere [12]. The schematic diagram (Fig. 1) and the test procedure are briefly presented as follows. The probes (glass, stainless steel, polyurethane and Teflon) are attached to the shaft of the captive type linear actuator (Motor size 11 28H47, Hydon Switch and Instrument Inc., USA). The contact diameter of probes was 2.5 mm except that of glass which was 3.17 mm. The motor was driven by Intelligent Motion System driver (IM 483I). Its motion was controlled through LabView Software. The droplet holder is made up of Teflon solid cylinder (diameter 5 mm) which is mechanically attached to the weighing section of the precision load cell (±0.1 mg). A digital video camera

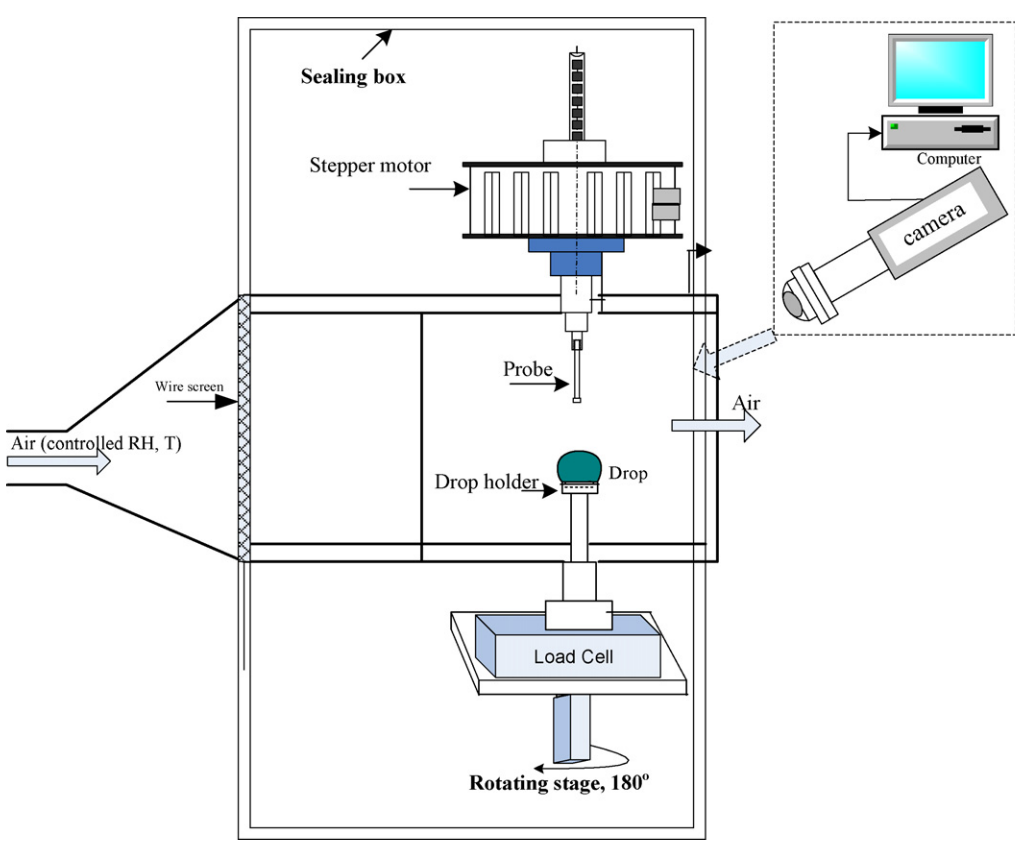

Fig. 1. Schematic diagram of the *in situ* stickiness testing instrument.