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Impact of effervescent atomization on oil drop size distribution of atomized oil-in-water emulsions

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Abstract

In this work the application of effervescent atomization to spray drying of food liquids like emulsions is explored. Therefore the influence of the atomization process on the breakup of oil drops inside the emulsion is investigated. It is expected that the oil drop size distribution of the emulsion is influenced by the stress inside the nozzle orifice and the following atomization. According to Grace the viscosity ratio between disperse and continuous phase is a crucial factor for drop breakup. A model oil-in-water emulsion was used. The viscosity of the continuous phase was adjusted by adding maltodextrin or gelatinized corn starch thus varying the viscosity ratio in the range between 15 and 0.1. The dry matter content and corresponding viscosity show only low influence on the spray drop size distribution. However, the atomized emulsions contain mostly smaller oil drops compared to the original emulsions. The influence of the atomization on the oil drop size distribution decrease with decreasing viscosity ratios. An influence of increasing stress due to increased atomization gas mass flow is present but less significant. The viscosity ratio thus allows controlling the influence of the atomization on the oil drop size distribution in the spray. The invariance of the spray drop size distribution on minor changes in fluid properties like viscosity is a favorable characteristic in food processing where such changes are common.

Keywords: effervescent atomization; emulsion; drop size distribution; viscosity ratio

1. Introduction & Theoretical Background

In spray drying, higher dry matter content of the feed is favorable due to decreased energy consumption for water evaporation. However the corresponding increase in liquid viscosity leads typically to an increase in mean spray drop size and possibly to a deterioration of product quality.

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Pneumatic atomizers may overcome this but only with a high atomization gas consumption [1]. The effervescent atomization is a special type of internal mixing pneumatic atomizer being distinct in the formation of a two phase flow prior to the nozzle orifice outlet [2]. A sketch of the atomization process and the atomizer geometry is shown in figure 1. Atomization gas is injected into the liquid in the mixing chamber. In an ideal state a bubbly flow is formed in the mixing chamber which transforms into an annular flow due to contraction to the nozzle orifice. Exiting the nozzle orifice the thin liquid sheath breaks up into liquid filaments due to the expansion of the atomization gas and further into single drops [2]. Due to its lower atomization gas consumption [1] it is a promising method for economical atomization of liquids with high viscosity. The air-liquid mass ratio *ALR* of atomization gas mass flow to liquid mass flow characterizes the atomization gas consumption – see equation 1.

$$ALR = \dot{m}_g / \dot{m}_l \qquad (1)$$

With: atomization gas mass flow $\dot{m}_g$, liquid mass flow $\dot{m}_l$

The objective of this work is to explore the applicability of effervescent atomization to spray drying of food liquids. Food liquids are often emulsions. Here, the oil drop size distribution is an important characteristic in the spray dried particles and in the liquid after reconstitution. Therefore the influence of the atomization process – the first step in spray drying – on the breakup of oil drops inside the emulsion is investigated. Shear rates inside the nozzle orifice were estimated from prior investigations [3] to be up to 10^6 1/s. Therefore it is expected that the oil drop size distribution of the emulsion is influenced by the stress inside the nozzle orifice and the following atomization.

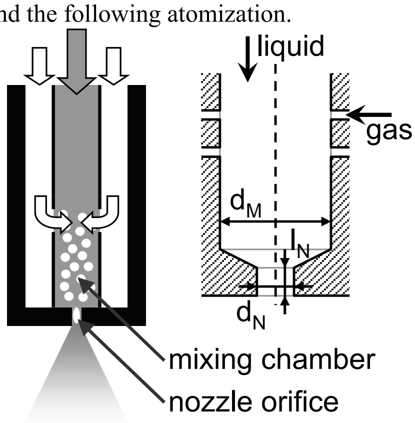

Fig. 1. Sketches of effervescent atomizer. Gas is injected into the mixing chamber filled with liquid and forms two phase flow which exits the atomizer through the nozzle orifice (left). Detail displaying the near orifice geometry with the mixing chamber diameter d_M and nozzle orifice diameter d_N and length l_N (right). [6]

Drop breakup can be described by the Capillary number *Ca* – see equation 2. The respective critical Capillary number Ca_{cr} has to be reached for breakup. Grace [4] demonstrated that the viscosity ratio λ between disperse and continuous phase is a crucial factor for the critical Capillary number. Grace stated also that between a viscosity ratio of 0.5 and 1 a minimum in critical Capillary number occurs and no drop breakup is possible above a viscosity ratio of 4 in laminar shear flow. Armbruster [5] showed that in case of a high concentrated system the viscosity of the emulsion is to be used instead of the viscosity of the continuous phase – see equation 3.