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# Adhesion of liquid food to packaging surfaces: mechanisms, test methods, influencing factors and anti-adhesion methods

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**ABSTRACT:** The adhesion of liquid food to packaging surfaces is an unsolved problem in the food industry. The theoretical backgrounds that are provided in this article are based on an adequate understanding of the mechanisms of adhesion between liquid food and packaging materials. Various mechanisms of liquid food adhesion are reviewed, such as mechanical interlocking, thermodynamic adsorption, diffusion, and electrostatic adsorption. The available tests and calculation methods are summarized and discussed, but there is no universal test standard. Basing on several available liquid food adhesion cases, it was found that liquid food adhesion results from multiple factors, such as rheological properties, surface tension, philicity, and roughness. Finally, we summarize some of the anti-adhesion methods developed in related fields, including surface coating technologies, surface structure design, and ecologically friendly approaches. It is important to produce re-entrant geometric structures combined with low surface energy compounds in the design of anti-adhesion packaging. In addition, for food applications, more attention should be paid to ecologically friendly materials. Comprehensive and systematic examination of these aspects would be conducive to the development of anti-adhesion materials for food packaging.

**Keywords:** liquid food adhesion; packaging; interface; surface tension; anti-adhesion

**Running title:** Adhesion Problems in Food Packaging

## 1. Introduction

The term “adhesion” is used to describe the attachment of microorganisms to abiotic surfaces and further biofilm formation (Shi and Zhu, 2009; Sjollem et al., 2017). It is also common in the food industry. Generally, in the food industry, adhesion includes solid-solid adhesion (including self-adhesion) and liquid-solid adhesion. Some typical cases are summarized in Table 1. In this review, we mainly summarize and discuss the adhesion of liquid food to packaging surfaces.

The adhesion of liquid food to packaging or equipment surfaces is of high economic importance. On one hand, due to the reduction in the amount of available product, liquid food residues left on packaging surfaces make consumers unsatisfied, therefore declining their willingness to buy. On the other hand, adhesion reduces the economic benefits due to the increased costs of recycling the packaging and cleaning the equipment (Adhikari et al., 2001; Michalski et al., 1999; Saikhwan et al., 2006). In addition, the adhesion of liquid food to the inner walls of the packaging may cause environmental problems (microbial growth) and even lead to the migration of ingredients (for example, bisphenol A) from the packaging to the food products (Meiron and Saguy, 2007a). To counter these problems, researchers have carried out numerous studies on the mechanisms of adhesion, the methods for measuring the amount of liquid foods which adhere to packaging surfaces, approaches to preventing adhesion, etc.

The adhesion mechanisms have been explained by different theories (Pizzi and Mittal, 2003), but so far, a universal theory for predicting the adhesion process has not been identified. Most studies focus

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