Investigations of Contact Angle and Adhesion Properties of Food Grade Coating Solutions on Maltodextrin Model Surfaces

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INTRODUCTION AND OBJECTIVE

The interaction of the solid phase, the particle of a powder and the liquid phase, the coating solution has a high influence on the quality of a coating (Vanderroost et al., 2011). According to previous studies, the contact angle measurement is a reliable method for investigations on the wettability of surfaces during coating processes (Kwok & Neumann, 1999). Contact angle measurements on the particles itself are not possible, because of the small size of about 100 µm to 1 mm. Therefore it is important to create a model surface which is appropriate for direct contact angle measurements.

Most investigations during the last years are made with food grade coating solutions on model surfaces like glass, PTFE or plastic films (Farris et al., 2011). For coating applications in the food industry, a glass surface is not appropriate to evaluate the interaction of particles and food grade coating solutions. Therefore it is necessary to find a suitable model surface to investigate these interactions.

The aim of the study was to create an appropriate model maltodextrin surface to investigate the wetting behaviour and the adhesion of food grade coating solutions. To fulfil this aim the interaction of different coating solution and two model maltodextrin surfaces was analyzed with two different contact angles, the directly measured contact angle and the contact angle calculated according to the method of Owens, Wendt, Rabel and Kaelble (OWRK) from the surface tension of the coating solution and the surface energy of the maltodextrin surfaces.

MATERIAL AND METHODS

The raw materials for coating solutions (sodium alginate [SA], iota-carrageenan [CG], hydroxypropyl methylcellulose [HPMC] and shellac [SH]) were kindly offered as product samples from FMC Biopolymer, Germany, CP Kelco, Denmark, Harke FoodTech, Germany and Stroever Schellack Bremen, Germany. The maltodextrin (MD) was a kind gift from National Starch, Germany.

The coating solutions were prepared with distilled water at a viscosity of 84.5 - 90.2 mPa·s. Two types of MD surfaces were prepared, the tablet form (MDT) and the glassy state form (MDGSS). The tablets were compressed with an EK0 tablet compressor (Krosch AG, Germany) with 1% magnesium stearate to a hardness of 91 N. The surfaces of the glassy state form were build on an object slide by layer-by-layer application of a 50% MD solution and a drying step at 70 °C after every layer.

The contact angle (CA) measurements were carried out using the sessile drop technique with an OCA 20 (Data Physics, Germany). The surface energy of the two MD surfaces was calculated by the method of OWRK by using standard fluids (water, ethylenglycol, diiodomethane and formamide) with known surface tension (disperse and polar fraction). In addition the CA was directly measured on the MD surfaces. For calculation of the wetting envelopes and work of adhesion the surface tension of the coating solutions was detected against the air-water interface and against a polar solvent (n-hexane or dodecane). For plotting of the wetting envelopes and the work of adhesion windows the software SCA 20 (Data Physics, Germany) was used.

RESULTS AND DISCUSSION

When using object slides without MD, only marginal differences between the directly measured CA and the calculated CA was found (min. 0.3° for SH and max. 9° for SA). Both methods may be used to measure the CA on glass surfaces. However, object slides are not considered to be an appropriate model surface for food applications.

The work of adhesion windows with included wetting envelopes for coating solutions on MD surfaces are shown in figure 1. The wetting and adhesion behaviour of the coating solutions can be divided in "two groups", first: the two hydrocolloids, and second: the cellulose derivate and the gum. According to the OWRK calculation the two hydrocolloids (SA and CG) show poor wetting properties on both MD surfaces, MDT and MDGSS. Based on the calculation of the adhesion properties both hydrocolloid solutions would adhere on the surface. In contrast, according to the OWRK calculations SH and HPMC would not adhere on the two surfaces but would spread on it. SH spreads much better than HPMC.

The data points of the coating solutions are the same of both surfaces, because these points are defined by the surface tension (SFT) and the polar contribution of the liquids. The wetting envelopes, shown from 0 ° to 30 °, are different for the prepared surfaces. Both, the wetting envelopes and the work of adhesion (with a optimal adhesion corridor between minimum and maximum) are calculated from the surface energy (SE) by the OWRK model.

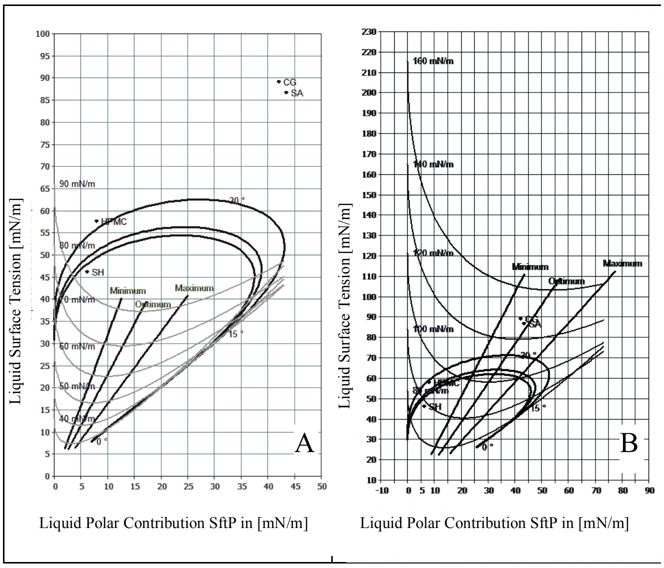

Figure 1 : wetting envelopes and work of adhesion window of SA, CG, SH and HPMC on MDT (A) and MDGSS (B) according to OWRK

The calculated surface energy of the two MD surfaces was 55.5 mN/m for the MDT and 62.1 mN/m for MDGSS, respectively. As a consequence of the similar surface energy the food grade coating solutions show a similar wetting and adhesion behaviour on both surfaces.

Table 1 shows the results for the direct CA measurement and the CA according to OWRK. According to the directly measured CA all coating solutions, accept SH, would spread on the MDGSS, while only HPMC and SH would spread according to the calculated CA of the OWRK model. The CA measured for the hydrocolloids on the MDT is lower than the calculated one. In contrast, the directly measured CAs for the cellulose derivate and the gum are higher than the calculated ones.

Table 1 : CA [°] of CG, SA, HPMC, SH on MDT and MDGSS , directly measured and calculated (calc.) by OWRK

	MDT		MDGSS	
	measured	**calc.**	**measured**	**calc.**
CG	38.1 ± 1.6	54.6	26.3 ± 1.3	48.1
SA	39.9 ± 1.2	53.2	27.7 ± 1.5	46.8
HPMC	44.3 ± 1.4	34.3	26.6 ± 1.2	27.1
SH	55.3 ± 1.4	0	34.7 ± 1.5	0

The directly measured CA of the two hydrocolloids on the MDT were located in the area of partial wetting near to the limit of 30°, where the total wetting area starts (Myers, 1999). Whereas the drops of HPMC and SH formed a higher CA on the MDT, which predicts a poorer wettability, than it was calculated by the OWRK model.

This difference between the directly measured and calculated CA might be caused by the rough surface of the MDT and MDGSS. As described earlier (Bico, 2002) the measurement of the CA on a textured surface needs more correction parameters to be included for direct CA measurement. Another possibility is to include more parameters of the surface and the solution into the OWRK model (Erbil, 2006). Especially when using more complex systems, the direct measured and the calculated CA will differ.

In addition a difference between the directly measured CA on the MDT and MDGSS occurred. This difference can be caused by the Mg-stearate contained in the MDT. Mg-stearate generates a more hydrophobic surface leading to a higher CA on the MDT compared to the MDGSS.

CONCLUSION

This study showed that on object slides without MD the directly measured CA is similar to the CA calculated according to OWRK.

The calculated CA of the food grade coating solutions is similar on MDT and MDGSS due to the similar surface energy of both surfaces. This indicates that both MD surfaces are appropriate for investigations using OWRK.The difference between the measured and the calculated CA of both MD model surfaces might be caused by inhomogeneity of the surface (e.g. roughness, porosity). Alternative methods on the preparation of the surfaces should be investigated to reduce the roughness of the MD surfaces.

Inclusion of Mg-stearate led to a higher measured CA on MDT compared with MDGSS. It seems that the addition of a lipophilic ingredient can offer the possibility to simulate a mixed surface of dispersed systems like spray-dried emulsions.

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