Edible and Sustainable Hot-Melt Adhesive

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ABSTRACT

Hot-melt adhesives (HMA) are used for hobby as well as in industrial applications as a fast-setting alternative without solvents. They are used for corrugated boxes and in electronic devices to affix parts and wires, as well as for bookbinding as well as a glue in hygiene products.

An edible HMA can be used for e.g. food decorations, for the childcare sector as a safe alternative to other glues as well as in packagings where corrugated boxes and paperboard cartons are glued.

We have developed an edible HMA based on sugars which can be applied by the same application techniques as conventional HMAs. The rheological properties showed a similar melting behaviour as a conventional HMA. A characterisation of the mechanical properties of the glue showed that the edible HMA was strong but fragile as compared to the more rubbery conventional HMA.

INTRODUCTION

Hot-melt adhesives are popular for fast joining of two surfaces without using solvents. It is used for industrial applications as well as for hobby and is often based on polymers such as ethylene-vinyl acetate (EVA) copolymers, polyolefins, polyamides, polyesters, polyurethanes and styrene block copolymers. These are combined with low-molecular weight compounds as tackifiers, fillers and other additives.

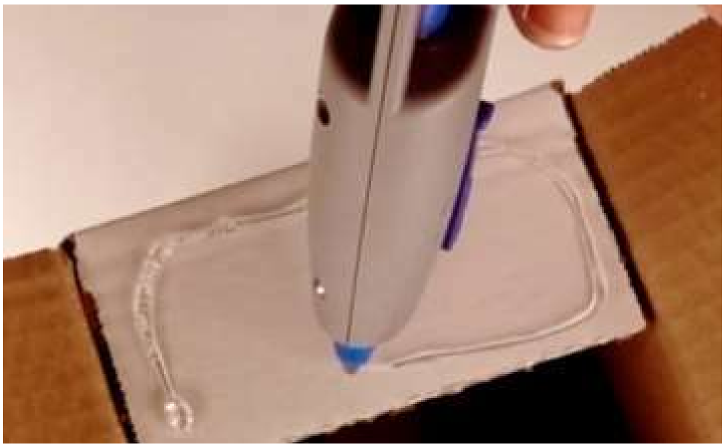

FIGURE 1: Application of the edible HMA using a hot-glue gun.

An edible HMA open new application area and for e.g. food decorations and artistic gastronomy, as well as for the childcare sector as a safe alternative to other glues. Corrugated boxes and paperboard cartons are glued with synthetic hot-melt adhesives and an edible, bio-based version would be a safe and sustainable option.

We have developed an edible hot-melt adhesive based on sugars which can be applied by the same application techniques as conventional HMAs. The aim of the present study is to characterise the rheological and mechanical properties of the edible HMA as compared to a conventional one.

MATERIALS AND METHODS

Four different sugars were mixed at 170°C: sucrose, glucose isomalt and inulin. Conventional, synthetic HMA was used as a reference. The melt was transferred to the pre-heated (90°C) bottom plate of the rheometer TA Instruments (New Castle, DE, USA) HR30 with 20 mm plates in a convection oven). The plates were enclosed in an insulating plastic cylinder to minimize temperature gradients. The temperature was lowered to 50°C before starting the measuring sequence.

The samples were heated from 50°C to 120°C at 10°C/min while monitoring melting with small amplitude oscillatory shear (SAOS) at 1Hz, 1000Pa oscillating amplitude which was in the linear range. The upper plate was raised 20 mm at 120°C and the oven opened to form a filament. The temperature was decreased to 50°C and the filament diameter measured before performing a fracture test at constant extension of 6 mm/min.

RESULTS AND DISCUSSION

Melting behaviour

Fig. 2 shows the melting of the edible glue as compared to a conventional HMA. The modulus in the more solid state at 50°C was higher for the edible HMA as compared to the conventional, whereas it more rapidly dropped on increased temperature. The melting temperature was 56°C for the edible HMA and 79°C for the conventional HMA, taken as the temperature at which the phase angle = 45°. The melting behaviour over 70°C was similar for the two HMAs as expressed by the storage modulus, but the conventional HMA had about one order of magnitude higher storage modulus. Practical application tests still showed that the handling of the HMAs in a hot melt gun (**Fig. 1.**) were similar.

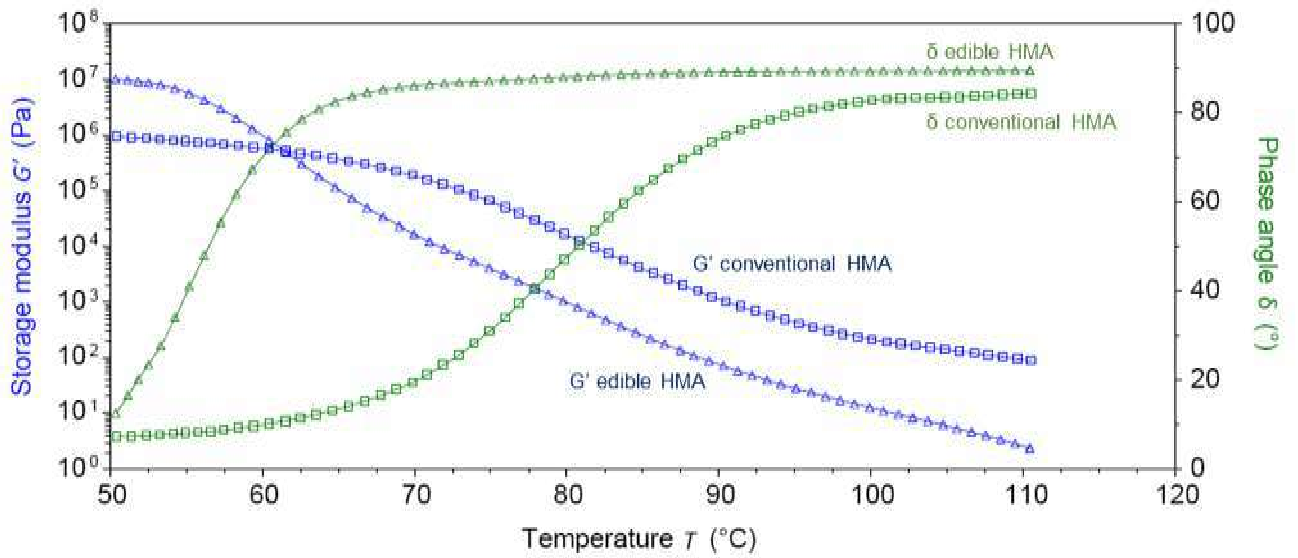

FIGURE 2: Melting of the edible hot-melt adhesive as compared to a conventional, synthetic one.

HMA strength

In the solid state at 50°C the edible HMA was more brittle as compared to the more rubbery conventional HMA as shown by the stress-strain curve in **Fig. 3**. The edible HMA fractured at 3% strain whereas the conventional HMA could be extended beyond 60% strain without fracturing.

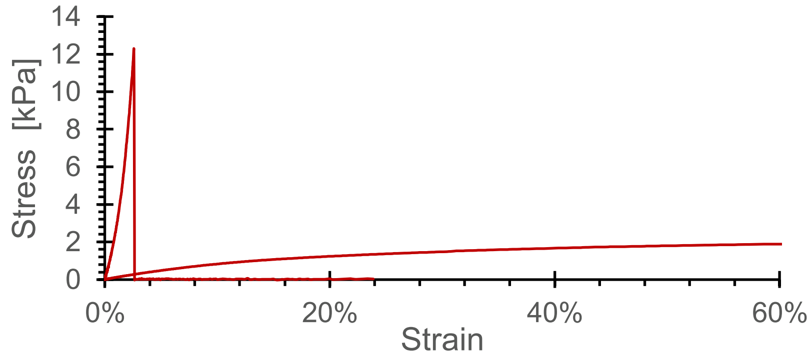

FIGURE 3: Stress-strain curves for the edible hot-melt adhesive and a conventional, synthetic HMA.

CONCLUSIONS

An edible HMA was developed based on a blend of sugars and was compared to a conventional, synthetic HMA. Both HMAs exhibited similar melt behaviour although the edible HMA had an order of magnitude lower storage modulus in the molten state. The edible HMA also displayed brittle fracture at low strain in the solid state. Nonetheless, the handling of the glues was similar and both glues could be applied using a commercial hot glue gun. Potential applications of the edible HMA developed include food and the packaging uses which both involve brittle or stiff materials that are not much extended in commercial applications.