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The potato as raw material for biodegradable plastics

Bioplastic offers the advantages of linking the advantages of plastics with natural recycling. Potato starch with its natural macro-molecular structure suitable for plasticizing, has particular advantages in this context with a mixed plastic experimentally produced directly mixed in the injection-mould machine or via granulate in double-screw extruder both with 30 to 75% potato starch content giving mechanical strength values lying between those of synthetic and starch-based plastics.

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Keywords

Starch, potatoe starch, biodegradable plastics

Bioplastic offers the advantages of linking the advantages of the usefulness of plastics in general with the natural recycling economy. This last means modifying suitable natural macromolecules to give useful properties with molecular basic structure retained to a large extent and the material degraded after use through composting or natural action of enzymes and microbes to CO_2, water and humus.

The mix of potato starch, peel, tissue and soluble contents produced in a shortened decentral process [1 to 3] from now on called potato substrate, when dried, is suitable, just like pure potato starch, for manufacture of plastics especially as a blend with synthetic plastics.

Average potato substrate components were 82.3% starch, 6.5% fibre (peel and tissue), 3.1% protein, 2.5% amino acids and amides and 5.6% organic acids, sugars and minerals. Through storage with air contact, the water content of the substrate was 18%.

Variation of the blend components enables the production of certain characteristics in the thermo plastically processable material.

Investigations into the thermoplastic processing of potato substrate

The aim was to investigate through systematic experiments the mix proportions with different plasticizing agents [49]. Along with the water from the hygroscopicity these were glycerine, urea, oils, organ silicate, ester and detergents. A first rough selection took place on the basis of qualitative characteristics such as flexibility, stickiness of the material surface and foaming tendency during extrusion. These mixes could still be described as thermoplastic starch (TPS) but were in no way waterproof and also had only a limited mechanical strength when elasticity was sufficient (*table 1*).

For producing a usable thermo plastically processable material based on starch, water resistance has to be increased. A possible way is by mixing the thermoplastic starch with waterproof synthetic polymers. The characteristics would then not only be determined by the individual components but instead would be decisively depend on the blend structure. Through processing the TPS with only 30% polyvinyl acetate (PVAc) a usable material with a certain degree of waterproofness, e.g. for production of plastic sheeting, can be obtained through the creation of optimum mix structures.

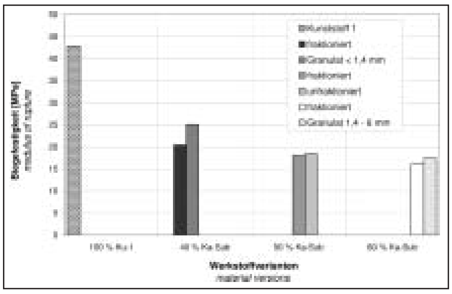

Fig. 1: Bending strength and maximum bending force versus mixing ratio of potato substrate to plastics; Ka-Sub – potato substance ; Ku – plastics

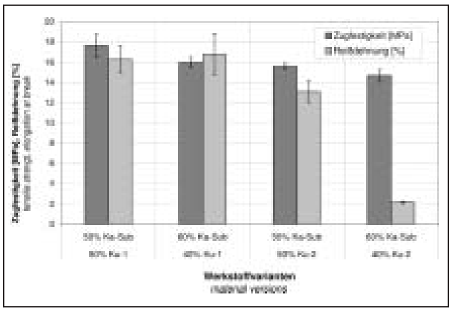

Fig. 2: Tensile strength and tearing extension versus mixing ratio potato substrate to plastics; Ka-Sub – potato substance ; Ku – plastics

Mix of potato substrate with plastics and recycled plastics

Mix production

The following investigations were aimed at highlighting the procedural-technological problems to be solved with a combination of potato substrate with commercially available cost-efficient plastic under practical aspects. In mixes with polypropylene (PP) and polyethylene (PE), the potato substrate can partly be looked upon as structural material and also as price-efficient filler. The potato substrate was in powder form. The released starch (proportion ~ 80%) had a grain size spectrum of 0.020 to 0.120 mm while that for the tissue remains and the peel was bet-

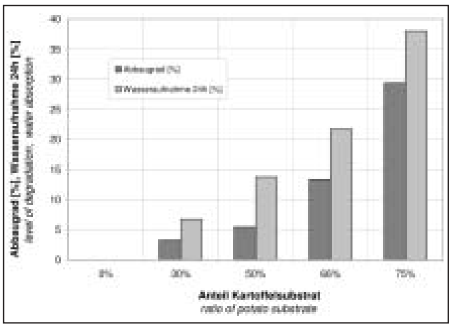

Fig. 3: Biological degradation ref. to DIN 54900-3 and water absorption of extruded samples versus ratio of potato substance in material

ween 0.125 and 2.5 mm diameter. Where required, these grains could be reduced in size by milling.

From the start it was apparent that mixing plastic as granulate and potato substrate is possible directly in the auger press of an injection-mould machine. For optimum dosing and mixing under practical production conditions, however, a granulating of the potato substrate would have been better.

For this reason granulating was chosen for the potato substrate-plastic mix in a double-screw extruder. The components were mixed in the desired proportions before the extruder and then metered-in. Mixes of 40, 50 and 60% potato substrate and appropriate proportions of PP or PE were prepared.

Mechanical properties of the material

The potato substrate and PP and PE mixes direct in the injection-mould automatic showed a clear reduction in bending strength compared with pure plastic (*fig. 1*). For simple injection-mould components undergoing comparatively low mechanical stresses under use, such results could be regarded as sufficient.

Also from the injection-mould mixes using granulate material, samples were tested according to DIN 53455. *Figure 2* shows that the tensile strength of the mix with 17.5 and 16 MPa compared with a pure TPS blend according to table 1 is clearly increased. The starch in the potato substrate also contributed to the structural strength of the compound as was made clear from the only small drop in strength to 17.5 and 16 MPa of the mix with 50% and 60% potato substrate compared with pure PE which, according to table 1, shows strength of 20 MPa. Here the mixing in the double screw extruder had the effect that the more intensive shear processing gave a better integration of the natural and synthetic polymers.

This clearly high quality material is also suitable for the manufacture of stress resistant building components and for processing in complicated injection tools.

Water absorption capacity and biological degradability

The water absorption capacities of the different mixes were recorded to determine the biological degradability.

It was clear (*fig. 3*) that with an increasing proportion of potato substrate in the material, the source materials for which having been directly mixed in the injection mould automatic, the water absorption also increased.

The degree of biological degradability directly follows that of water absorption capacity as in nature.

Processability

With the granulated substrate-plastic mixes, many-sectioned and relatively thin walled forms, e.g. a 50 • 50 cm and 5 cm high slope attachment panel could be injected for a serially-produced tool from a mix with 50% substrate and 40% PP and also with PE (*fig. 4*).

Summary

The investigation results presented here confirm the usefulness of the cost-effective raw material representing all the solid components of the potato for manufacturing of cost-efficient and biologically degradable material. After the basic determination of the starch's processability in the presence of peel, tissue and other contents of the potato – all as potato substrate – processable plastic could be produced under practical conditions.

The substrate can therefore be used for many applications as a cost-efficient material component instead of more cost intensive plastic components. Additionally, such plastics, depending on the proportion of starch, are as natural polymers biologically degradable.

Fig. 4: Slope fastening element made of potato substance- plastics- compound

Experiment	σ_S [Mpa]	ε_S %	σ_R [Mpa]	ε_R %
D3007	4.1	67.1	3.7	84.4
D3009	3.5	54.3	3.0	71.8
D310	4.3	49.5	3.7	62.9
10% Glycerin				
D310	2.5	52.8	2.1	69.7
15% Glycerin				
E308	4.1	51.7	3.4	82.2
F3011	2.9	39.7	2.3	57.8
LDPE *)	8 – 10	20		600
HDPE *)	20	12		400 – 800

σ_s : yield stress (tensile stress on yield point) = tensile strength;
ε_s : associated extension; σ_R : tensile stress at breaking = tearing strength
ε_R : tearing extension
Trial*) from H. Saechtling: Kunststoff-Taschenbuch, 22. Ausgabe, München-Wien 1983, S. 208

Table 1: Indexes from strength tests on extruded blends of TPS / potato substance (strength test DIN 53455)

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