Mass transfer during gelatinization of barley starch

Simon Henke, Karl Sommer

Motivation

Gelatinization of starch is evident for an efficient enzymatic degradation during mashing. As gelatinization of starch is a general term to describe all physicochemical changes starch undergoes during heat treatment, it is worth to have a closer look at the single mechanisms of gelatinization.

In this work polymer leaching from granular barley starch was examined. From a procedural point of view, this process is considered as an extraction in the system solid/liquid. Extractions are commonly described with the laws of diffusion and mass transfer. For a description of the extraction kinetic a differential equation is necessary whether the resistance against mass transfer is within the solid or within the liquid phase. For this purpose transport coefficients for both phases are determined experimentally.

Experimental approach

Diaphragm Diffusion Cell

- Diffusive mass transfer of soluble starch polymers through a membrane of known permeability constant ψ
- Concentration data in both cell halves, before and after a given diffusion time t, allow the calculation of an integral diffusion coefficient Di of solutes

\[ D_i = \frac{1}{\psi} \ln \left( \frac{c_i(t) - c_i(t_0)}{c_i(0) - c_i(t_0)} \right) \]

- Concentration measurement by means of enzymatic and colorimetric methods

Fig. 1 diaphragm diffusion cell

Polymer leaching from particulate starch

- Particulate barley starch industrially purified (Fa. Allia, FN)
- Water extraction at constant temperature under defined agitation conditions
- Quantification of leached polymers by means of colorimetric and enzymatic procedures (Total Starch Assay, AACC Int. Method 78-13.01)
- Comparison of iodine stained leached polymer solutions with pure amylose and amylopectin delivers a qualitative classification of polymer composition

Theoretical considerations

Convective mass transfer within agitated fluid phase

\[ Sh = \frac{\beta_i \cdot d_i}{D_i} = f(Re, Sc) \]

Biot-Number - definition of location of resistance against mass transfer

\[ Bi = \frac{\beta_i \cdot d_i}{D_i} \]

- Bi < 0.1 resistance within fluid phase
- Bi > 40 resistance within solid phase
- 0.1 < Bi < 40 solid and liquid phase resistance have to be considered

Fig. 2 Concentration drop with time within a spherical particle as affected by Biot-Number

Results

Starch Gelatinization

- Besides water uptake and swelling polymer leaching from granules is important for disintegration of granules in excess water.
- Granule disruption is of major interest for enzymatic conversion of starch
- Leaching occurs from amorphous parts of granules through surface pores
- Leached polymers are a mixture of amylose and amylopectin

Diffusivity of starch polymers in solution

- Diaphragm cell method is an effective and easy way for measuring diffusion coefficients of solutes
- Strong temperature dependence of coefficients
- Diffusion coefficients allow calculation of mass transfer coefficients with tabulated Sherwood functions

Fig. 3 Absorption spectra of starch polymers

Mass Transfer of starch polymers from solid starch granules

- Leaching of polymers shows strong temperature dependence for speed of extraction as well as for equilibrium concentration of polymer in solution
- Progress of leaching is in very good agreement with fitting by mass transfer correlations

Fig. 4 Effective diffusion coefficients of polymers within starch particle

Conclusion

- Polymer leaching is of major importance for gelatinization of starch granules
- Resistance against mass transfer of starch polymers is within starch particle
- Internal structure of starch particles is limiting for the process
- Measures for intensifications of mass transfer within fluid phase (e.g. agitation speed) are not useful

Contact Information

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